ABSTRACT

HARGROVE, RYAN ANTHONY. Creating Creativity in the Design Studio: Assessing the Impact of Metacognitive Skill Development on Creative Abilities. (Under the direction of Art Rice.)

Design is a discipline of innovation. The very essence of design is the creation of something new and unique. An assumption has been that, as in the case of native intelligence, the inclination and ability of a person to respond in novel and useful ways is largely inherited. Present research refutes this view, and it is now believed by many that, however creativity is defined, it is a form of behavior that can be taught. If as Dr. Daniel Pesut suggests, most creativity training programs are successful in that they encourage the development of metacognitive abilities, then the study of creativity as a self-regulatory metacognitive process is timely and important to design education.

Metacognitive knowledge guides people to select, evaluate, revise, or abandon cognitive tasks, goals, and strategies in light of their own abilities and interests. Acknowledging this point leads to questioning our understanding of the creative design process. Therefore, we must return to the issue of cognition and recognize how little we really know about designers’ creative processes, and seriously question how such an immensely important component of problem solving remains absent from design education.

This study statistically tests the introduction of structured metacognitive skills on the development of creative thinking ability for a diverse population of undergraduate design students. Two of the most highly regarded standardized tests for convergent and divergent thinking, structured faculty assessment, and a comprehensive review of generated outcomes were used to assess the impact of the introduction of these skills in the design studio environment. The study involved over 120 freshman undergraduate design students. Half of the group participated in a semester long intervention that introduced metacognitive skills as a part of creative thinking. Each student’s creative skills were then evaluated multiple times over the course of an academic year. Results from creativity tests as well as faculty and outcome assessments were analyzed to determine the impact of this intervention.
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CREATING CREATIVITY IN THE DESIGN STUDIO: 
Assessing the impact of metacognitive skill development on creative abilities

by

RYAN ANTHONY HARGROVE

A dissertation submitted to the Graduate Faculty of North Carolina State University in partial fulfillment of the requirements for the Degree of Doctor of Philosophy

DESIGN

Raleigh, NC

2007

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Chair of Advisory Committee
DEDICATION

Sarah Hargrove
    my wife

Dennis and Rosann Hargrove
    my parents

Allison Hargrove
    my sister

and to:
    my entire family past and present
Ryan Hargrove began his design education at the University of Kentucky where he enrolled in the Landscape Architecture program. While studying at the university he worked at Korfhage Design in Louisville, Kentucky as a part of a supervised internship program. It was during his senior year that Ryan became interested in the role research plays in design and considered pursuing an area of specialized research. While studying at the University of Kentucky Ryan was awarded a Merit scholarship and was recognized as a student award honoree by the ASLA. He graduated magna cum laude in May of 2002 with a Bachelor of Science in Landscape Architecture degree.

Deciding to continue his education, Ryan enrolled in the Landscape Architecture graduate program at the University of Florida in the fall of 2002. As a teaching assistant for two years he was able to explore future interest in teaching, while conducting research focusing on healthcare design. His master’s thesis studying Alzheimer’s patients “Remembering the Past Designing the Future” was recognized at the 2005 National Alzheimer’s Conference in Chicago, Illinois. Working in collaboration with the Alzheimer’s Association and the American Society of Landscape Architects he studied a series of memory gardens across the country. The project involved a qualitative research design and created a set of future guidelines that will improve current and future facilities. While at the University of Florida he was awarded the student award scholarship and was a part of an Eco-Architecture study abroad program in Costa Rica. He graduated on April 30th 2004, and decided to attend the North Carolina State University to pursue a doctoral degree in design.

At North Carolina State University Ryan conducted research in design education. Under the supervision of Art Rice he completed coursework and began a focused research study examining how to enhance the creative thinking of design students. His study entitled “Creating Creativity in the Design Studio” was presented at the 2007 CELA Annual Conference at Penn State University. While at North Carolina State University Ryan was
director of the NCSU Design Camp for high school students pursuing academic ambitions in design. In addition he was rewarded a graduate teaching assistantship that allowed him to teach graduate design studios as well as design thinking courses in partnership with Marvin Malecha, Dean of the College of Design. Ryan graduated with his doctoral degree in design August 2007.

Since December 2006 Ryan is married to his soul mate Sarah Hargrove.
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It is with enormous admiration that I express my gratitude to those who have taken part in my academic journey. As this chapter in my life comes to a close I want to thank those who have made it the most rewarding period in my life. During my studies at North Carolina State University I grew as a scholar but more importantly as a person. This growth can be attributed to the guidance and support of a core group of people. It is now time to acknowledge this group of people for generously giving their time, fostering intellectual growth and curiosity, and guiding me toward the realization of my potential.

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CHAPTER 1
INTRODUCTION: FOCUS OF STUDY AND CONTEXT

1.0 Introduction

One of the most critical aspects of design education is teaching creative thinking processes. This ability enables designers to succeed in traditional practice or in other disciplines that they choose to enter. Metacognition, the ability to be aware of, attend to, and use information about their own cognitive processes serve designers for a lifetime and transcends changes in design styles, materials, construction methods, and technology. Metacognitive thinking allows designers to build a metacognitive knowledge base and apply their creative thinking skills to an infinite number of design applications. Knowing this, design educators should ask themselves; how effective is current design education at developing students with strong creative thinking abilities and how can this potential connection between creativity and metacognition be explored and tested?

With design thinking as the core competency, design school graduates have the vast potential to add tremendous value to society through the design of a range of ideas from products, buildings, businesses, and organizations to entire communities. Designers use these skills to offer more services to clients, and recent graduates capitalize on this knowledge to excel in a large variety of settings. A core value of the discipline lies in how effectively educators prepare students to utilize the cognitive processes associated with design thinking.

Design education is a place where creativity and spontaneity should guide exploration and serve as a basis for learning. To promote creativity and innovation, design education should build and support an understanding and awareness of the cognitive processes related to creative thinking.
Creativity is not only healthy for student projects, but also when applied to the academic context in the larger sense. In a culture of creative thinking, design schools and educators imagine more effective teaching methods and learning objectives. Also instructional techniques in design remain in development and provide a framework for continued innovation. In her book, *Design Juries on Trial* (1991), Kathryn Anthony wrote, “It is indeed ironic that throughout the term, design instructors encourage their students to be creative, go out on a limb, take risk – and then when it’s all over most of those same instructors rely on the same technique they’ve been using for years” (p.129).

A culture of creative thinking should be embraced in order to create alternative teaching and learning models. To create a healthier and more successful academic experience, design schools need to rethink existing practices and develop creative alternatives. In the end, the innovative nature of design can serve as a basis for creating an improved design education that embraces creative thinking.

When one thinks of creativity, eminent artists or scientists such as Michelangelo or Einstein immediately come to mind. Historically, the study of creativity began with the concept of genius. There is a longstanding tradition of examining prominent creators, who are viewed as “unambiguous cases” of creativity. However, these highly creative people are rare and difficult to study in the psychological laboratory.

An assumption previous to this time has been that, as in the case of native intelligence, the inclination and ability of a person to respond in novel and useful ways was largely inherited. Present research refutes this view, and it is now believed that however creativity is defined, it is a form of behavior that can be taught (Adams, 2001; Davis, 1997; De Bono 1973, 1992; Kvashny, 1982; Nickerson, 1999; Parnes, 1967, 1981; Sternberg & Lubart, 1996; Sternberg & Williams, 1996; Torrance, 1962, 1974). Creativity is indeed complex and may disappoint educators who wish for easy targets. On the other hand, there is an appeal to optimistic educators, for research suggests that there are many possibilities when attempting to enhance creativity.
Contemporary pressures to meet the needs of professional offices has focused many programs on the technical and management skills most immediately related to practice-based performance, sometimes at the sacrifice of the development of thinking skills. Irrespective of the specific design domain, some educational models in design education are based upon the replication of professional task performance. The measure of learning is generally equated with the evaluation of the design product rather than learning process or skill. The cognitive skill sets of design are not adequately addressed by pedagogy in design education. As a consequence, there presently exists a lack of cognitive theories that function as underpinnings of design education (Oxman, 1999).

An examination of design education reveals the lack of instructors’ formal training in education / learning theory. While many design instructors are accomplished professionals, this competency does not automatically translate into the skills needed to help others reach their creative potential. Design educators should seek out and explore effective models of education and problem-solving that challenge creative practices in the design curriculum. Refusing to acknowledge the shortcomings and limitations of the current educational approach is creating inferior conditions across all design professions and continues to suppress the designer’s ability to reach their potential. Design educators should do better than to teach what they were taught; the standard of the profession is perpetually rising and, without change, designers will not be prepared to meet these challenges. Sidney Parnes, president of the Creative Education Foundation and professor of creative studies at State University of New York at Buffalo explains (1981, p. 21):

“We may not be sure what we’ll need to know for the future, but we can be reasonably sure that we will need increasing ability to sense and meet the challenges and problems our changing lives present rather than using tranquilizers to deal with them…”

Design is a discipline of innovation. The very essence of design is the creation of something new and unique. But innovation goes beyond simply doing something new or different; it entails responding to challenges and making improvements. As culture grows more
complex, science more all-encompassing and choices more diverse designers need innovative solutions that will address these challenges and provide a framework for continued innovation.

The U.S. Department of Labor appointed a commission to determine the skills young people need to succeed in the world of work. The purpose of the Secretary’s Commission on Achieving Necessary Skills (SCANS) was to encourage a high-performance economy characterized by high-skill, high-wage employment. Although the commission completed its work in 1992, its findings and recommendations continue to be a valuable source of information for individuals and organizations involved in education and workforce development. The SCANS recommendations provide curricular and pedagogical guidance for preparing students for adult life and pose a substantial challenge to the major institutions charged with responsibility for developing worker competencies. The report distinguishes, in a commonsense way, the elements of being “educated” and then introduces a set of higher-order competencies necessary for participation in future economics and politics (Davis, 1997).

The final report issued in July 1992, named five competencies and a three-part foundation of skills and personal qualities the Commission believed is necessary for strong future job performance. The foundation of skills consists of thinking skills, specifically creative thinking, as well as the personal qualities associated with self-management or self-regulation, decision-making and seeing things in the mind’s eye (U.S. Dept. of Labor, 2000).

To best promote creative reasoning in design students the dominant model of design education should be modified to provide a robust and reflective model of design thinking. There is no doubt that there is a great deal of room for improvement knowing that designers must be competent in all aspects of the design process. However, it is also clear that students’ design abilities can be enhanced through educational programs with iteration and reflection as essential parts of the process (Eastman, 2001).
Design theorist J. Christopher Jones (1980) clearly articulates this distinction when comparing what he terms “black box” thinking with the more reflective approach of “glass box” thinking. The black box view of designing can be quite clearly expressed in cybernetic or physiological terms: one can say that the human designer, like other animals, is capable of producing outputs in which he has confidence, and which often succeed, without his being able to say how these outputs were obtained. Most human actions can be explained only if one assumes that they are largely governed by the skilled nervous system without the intervention of conscious thought. The black box view of thinking posits that skilled actions are unconscious and it is irrational to expect designing to be wholly capable of rational explanation. According to this theory, for which there is little physiological evidence, the ‘leap of insight’ that many creative people report, is the result of the neural network suddenly adopting, after many fruitless attempts, a pattern that is compatible with inputs that it has recently received. This suggests that past experiences are patterned and then re-patterned every time one tries to remember them. The brain is a semi-automatic device that is capable of resolving incompatibilities between inputs (i.e. solving problems) by assuming a pattern is compatible not only with current inputs but also with the many previous inputs of which memory is composed (Jones, 1980).

There is opposition to this explanation of creative behavior. Cognitive scholars such as Brodbent (1966) have identified mental rigidity (or a desire for certainty) as the chief enemy of creative thinking, and caution about the production of stereotyped responses. The glass box view of designing is concerned with externalized thinking rather than relying on assumptions of mystical processes. It implies that the designer has knowledge of what he is thinking and why he is thinking. Design thinking conceptualized as a glass box process can be described as stepping outside of the process to watch oneself solve a problem. Because no future design will be exactly the same as the one that you are now solving, designers learn to focus on process as the content of activities (Jones, 1980). This reflection and regulation of thought, (planning, monitoring, evaluation) helps designers learn from their failures and build on their successes. Metacognitive knowledge guides people to select, evaluate, revise, or abandon cognitive tasks, goals, and strategies in light of their own abilities and interests.
(Schraw & Moshman, 1995; Pesut, 1984). Acknowledging this point leads to questioning our understanding of the creative design process. Therefore, one must return to the issue of cognition and recognize the importance of designers’ creative processes, and how one can amplify the strongest creative behaviors in the education of designers.

Design educators are faced with a unique challenge in respect to the need for increasing the level of the creative performance of their students. Teachers have a responsibility that goes beyond contributing to the development of creative designers. Design courses stand out as the ones in which students not only have the time and freedom to be creative, but are required and rewarded for such behavior. Teachers in design should develop creative strategies in all design courses. The transfer of such strategies across the entire education of designers will then be a consequence. To date, however, there is little indication that deliberate creative thinking / strategies are being taught in design courses (Oxman, 1999). If creative behavior is to be the central theme in the designer’s education, new approaches to pedagogy and curriculum are needed.

Metacognition is an essential ingredient of creative thinking (Sternberg & Williams, 1996); therefore, it is critical to the effectiveness of designers. Creative thinking can be defined as a metacognitive process – of generating novel or useful associations that better solve a problem, produce a plan, or result in a pattern, structure, or product not clearly present before. What one knows about knowing (metacognitions) are presuppositions that guide design practice, research efforts, and daily behavior. Thus, “knowing about knowing” (Brown, 1978) is valuable information. Designers can improve creativity by focusing on metacognitive thinking in the classroom. Teaching designers to explore their own cognitive processes in a systematic way helps them manage their own creative thought processes and develop their metacognitive knowledge. This knowledge provides designers with the knowledge of when, where, and why to use specific thinking strategies or cognitive approaches. Through an understanding of their thinking designers can trace the success or failure of a decision back through a process of thinking and build knowledge through past experience. For example, designers can build a series of associational connections for future
problem solving or learn something about what connections produce idea fluency, so when fluency is demanded in the future, they can recreate those conditions.

Metacognitive research (Brown, 1978; Flavell, 1979, 1981) has contributed to the psychology of teaching creative skills (Lawson, 2006), as well as the analysis of problem solving, remembering, and thinking. In accordance with Pesut (1984) the author believes that the fundamental skills of creativity are really action-oriented metacognitive guides that operate in concert with metacognition to sustain and enhance creative thinking. As a students’ level of metacognitive thinking increases so does their capacity to utilize their creative thinking. By becoming more aware and having a greater understanding of thinking process this clarity and comprehension allow for new and more complex modes of creative thinking and strategy use. What effects would there be if educators taught designers to conceptualize creative thinking as a metacognitive process?

Most creativity training programs are successful (Davis et. al., 1972; Mansfield, Busse & Krepelka, 1978) because these programs encourage the development of “thinking about thinking” or metacognitive abilities. These training programs provide metacognitive experiences to participants and thereby encourage the development of an individual’s metacognitive knowledge. Creativity training experiences affect how individuals map and or represent experience by providing them with a generative model to guide future thinking and behavior. One can speculate that creativity training programs install in the participants creative strategies that are supported by metacognitive thinking skills.

Analyzing creativity from a cognitive framework enables one to gain a perspective of the metacognitive dimensions associated with creative thinking. Pesut (1984) has conceptualized creativity as a metacognitive process, meaning the ability to think about one’s own thought processes, to regulate thinking through planning, monitoring and evaluation is the essence of creativity. Creative strategies guide thinking and promote the generation of novel, useful associations. Creativity conceptualized as a metacognitive process can be enhanced because of treatment methods developed by combining cognitive and
metacognitive skills. As a result of the synthesis between educators and psychologists have developed intervention strategies designed to teach people how to “think about thinking.”

One way to achieve this synthesis is to disseminate information and develop creative thinking skills of designers through the use of cognitive-behavioral modification techniques (Adams, 2001; De Bono, 1973, 1992; Gordon, 1976). If knowledge is the “mapping of experienced reality,” designers need to gain knowledge of creative thinking by “mapping the experience” of an encounter with a creativity training program (Kaplan, 1982). Knowledge of cognition may be very important to creativity in that one becomes aware of our biases and preconceived ideas, allowing for an advanced level of creative thinking.

If as Pesut (1984) suggests most creativity training programs are successful because they encourage the development of metacognitive abilities, then the study of creativity as a metacognitive process is timely and important to design education. Building awareness an understanding of designers thinking processes strengthens their ability to utilize various creative thinking strategies. There is very little literature that conceptualizes creativity as a metacognitive process. Thus, the unexplored strategy of regulating creative thought provides many rich research possibilities. The author suggests that design education consider metacognitive thinking with students to promote creative thinking strategies. Using this approach students may enhance creativity and learn to break through barriers that hamper ideation in order to increase their creative cognitive potential.

A study that focuses on the development of creative thinking skills of design students will be a useful addition to the literature because such a study will serve as a model for the dissemination of creativity strategies to design students. Experimental curricula need not be the only way to disseminate creative strategies to students. If creative strategies could be disseminated to design educators through creative training programs, perhaps it would be better utilized for improving the context for effective design education, practice, and research. This would include an optimal and sustained method for dissemination throughout a designers’ educational experience.
However, before disseminating information about creativity, it would be useful to have answers to the following questions:

1. What is the most relevant dimension of creativity to design?  
2. How can one reliably evaluate this dimension of creativity?  
3. How might one systematically develop this dimension of creativity along with other creative cognitive skills of design students?

These are some of the questions the author hopes to answer in the following review of literature.
2.0 Literature Review

- Creativity
- The Creative Process
- Creativity and Cognition
- Enhancing Creativity
- Creativity as a Metacognitive Process
- Metacognition
- Metacognition and Design
- The Role of Metacognition in Educating Designers

Figure 2.1: Diagram of Literature Review
2.1 Creativity

Creativity is the ability to produce work that is both novel (i.e., original and unexpected) and appropriate (i.e., useful or meets task constraints) (Sternberg & Lubart, 1996). It is through creativity that we cope with significant challenges in our environments in novel and appropriate ways. Indeed, given the rate that the world is changing, the importance of creativity to our lives is likely to increase.

Despite the range of descriptions of creativity, it seems to be a concept that has appeal and value for designers in innovation and advancement. Gowan (1972) believes that the development of creative talent is not an educational frill but a central issue in the preservation of our culture. The development of creative behavior has been linked with the ability to do work, and maintain mental health. Additionally, creativity has been identified as an important developmental task for men and women (Maslow, 1976; Brandstader & Schneewind, 1977; Helson, 1982).

Beginning with the work of philosopher John Dewey (1910), students of creativity have sought to unravel the cognitive processes contributing to the production of novel problem solutions. This fascination with processes might be attributed to the fact that they play a crucial role in problem solving and, therefore, initial idea generation. More centrally, however, these processes, by nature of their generality, provide a particularly attractive mechanism for understanding how people generate new problem solutions in novel, ill-defined, and complex domains. Dewey took this a step further by questioning how thought is important. His conclusions stated that thought can rise above impulse or habit; thought can aid by being able to see future problems and thus allowing us ways to figure out how to avoid them; and thought enlarges the meaning of things in the physical world. Dewey also stated that thinking is important because it reaches through to that which is not from that which is. Specifically, things that are known, things that begin the thinking process, point to other thoughts, other concepts and ideas that are the rewards of the thinking process (Dewey, 1910). In exploring this question he shed light onto the kind of training thought requires if it is to serve this end. Dewey pointed to reflective thought as being essential, as well as the
need for self-regulated thinking.

Mihaly Csikszentmihalyi and Howard Gardner, both highly regarded for their research and writings about creativity, have contributed multiple works and are seminal authors on the topic. Csikszentmihalyi most well known for his bestselling book *Flow: The Psychology of Optimal Experience* (1990). In this work, he defined and explored the concept of "flow" as the experience of optimal fulfillment and engagement. Flow, whether in creative arts, athletic competition, engaging work, or spiritual practice, is a deep and uniquely human motivation to excel, exceed, and triumph over limitation. The experience of “flow” involves a loss of consciousness about the task as an individual reaches an optimal experience of concentration and deep enjoyment. Flow includes clear goals, concentrating and focusing, loss of the feeling of self-consciousness, distorted sense of time, direct and immediate feedback, sense of personal control, activity that is intrinsically rewarding and balance between ability level and challenge. The analysis of flow has to do with where people and problems reside. Csikszentmihalyi’s suggestions for experiencing flow include picking an enjoyable activity that is at or slightly above your skill level and continually raising the level of challenge as performance improves (Figure 2.2). This seems to contradict the idea of reflection and regulation of thought associated with metacognitive thinking. And while the idea of finding flow seems appropriate for well-defined tasks with clearly defined outcomes, the concept is less convincing when applied in to ill-defined problems associated with design and other creative fields. Overall the concept is very intriguing but lacks a strong connection between theory and practice.
A more recent publication, Csikszentmihalyi's *Creativity: Flow and the Psychology of Discovery and Invention* (1996) is a compilation and in-depth reporting from interviews with nearly one-hundred individuals, who, in the author's opinion, have demonstrated unusual capacities for creativity. In this book, Csikszentmihalyi has brought together convincing information about what makes for a creative mind and what kinds of lives such individuals lead, from childhood through late in life. The list of respondents interviewed includes a wide range of professionals from philosophers, actors, composers, psychologist and politicians to jazz pianists. Responding to a series of detailed and complex questions, individuals revealed to the author what qualities from childhood, parental relationships, academic preparations, and their personal and professional relationships influenced creativity and brought them to
understand their capabilities as leaders in the arts, humanities, politics, the sciences, or business. Csikszentmihalyi's *Creativity* includes observations about lives of individuals and outlines attributes that brought about successes as well as the frustrations. While this book has some faults and reintroduces some of the same concepts discussed in earlier works, it offers an important framework and vocabulary for thinking about the topic of creativity. Of particular relevance is Csikszentmihalyi's insight that successful control of the way one directs one’s mental attention is crucial both to personal satisfaction and to the successful achievement of creative work. Although the notion of conscious thought is not supported in the authors’ concept of flow this book seems to uncover the importance of the regulation of cognition as it relates to creative outcomes.

Howard Gardner's *Creating Minds* (1993) delves into the lives of seven of the most important creative individuals of the twentieth century. Gardner presents studies of Sigmund Freud, Albert Einstein, Pablo Picasso, Igor Stravinsky, T. S. Eliot, Martha Graham, and Mahatma Gandhi. Gardner's approach is less scientific than Csikszentmihalyi's in that his research does not evolve from personal responses by individuals. The author's findings rely on an abundance of biographical information to provide an understanding of the circumstances and talents that resulted in his subjects' unique contributions. This form of creativity research is difficult to operationalize because of its anecdotal/biographical nature. Even so, *Creativity* and *Creating Minds* are major contributions to the research literature on creativity, and both works are of great importance to educators, artists, as well as those across all disciplines. Our understanding of how the most gifted have made significant contributions can be instrumental in developing our own skills and knowledge. In all areas of life one can benefit from the explorations of what the best and brightest developed, accomplished, and most importantly learned on their way to success (Potter, 1998).

Gardner’s contributions are not limited to creativity. Perhaps his most recognized deals with his theory of multiple intelligences. In formulating his own ideas about the human mind Gardner re-evaluated Piaget's theories as "too narrow a notion of how the human mind works” (Gardner, 1983). Gardner further stated that he did not believe in the existence of
"one form of cognition" that "cuts across all human thinking" (Gardner, 1983). Through his own research, Gardner observed multiple intelligences. Subsequently, Gardner wrote about his observations of multiple intelligences in what has turned out to be a seminal book in the educational community, *Frames of Mind* (1983). The theory of multiple intelligences, which Gardner proposed in this book, has become a catalyst, as well as the framework, for many current educational strategies across pre-school, higher, vocational and adult education initiatives. The theory advances a mental paradigm in which an individual's mind can be thought of as possessing a unique blend of intelligences. Gardner’s multiple intelligences include language, math and logic, spatial reasoning, music, movement and inter- and intra-personal skills. Gardner stated, “although they are not necessarily dependent on each other, these intelligences seldom operate in isolation. Every normal individual possesses varying degrees of each of these intelligences, but the ways in which intelligences combine and blend are as varied as the faces and the personalities of individuals” (Gardner, 1983).

There are some significant questions and issues surrounding Howard Gardner's notion of multiple intelligences, and the theory has not been readily accepted within academic psychology. However, it has been embraced by a range of educational theorists and applied by teachers and policymakers to the problems of schooling. A number of schools in North America have looked to structure curricula according to the intelligences, and to design classrooms and even whole schools to reflect the understandings that Gardner develops. At the very least it has helped a significant number of educators to question their work and to encourage them to look beyond the narrow confines of the dominant discourses of skills, curriculum, and testing.

2.2 The Creative Process

It must be emphasized that creativity actually represents a family of skills and processes. By examining literature related to the creative process one can begin to develop a theoretical understanding of creativity and identify essential skills and behaviors. According to one group of researchers (Ribot 1900, Spearman 1931, Mednick 1962, Wallach & Kogan 1965,
Koestler 1964, Maltzman 1960) the ability to think creatively is a matter of utilizing a variety of associations accessible to an individual. Unusual recombination of these bonds results in creativity. Ribot, a forerunner of the modern associationistic approach to creativity, described the process as one in which mental states become joined in such a way that one state tends to evoke the other. Unlike association by contiguity, which often happens in stereotyped responses when ideas are connected based on reflexive thought, associations by resemblance – a reflective thought, either direct or through a mediating idea, as in analogical thinking – are the bases for creative association. In the creative process, complementary processes of association and disassociation occur by spontaneously causing ideas to associate into groups through imagination (Taylor, 1975). In other words, one relies on associative thought to bring about creative outcomes.

Spearman (1931) claimed that the generation of new ideas could be explained by three “neogenetic processes,” each capable of generating new mental content. Two of these processes are explained by the Principle of Relations – “When two or more items (percepts or ideas) are given, a person may perceive them to be in various ways related”; and the Principle of Correlates – “When any item and a relation to it are present to mind, then the mind can generate in itself another item so related.” Spearman’s basic model (Figure 2.3) involves an active process in which associations with an initial idea can be freed from their relation to it and thus lead to something entirely new:

The final act in creativity must be assigned to the Principle of Correlates; that of displacing a relation from the ideas which were its original fundaments to another idea, and thereby generating the further idea which is correlative to the past named, and which may be entirely novel.
Many approaches to creativity including Spearman’s, are implicitly associationistic: a creative idea results from the novel combination of two or more ideas that have been freed from their normal correlates. Mednick (1962) and his colleagues were the leading associationists concerned with creativity. Mednick (1962; Mednick & Mednick 1964) offered an explicitly associationistic theory of creativity based on introspective accounts of creativity. Mednick (1962, p.221) defined the creative thinking process as:

the forming of associative elements into new combinations which either meet specified requirements or are in some way useful; the more mutually remote the elements of the new combination, the more creative the process or solution.

Mednick’s straightforward theory has stimulated a growing body of research in which creativity is characterized by the combining of mutually distant associative elements of thought. Creative individuals solve problems by juxtaposing a number of ideas not previously related to one another. Creativity is a matter of novel arrangement of temporarily contiguous, unusual associations to a given stimulus. Mednick has further defined the creative process as the distribution of the individual’s associations around ideas that he has called the associative hierarchy of responses (Figure 2.4) (Taylor, 1975).

Although not stated explicitly, one cannot ignore the influence of J.P. Guilford’s theory on the production of remote associations, as he states that originality in divergent thinking is a result of infrequent and clever responses and “remote associations” (Guilford, 1959, p.150).
This theory also arose as a result of distilling accounts from highly creative people (e.g. Einstein, Coleridge, and Poinecare) concerning their discovery processes.

For Mednick (1962), creativity was a function of people’s “associative hierarchy,” which is the way that one attaches associations to words or problems. Each individual’s associative hierarchy determines the probability and speed of reaching a creative response (Mednick, 1962). Similarly, the likelihood of producing a creative response increases as the number of associations between ideas increases. The easiest way to conceptualize these associative hierarchies is through a graph (Figure 2.4) of possible associations for a given solution showing the hierarchy for a creative and non-creative person. A non-creative person will show a relatively steep associative hierarchy (higher response rate with fewer responses) because he does not associate the more unique elements with the product, so his web of responses will drop sharply after the common responses are generated. Also, his subjective association with the most common response will be quite strong. The creative person, however will show a flat associative hierarchy (slow, steady responding) that includes the more commonly produced elements (at lower subjective strength) and the more unique, or “remote”, associates as well because he does not become fixated on the over-used response. In fact, the likelihood of producing a creative response was shown to be inversely related to that familiarity with the associative relationships for a given solution (Mednick, 1958).
According to Mednick's theory, for people to be creative it is necessary that they have an abundance of associate elements (i.e., knowledge), as well as a weaker (i.e., flatter) associative network. This means that the creative person may reach the same conclusion to a given problem as the less creative person, but that alternative solutions are also available and may impinge upon the conscious thoughts of the creative thinker. Mednick's theory emphasizes loose associations that allow for unusual relationships to emerge. Mednick explained these loose associations in terms of a hierarchy of thought.

As evidence for his theory of associative hierarchies, Mednick cites his research with scientists rated by experts for the creativity of their work. He found that the less creative scientists gave more stereotyped responses to 80% of the words in a standardized word association task (Mednick, 1958).

Mednick (1962) also created the Remote Associates Test (RAT) to investigate further the importance of associative ability in creativity. He used the RAT to measure ability to make remote associations and evaluate their appropriateness. Mednick developed the RAT as a measure of creative thought that would not require knowledge specific to any field.
constructed two college-level versions of the test, each consisting of 30 items (Mednick, 1968; Mednick & Mednick, 1967). The items in the RAT consist of three words that can be associated with the solution word in a number of ways (e.g., the three words SAME / TENNIS / HEAD are associated with the solution MATCH by synonymy (same = match), by formation of a compound word (matchhead), and by semantic association (tennis match). Thus, reaching a solution requires "creative thought" because the first, most-related, information retrieved in solution attempts is often not correct, and solvers must think of more distantly related information to connect the three words. Problem solvers’ success on items from the original RAT reliably correlates with their success on classic insight problems (Dallob & Dominowski, 1993; Schooler & Melcher, 1995). An insight problem is a problem that requires the examinee to shift his or her perceptive and view the problem in a novel way in order to achieve the solution. There are several types of insight problems. The three predominant types are verbal, mathematical, and spatial (Dow & Mayer, 2004).

Although RAT items are not as complex as classic insight problems, they exhibit the three properties of insight problems that distinguish insight solutions from non-insight solutions: (1) they misdirect (or fail to direct) retrieval processes; (2) solvers often cannot report the processing that led to the solution (Ben-Zur, 1989); and (3) upon solving RAT items, solvers often have the Aha! experience (Bowden & Beeman, in press). This third property is considered the centrally defining feature of insight problems. Thus, solving RAT-like items appears to involve the same component processes that are critical for, and the same phenomenological experience of, insight solutions to more complex problems.

For the most part the RAT and RAT-like problems have been used to study problem solving and creative thinking (e.g., Ansburg, 2000; Beeman & Bowden, 2000; Bowden & Beeman, 1998, in press; Bowers, Regehr, Balthazard, & Parker, 1990; Dallob & Dominowski, 1993; Dorfman, Shames, & Kihlstrom, 1996; Schooler & Melcher, 1995; Shames, 1994; Smith & Blankenship, 1991). Of most significance to the understanding of creative thinking may be that original ideas are typically found after obvious ideas (Mednick, 1962; Milgram & Rabkin, 1980; Runco, 1986).
The RAT has shown excellent reliability and validity (based on expert judgments of creativity and research ability), is negatively correlated with grades and not correlated with general intelligence, is positively associated with anagram problem-solving, and is positively associated with creative personality and teacher’s ratings of creativity (Mednick, 1962). Other studies have found that the preparation (Mednick, Mednick, & Jung, 1964a) and incubation (Mednick, Mednick, & Mednick, 1964b) stages of the creative process are also implicated in successful RAT performance implying a similarity in process among other theories of creativity.

Another comparison to expert ratings of creative potential, this time for a group of architects, showed that the more creative participants were better able to make the unusual associations necessary to solve the word problems. In a further test using psychology graduate students, Mednick found essentially the same relationship. More creative students, as rated by their advisors, had higher Remote Associates Test scores as compared with the less creative students (Mednick, 1962).

Associative theory (Mednick 1962; Wallach & Kogan, 1965) therefore, has something to say about ideational creativity. In Mednick’s view, thought involves the association of ideas, and a creative idea reflects a remote association. These remote associations represent the unique relationships that exist among associates that result in a non-stereotype response or idea.

Mednick suggested that there are three ways to find creative ideas, namely serendipity, similarity, and mediation. Each of these three processes functions to connect ideas or at least bring them close together in an associative chain. Serendipity involves accidental associations (usually environmental accidents); similarity involves associations that result from ideas being brought together by stimuli that resemble one another; and mediation involves two ideas brought together as a result of their common association with a third idea (Runco, 1992). Mednick (1962) suggests that the mediation process is significantly important among the more remote associates in developing truly creative responses.
The associative view of thinking has a long history and the work of many have contributed to what is presently considered associationistic theory. A specific example of an early associative theory is that of Alexander Bain. In 1886 he wrote that “…by means of association, the mind has the power to form new combinations or aggregates, different from any that have been presented to it in the course of experience” (Runco, 1992).

Koestler’s (1964) approach to creativity may be considered, in certain respects, associationistic in nature. In his book The Act of Creation, he suggested that creativity involved “the displacement of attention to something not previously noted, that was irrelevant in the old and relevant in the new context; the discovery of hidden analogies as a result of the former; the bringing into consciousness of tacit axioms and habits of thought that were implied in the code and taken for granted; the uncovering of what has always been there” (pg.119-120). He coined the word “bisociation” to make a distinction between routine skills of thinking which occur on a single plane and the creative act, which operates on more than one plane (Taylor, 1975).

In his book, The Magic of Your Mind, Sidney Parnes (1981, p.59) describes what seems to be association as the essence of creative problem solving in design:

“Creative problem solving becomes the task of finding the greatest number of interconnections and interrelationships among our vast and diverse internal and external resources, connecting them in both obvious and not so obvious ways. The more seemingly remote the relationship, the more likelihood of originality in the idea. But remember producing a highly original idea that is also a useful solution to problem requires responsible creative action…”

Wallach and Kogan (1965) adopted Mednick’s basic theoretical view that creativity is an associative process and defined the creative process as involving “the production of associative content that is abundant and that is unique.” The idea that divergent thought largely focuses on ideational fluency led to the construction of a battery of verbal and visual tests that emphasizing the associative processing of the creative process. Wallach and Kogan
asserted that the process would yield its greatest effects if given under game-like conditions (Wallach, 1970). One test in particular, similarities, focused on associational fluency, “tell me all the ways in which a potato and a carrot are alike” (Brown, 1989).

Wallach (1970) considered his earlier research (Wallach & Kogan 1965) and Mednick’s (1962) work in relation to Maltzman’s (1960) approach to training creativity. He concluded that “what matters most is the generating of associates; once produced, the evaluation of their relevance and appropriate action in the light of this judgment seems to pose little difficulty” (pp.1254-1255). He further suggested that the process underlying the generation of many associates was attention deployment. Creative individuals can attend to many aspects of a given stimulus and, thus, produce more and more varied associations (Brown, 1989). For example, when generating creative content for a design project, ideas are expressed in larger quantity and are more unique in the case of a creative individual. This is due to the ability to attend to multiple possible associations based on stimulus.

2.3 Creativity and Cognition

When one thinks of creativity, eminent artists or scientists such as Michelangelo or Einstein immediately come to mind. Historically, the study of creativity began with the concept of genius. There is a longstanding tradition of examining eminent creators, who are viewed as “unambiguous cases” of creativity. However, these highly creative people are rare and difficult to study in the psychological laboratory. In his American Psychological Association address, psychologist J.P. Guilford (1950) noted that the rarity of these individuals had limited research on creativity. He proposed that creativity could be studied in everyday people with a psychometric approach, using paper-and-pencil tasks. Guilford presented several reasons for conducting this type of research in creativity, with understanding and enhancement as two of the most important reasons (Sternberg & Lubart, 1996).

Many researchers adopted Guilford’s suggestion, and divergent thinking tasks quickly became the main instruments for measuring creative thinking. The tests were a convenient
way of comparing people on a standard “creativity” scale. This psychometric revolution for measuring creativity had both positive and negative effects on the field. On the positive side, the tests facilitated research by providing a brief, easy-to-administer, objectively scorable assessment device. Therefore, research was now possible with “everyday” people (i.e., noneminent samples). However, critics suggested that the criteria for testing suggested by Guilford and expanded upon by Torrance (1974); fluency, flexibility, originality, and elaboration failed to capture the holistic concept of creativity. In fact, the definition and criteria for creativity are a matter of ongoing debate. Thus, it is hardly surprising that in the years since the cognitive revolution began in the late 1950s and early 1960s a large number of cognitive psychologists have concentrated more on other, more tractable cognitive constructs, such as perception, memory, reasoning, and decision making (Sternberg & Lubart, 1996).

Many researchers have concluded that a search for the essence of creativity is overwhelming unless it is approached with a domain specific focus. Brown (1989) stated that it is unlikely that there will ever be an essence of creativity, and that creativity might be a domain specific construct due to the fact that it is so complex and multidimensional. Taylor (1987) delineated the elements of creativity and concluded that because of the complexity of the creative process in individuals, assessment must focus on one element in a larger comprehensive construct. Hocevar and Bachelor (1989) have acknowledged that no single test of creativity will accurately represent the entire construct. This supports the notion of identifying the most relevant aspect of creativity for the particular domain under investigation. It is critical to select a test or battery of tests to assess a particular component or correlate of creativity that you wish to measure. Most notably by breaking down creativity to a single element of focus a study can maintain greater validity and reliability.

Speedie, Houtz, Ringenbach, and Feldhusen (1973) and Feldhusen (1993) found a number of skills and strategies that are components of creative thinking and problem-solving. One of the essential skills was the ability to redefine or create a new use for a familiar concept or object. Davis and Rimm (1985) found 19 skills or abilities that could be used as a basis for a
creativity assessment program. Among these were analogical /metaphorical thinking and synthesis. In more recent work, Weisberg (1993) proposed that creativity involves essentially ordinary cognitive processes yielding extraordinary products. Referring to case studies of eminent creators and laboratory research Weisberg attempted to show that the insights depend on participants’ use of conventional cognitive processes (e.g. analogical transfer) applied to knowledge already stored in memory (Feldhusen & Eng Goh, 1995).

Creative thinking and design in general can often be characterized by periods of incompatible or at least conflicting demands. A good idea is rarely easily found and often comes after a long periods of thought. It is hardly surprising then that good designers tend to be at ease with the lack of resolution of their ideas for most of the design process. Characteristically designers seem to cope with this lack of resolution through the generation of alternatives. Creative thinkers and designers in particular seem to have the ability to change the direction of their thinking thus generating more alternative ideas (Lawson, 2006). Elsewhere Mansfield and Busse have proposed that creativity is a function of number of cognitive abilities and skills as well as a number of motivational, personality, and situational factors. Since no training program is likely to influence more than one or two of these necessary characteristics, the success of any training program will be based on isolating a particular component or correlate and integrating training with instruction in a particular domain (Mansfield, Busse & Krepelka 1978).

2.4 Enhancing Creativity

The impact of cognitive psychology on instruction has been impressive. Efforts to improve thinking and problem solving based upon directed or glass box approaches have included course and curriculum revisions focusing on the development of component thinking skills and strategies. Developing curricula to enhance problem solving or creativity within a particular field or domain of knowledge has also received much attention. While numerous domains have embraced the development of curricula, the modification of the existing design curricula to develop new learning experiences for designers remains unrealized. The idea of
enhancing creative thinking continues to escape the vast majority of design educators (Houtz, 1994).

In all areas of education there is a need for reconsideration of educational objectives. New concepts, new theories, and new experimental equipment supplied by the ever-expanding technology are the very nature of education. Thus, the student in any field, trained in a narrow discipline to be proficient in certain skills, will find that these skills become out of date, and that he/she has acquired nothing but knowledge which, after a few years, ceases to be of direct use (Kwashny, 1982).

To meet this challenge, many educators from different fields (Torrance 1962, Osborn 1962, Parnes 1967, and others) suggest the cultivation of deliberate effort to enhance creative thinking. This includes requiring every individual to have a flexible mind, and to be able to absorb, acquire and produce new ideas. Experts suggest that a central purpose of education should be to develop cognitive skills of creative thinking, thus preparing students for the effective and innovative use of the mind with whatever subject matter and whatever problems that the future may have to deal with.

Currently millions of hours are devoted to problem solving training, however, many programs are limited in their focus on specific creative skills. While teachers may recognize that there are creative and cognitive factors, many do not understand how to tap and encourage them.

Parnes (1967, p.66) summarized:

“Our bibliographic search has uncovered over forty studies evaluating programs for teaching students to improve their creative abilities. These investigations range from the first grade through college and adult education. Approximately ninety percent of the total number indicated that subjects’ creative levels were significantly increased by a deliberate educational program. A number of informal and unpublished studies include similar findings, so the bulk of research is quite consistent and impressive on this question.”
Many other studies reported similar findings: Brown (1968) and Mitchell (1971) both found that experimental groups made significantly greater gains in creative thinking scores than control groups.

Evidence supports the notion that one can improve creativity with the proper approach to the educational system through which designers pass. Alon Kvashny (1982) in his study on creativity in the Landscape Architecture studio provided major implications for the training and education of all design students. Among these implications was the conclusion that there is a creativity shortfall under current design education pedagogy and that creativity training should be included in courses of design in Landscape Architecture. In addition, Kvashny stated that creativity training should be integrated into the studio education and continued throughout the entire design education. One of the findings of the study was that creativity training with direct involvement in exercises designed to enhance creativity produced greater overall effects than did creativity training that consisted of only reading books on the subject (Kvashny, 1982).

Assuming that most people have some creative potential, the next question is how to evoke, access, stimulate, train, or develop the creative potential. The main question perhaps is whether creativity can be taught within a large scale educational system, and if so, how. Many researchers in the field of creativity are convinced that creativity can be taught, but critics say that the research evidence supporting this is weak, and the instructional approaches are so diverse that clear, solid guidelines cannot be found (Feldhusen & Eng Goh, 1995).

In general, research suggests that if creativity training strategies can be accessed, and if the skills and strategies used in creative activities can be defined, then it should be possible to develop curricular models for use in the classroom. However, good instructional strategies alone do not guarantee successful real-life creative production. At best they facilitate thinking processes making it easier to access creativity. The best sources in the development of creative training are theories and models of creative thinking processes. Constructing a set
of program goals would then consist of sorting among the components of these processes and
deciding on a manageable set for inclusion into the program (Feldhusen & Eng Goh, 1995). Using this approach, educators would not try to teach “creativity” but rather isolate creative thinking strategies and introduce metacognitive thinking in support of these skills.

Davis and Rimm (1985) reviewed many techniques and methods for accessing creativity and combined them with Davis’s (1982) awareness, understanding, techniques, and actualization (AUTA) model. The essential techniques or creative strategies, according to Rimm and Davis are brainstorming, attribute listing, morphological synthesis, idea checklist, and synectics. After their extensive review of research, Davis and Rimm concluded that using these strategies could definitely allow students to reach their creative potential.

Creativity is often seen as the unique human capacity to think up something new out of nothing, a magical gift that all great creative minds possess. Creativity is surrounded by myths about sudden inspiration, the Eureka moments and ‘aha’ experiences. One uses the word creativity for anything experienced as new, when one cannot easily explain where it came from. Creativity is a difficult and fascinating process, but certainly not a magical one. Being creative doesn’t mean sitting around waiting for a sudden bolt to hit you. It is a pity that the myths surrounding creativity tend to cloud people’s views of the work that is necessary to be creative. Fortune favors the prepared mind (Dorst, 2003).

2.5 Creativity as a Metacognitive Process

There is a general consensus that the major components of creative thinking processes and creativity include metacognitive skills in planning, monitoring, and evaluation (Armbruster, 1989). These metacognitive skills are also essential for effective and efficient problem solving and creative thinking (Jausovec, 1994). In Beyer’s (1987) basic model of metacognition, the metacognitive skills – planning, monitoring the thinking processes, and evaluating outcomes - form the core of a training program. Pesut (1990) also suggested that the fundamental skills of creativity such as brainstorming, synectics, attribute listing, and free
association are really action-oriented metacognitive guides that operate in concert with self-monitoring, self-reinforcement, and self-evaluation to sustain and enhance creative thinking. Armbruster (1989) broadened the scope of metacognition in creativity by proposing that there are guiding skills, regulatory skills and awareness that function metacognitively in support of creative thinking and are trainable operations.

One approach to increasing certain aspects of creativity might be through deliberate educational programs that conceptualize creative thinking as a metacognitive process. Using this approach students may enhance creativity and learn to break through barriers to change habits that hamper ideation in order to increase their creative cognitive potential.

An important aspect of the growing interest in metacognition in recent years has been an increasing emphasis on the role of self-management. Runco (1990) has stressed the importance of self-evaluative skills and metacognition more generally to creative thinking. Self-management involves becoming an active manager of one’s cognitive resources. It is, in part, a matter of paying attention to one’s own thought processes and taking responsibility for thinking. It involves learning one’s strengths and weaknesses as a creative problem solver and finding ways to utilize the strengths to mitigate or work around the weaknesses. It means making an effort to discover conditions that facilitate one’s own creative work (Nickerson, 1999).

A profitable area of research dealing with metacognition is intervention studies that are designed to teach the metacognitive skills that support creativity. It seems likely that some of the principles of metacognitive skills that are derived from intervention studies in learning could be effectively applied to creativity. The potential for such transfer has already been demonstrated by Scardamalia and Bereiter (1983) in the area of writing. These researchers have completed a number of studies in which students receive instruction and help in various cognitive and metacognitive skills that are associated with writing; for example, planning a composition, making evaluative judgments about their writing, and diagnosing text problems. Similar research should be carried out in creative domains such as design.
Knowledge and Regulation of Cognition

“unless you know everything, what you need is thinking”
Edward de Bono (Maclure and Davies, 1991, p. xii)

Knowledge and strategies in isolation are not sufficient for creative thinking. Students must understand the strengths and limitations of their knowledge and strategies in order to be able to use them efficiently. This capability builds explicit knowledge of one's own cognition (Figure 2.5). Metacognition includes two main components referred to as knowledge of cognition and regulation of cognition (Schraw & Moshman, 1995; Baker 1989). Knowledge of cognition consists of explicit knowledge of one's memory, knowledge base, and strategy repertoire, as well as what often is known as conditional knowledge, or knowledge about why, when and where to use strategies. Regulation of cognition consists of knowledge about planning, monitoring, and evaluation.

Figure 2.5: Knowledge and Regulation of Cognition (Schraw & Brooks, pg.199)

If students understand the role of regulation and knowledge of cognition as the main requirements of metacognition they will be able to build metacognitive knowledge through
the interaction of these skills. To facilitate this understanding, teachers can discuss the importance of metacognitive knowledge and regulation. Ideally, such a discussion helps students construct an explicit mental model of a metacognitive thinking process (Schraw & Moshman, 1995). Another way is for teachers to model their own metacognition for students. When thinking out loud, teachers too often discuss and model their cognition (i.e., how to perform a task) without modeling metacognition (i.e., how they think about and monitor their performance). A third way is to provide time for group discussion and reflection. Peer modeling of both strategies and metacognition not only improves performance, but increases self-efficacy as well (Schraw, 1998).

**Promote Regulation of Cognition**

The regulation of cognition is the way an individual monitors, controls, and directs aspects of his or her cognitive processes and behavior for themselves by coordinating thinking skills. The regulation of cognition involves the following processes:

**Planning:** involves goal-setting, developing a strategy, and identifying obstacles; the purposeful selection of strategies for specific tasks and organized steps to execute them.

**Monitoring:** involves the ability to observe, acknowledge, and measure progress toward one's objectives.

**Evaluating:** involves assessing outcomes, gauging progress; an ongoing assessments of knowledge or understanding, resources, tasks, and goals.

Evaluation, planning, and regulation help students gain executive control of behavior and should take place before, during, and after stages of tasks.

Designers may benefit from the regulation of cognition because it allows them to create order out of an often chaotic existence, and it helps them organize time, energies, and resources. When educators help students develop an awareness about their own thinking and learning processes they are helping students think about the effectiveness of the strategies they use in reaching the goals they have set. Students are essentially thinking about their thinking. In general, use of a long-term metacognitive strategy of planning what is to be done, monitoring
our progress, and evaluating the results is an effective way of helping students take more control of their own thought and feeling processes (Barell, 1985).

You cannot help each student during each creative process; students must take control of the process. After forming initial creative products and awakening the joy of creating in students, one should teach strategies for regulation of cognition. Self-directed creating is how most of us work throughout our lives-and especially in our lives outside of school. Some things students can do to promote their regulation of cognition:

1. List multiple ideas (solutions) to a problem (project)
2. Assess creative strategies and pursue one
3. Defend your choice
4. Develop plans for completing the project, including how and where to find information, and how and when you will finish the project
5. Keep a daily thinking log of progress, roadblocks, and how you surmounted problems
6. Discuss teacher feedback on finished projects
7. Assess a classmate's project and review and discuss peer evaluations.
(Sternberg & Williams, 1996)

Regulation of Problem-Solving

Students at almost any age are capable of taking charge of their own problem solving. When faced with a problem, self-regulated problem-solvers typically do the following:

1. They begin by analyzing the task and interpreting task requirements in terms of their current knowledge and beliefs. (Planning)

2. They set task-specific goals, that they use as a basis for selecting, adapting, and possibly inventing strategies that will help them accomplish their objectives. (Planning)

3. After implementing strategies, they monitor their progress toward goals, thereby generating internal feedback about the success of their efforts. (Monitoring)

4. They adjust their strategies and efforts based on their perception of ongoing progress. (Evaluating)

Self-regulated learners are iterative. They don't do these steps just once. Rather, they go through the above list repeatedly, looping back to make adjustments as necessary.
2.6 Metacognition

According to Samek (1981) the “Meta” phenomenon is a consequence of human beings’ evolving conscious awareness. Metacognition is the ability to be aware of, to attend to, and use information about personal cognitive processes, so that one can effectively enhance performance on cognitive tasks. Metacognition refers to “knowledge about cognitive phenomena”. It includes knowledge about general cognitive strategies, and knowledge about monitoring, evaluating, and regulating these strategies. It may also include beliefs about factors that affect cognitive strategies. In most cases however, metacognition refers more narrowly to monitoring one’s own cognitive processes and the influences on them while one focuses on a specific task (Kitchener, 1983).

The term "metacognition" is most often associated with John Flavell (1979). According to Flavell, metacognition consists of both metacognitive knowledge and metacognitive strategies. Metacognitive knowledge refers to acquired knowledge about cognitive processes, knowledge that can be used to control cognitive processes. Jacobs and Paris (1987) further define the knowledge component of metacognition into declarative, procedural, and conditional aspects of knowledge; knowing about skills and procedures you can use to improve your cognitive performance.

Metacognitive strategies involve sequential processes that one uses to control cognitive activities and to ensure that a cognitive goal has been met. These processes help to regulate and oversee problem solving, and consist of planning and monitoring cognitive activities as well as evaluating the outcomes of those activities.

Modern-day cognitive psychology recognizes the hierarchical nature of psychological processes that are involved in cognition. At the top of the hierarchy are the executive processes that oversee, regulate, and orchestrate the activities of cognition. Metacognition represents these executive processes and includes both knowledge and the control that individuals have over their own cognitive processes. Control, or regulation, includes setting
goals and subgoals, planning the next cognitive move, monitoring and evaluating the effectiveness of cognitive strategies, and revising cognitive strategies (Armbruster, 1989).

Metacognition is currently a popular topic in cognitive psychology. In the past 25 years, literally hundreds of studies have been conducted on the subject of metacognition. This research has had a significant influence on the area of learning, particularly learning from reading. More recent research in metacognition has concentrated on intervention research that is designed to overcome metacomprehension problems. Given the impact of metacognition on theory and practice in the area of learning, it seems appropriate to inquire about the relevance of metacognition to the study of one of the most intriguing of cognitive processes – creative thinking (Armbruster, 1989).

2.7 Metacognition and Design

In a seminal paper design researcher Nigel Cross (1990) summarized the knowledge in the field of design. According to Cross, designers produce novel unexpected solutions, tolerate uncertainty, work with incomplete information, apply imagination and constructive forethought to practical problems and use drawings and other modeling media as a means of problem solving. From this Cross went on to list the abilities that a designer must have. ‘They must be able to resolve ill-defined problems, adopt solution focused strategies, employ abductive/productive/appositional thinking and use non-verbal, graphic and spatial modeling media.’ In addition to these abilities there is clearly some group of activities that oversee the whole process and provide support for it, metacognitive activities. A more or less conscious effort is needed to keep the whole design activity on course towards its target. Designers seem to be actively looking at and thinking about design even when not actually designing (Lawson, 2006). Donald Schon (1983) has written most notably about a range of professionals who seem to depend upon these continuous monitoring and learning processes and calls them ‘reflective practitioners’.
Based on research in the area of metacognitive skills, it is worthwhile to draw some conclusions about how metacognitive strategies or skills relate to creative problem solving performance. From a theoretical viewpoint, metacognition is an important aspect of cognition, and can dramatically affect problem-solving performance (Doerner, 1974; Schoenfeld, 1983; Sternberg, 1982). Additional empirical research is needed to lend support to this statement. Findings that indicate individual differences in problem-solving are related to metacognition, and that basic metacognitive awareness and attention through instruction can significantly influence problem-solving and the educational enterprise. Put briefly, instruction should explicitly assist students in acquiring metacognitive knowledge of how to plan their problem solving efforts, how to set goals and sub-goals for their efforts, and how to monitor their progress toward their goals (Jausovec, 1994).

Activities, such as planning how to approach a problem-solving situation, are metacognitive in nature. Because metacognition plays a critical role in successful problem solving, it is important to study metacognitive activity and development to determine how students can be taught to better control their cognitive resources. Jausovec (1994) conducted a series of studies designed to investigate the influence metacognition has on problem-solving performance. The results suggested that instructions aimed at manipulating metacognitive processes had a significant impact on the responses to well- and ill-defined problems. Taken together, the results indicate that metacognition is an important factor in problem-solving performance. Metacognition appears to be important for solving open-ended (creative) problems. In addition, it was shown that proficient students seem to know much more about general cognitive strategies – how and when to apply them – than less proficient individuals. Poor problem solvers are also less efficient in monitoring their own cognitive processes during problem-solving than are skilled problem solvers, and they use more rigid solution approaches. In particular, good problem solvers engage in more self-checking procedures and bookkeeping strategies than inferior problem solvers. In essence, good problem solvers are able to carry on an effective and continuous monitoring process.
Bransford, Sherwood, Vye, and Riser (1986) described two approaches to teaching thinking and problem solving. The first approach emerged from the study of experts and focuses on the role of domain-specific knowledge. The second approach emphasizes general strategic and metacognitive knowledge. Bransford et al. suggested that metacognitive training may be able to help people improve their ability to think and learn. To that end, Davidson and Sternburg (1998) proposed a variety of approaches for training metacognition in problem solving, including integration of techniques into the curriculum. Mayer (2001) emphasized the importance of teaching through modeling of how and when to use metacognitive skills in realistic academic tasks.

There is evidence that problem solvers can benefit from interventions designed to facilitate their monitoring and evaluation skills. King (1991) taught fifth-grade students to ask themselves questions designed to prompt the metacognitive process of planning, monitoring, and evaluating as they worked in pairs to solve problems. The students in this guided question group performed better on written test of problem solving and on novel problem solving task than did students in an unguided question group and a control group. Berardi-Coletta, Buyer, Dominowski, and Rellinger (1995) found that college students given process-oriented (metacognitive) verbalization instructions performed better on training and transfer problem-solving tasks than did students given problem-oriented verbalization instructions and those given simple think-aloud instructions. The process-oriented instructions induced metacognitive processing by asking students questions designed to focus their attention on monitoring and evaluating their problem-solving efforts. In contrast, the problem-oriented instructions focused students’ attention on the goals, steps, and current state of the problem-solving effort. Berardi-Coletta et al. (1995) suggested that future problem solving research should emphasize the critical role of metacognition in successful problem solving.

At virtually all design schools, design is quite rightly considered the heart of the curriculum. Still, the term ‘design,’ as commonly used by designers and design educators, has taken on limited connotations, focusing more on the aesthetic and theoretical dimensions of design than on the cognitive nature of the process itself (Boyer & Mitgang, 1996). As a result
students leave school and face the profession without an awareness and understanding of their own cognitive processes and, therefore, lack the metacognitive knowledge to reach their creative design potential.

Design educators and administrators should carefully consider to what extent do our current educational practices and projects value and promote cognitive process as a main objective. The American Institute of Architecture Students (AIAS) has expressed concern that the current design education approach rewards students with the “best looking” projects and emphasis on appearance takes precedent over the quality of ideas and the process behind the design work. AIAS has confirmed this in their 2002 report on design studio culture. In the report they found that frequently in design schools, students without the ability to produce the “best looking” projects are marginalized and undervalued (AIAS, 2002).

The AIAS task force points to a creativity shortfall under the current design education pedagogy. In a call to action it states that design education administrators have the ability to set forth a vision in order to produce an improved educational experience. Through the design of programs and curriculum, leaders can implement policies and procedures to promote and understanding and awareness of the cognitive processes related to creative thinking. This in turn creates the potential to share and disseminate initiatives to promote creative thinking. They believe that most design schools currently exercise this improved educational approach on a very small scale and efforts could be made to integrate this approach throughout the curriculum (AIAS, 2002).

2.8 The Role of Metacognition in Educating Designers

Design Education - What is missing?

Irrespective of the specific design domain, some educational models in design education are based upon the replication of professional task performance. The measure of learning is generally equated with the evaluation of the product of designing rather than on what might be considered a learning process or skill. The cognitive skill sets of design are not adequately
addressed by pedagogy in design education. As a consequence, there presently exists a lack of cognitive theories that function to strengthen design education (Oxman, 1999).

The model of representation-redescription proposed by Karmilloff-Smith (1995) clearly articulates the importance of cognitive strategies in design education. This model refers to learning as the succession of representations that become progressively more manipulable and flexible due to the emergence of conscious access to knowledge structures. With this consciousness comes the belief that understanding and awareness of cognitive principles and processes will enhance ability to create novel solutions. In their research Karmilloff-Smith hypothesizes that learning in design is to be able to utilize various cognitive strategies of design thinking. That is, cognitive strategies of design thinking can become the content of design education (Oxman, 1999).

**Design Cognition - Why is this important?**

The need for exceptional designers has never been stronger. Designers must possess the ability to address and find innovative solutions to the emerging and ever changing of present and future society. Educators cannot rely on a novice understanding of how design students learn the skills and knowledge to be productive and innovative designers. Recognizing possibilities requires that designers have an understanding of design thinking and process. A focus on cognition tends to be stifled by the rigid framework of the university design programs. Students are often told how to think about the design process, without explicit and purposeful instruction that allows for reflection and regulation of cognitive processes. When educators stifle the understanding of cognitive processes, they shut out a great many possibilities, and in a world that so desperately needs better solutions, that is something that they cannot afford to do (Lyle, 1985).

Cross describes design as exploratory, rhetorical, emergent, opportunistic, reflective, and risky endeavor (Atman, 2005). It is expected that design institutions will develop these attributes in designers. First, they must have a basic understanding of design and how
students learn to design. A starting point for this transformation should be the cognitive processes that students naturally go through in solving design problems. Educators can teach designers about initial design states and construct an educational experience that affects the way students think about and practice design (Atman, 2005). This form of design education is desperately needed to support the idea that strengthening metacognitive skills is essential to improving one’s ability to think about and practice creative design.

To best formulate creative reasoning in design students the dominant model of design education should be modified to provide a robust and reflective model of design thinking. There is no doubt that there is a great deal of room for improvement, knowing that designers must be competent in all aspects of the design process. However, it is also clear that students’ creative design abilities can be enhanced through educational programs with iteration and reflection as an essential part of the process. Acknowledging this point leads to questioning our understanding of the creative design process. Therefore, one must return to the issue of cognition and recognize how little one really know about designers’ creative processes, and seriously question how such an immensely important component of problem solving remains absent from design education.

Identifying design’s cognitive processes is attractive pedagogically because it suggests that there are some processes that if taught well would address the core goals of design education (Eastman, 2001). The area of metacognition should be the scaffolding for future problem solving, as the goal should be to enable designers to utilize creative design thinking/processes with optimum efficiency.

**Diagramming Change - Metacognition and Cognitive Strategy Instruction**

*The process of planning, monitoring, and evaluating one's own thinking.*

In an attempt to enhance designers’ problem solving ability it must be recognized that metacognitive processes play a central role (Bransford et. al., 1986; Berardi-Coletta et al., 1995; Davidson & Sternburg, 1998; Jausovec, 1994; King, 1991; Mayer, 2001). The
foundation, the utilization of one’s cognitive processes is reliant upon strong metacognitive knowledge and strategies. Therefore, the development of such knowledge and strategies should be a focus of a new design education approach.

Although most individuals of normal intelligence engage in metacognitive strategies when confronted with a challenging cognitive task, some are more metacognitive than others. Those with greater metacognitive abilities tend to be more successful in their cognitive endeavors (e.g. problem solving / design) (Berardi-Coletta et al., 1995; Jausovec, 1994; King, 1991). The good news is that individuals can learn how to better regulate their cognitive activities.

Steps toward such advancement are based on an instructional approach that emphasizes the development of thinking skills and processes as a means to enhance problem solving. The objective is to enable all students to become more strategic, self-reliant, flexible, and productive in their problem-solving endeavors. Programs such as these are based on the assumption that there are identifiable cognitive strategies, previously believed to be utilized by only expert problem-solvers that can be taught to most students. Use of these strategies has been associated with successful problem solving (Huitt, 1997). Therefore, the challenge is for each individual to become aware and consciously explore his/her own cognitive process to determine where strengths and weaknesses exist. Then strategies can be applied appropriately to ensure each individual reaches his/her cognitive potential, and ultimately maximum design potential.

Metacognitive thinking enables students to benefit from instruction and influences the use and maintenance of cognitive strategies. While there are several approaches to metacognitive instruction, the most effective involve providing students with both the knowledge of cognitive processes and strategies, and experience or practice in using both cognitive and metacognitive strategies while evaluating the outcomes of their efforts. Simply providing knowledge without experience, or vice versa, does not seem to be sufficient for the development of metacognitive control (Huitt, 1997). Design educators in all areas of a
students’ education should embrace this responsibility and structure a learning environment that builds both knowledge and reflective experiences of the cognitive process associated with design.

The study of metacognition has provided educational psychologists with insight about the cognitive processes involved in problem solving and what differentiates successful problem solvers from their less successful peers. It also holds several implications for instructional interventions, such as teaching students how to be more aware of their cognitive processes as well as how to regulate those processes for more effective (creative) problem solving.

Design is a complex behavior. Regardless of how much experience or knowledge a designer has, each new design situation is in some way unique, requiring creative application of problem-solving strategies for posing, solving, and resolving the problem at hand. Expert problem-solvers plan strategies for attacking thinking problems. When they hit conceptual blocks, they stop, analyze, and reflect, and often implore cognitive strategies. Effective thinkers pose alternatives for themselves and choose among them. These skills should become valued and reiterated throughout a designer’s education. The first step is making students aware of their own cognitive processes and building a greater understanding.

Surprisingly, metacognitive awareness is not uniformly developed in students. Even college age students are unaware and lack understanding of themselves as thinkers, and struggle with the most basic aspects of how to work through problems that have stumped them (Huitt, 1997). In design, novice designers often follow one procedure again and again without flexibility, even in the face of unsatisfying results.

**In the Classroom: A Model of Metacognition**

Metacognition combines various attended thinking and reflective processes, and the teaching of metacognitive skills is a valuable use of instructional time for design educators. When
designers reflect upon their problem-solving strategies, they become better prepared to make conscious decisions about what they can do to enhance their cognitive processes in design.

When assessing the role of metacognition in the classroom Neil Anderson (2002) divided these processes into five primary components: (1) preparing and planning, (2) selecting and using strategies, (3) monitoring strategy use, (4) orchestrating various strategies, and (5) evaluating strategy use. While Anderson’s assessment was focused on teaching and learning a second language, all of the components apply to problem-solving and the designer. Anderson states that a student’s educational experience should include all five areas, which are discussed below.

**Preparing and Planning**
Preparation and planning are important metacognitive skills that can improve student problem-solving. By engaging in preparation and planning in relation to a project goal, students think about what they need or want to accomplish and how they intend to go about accomplishing it. Teachers can promote this reflection by guiding the students in setting their own project goals. The more clearly articulated the goal, the easier it will be for the students to measure their progress. This relates to the infrequency with which design education engages the student in setting or defining the problem parameters. Many problems arrive stripped of their complexity by the teacher.

**Selecting and Using Strategies**
Researchers have suggested that teaching students how to use specific strategies to develop metacognitive skills is a prime consideration in the classroom. The metacognitive ability to select and use particular strategies that are appropriate in a given context for a specific purpose means that the design student can think and make conscious decisions about the design process. To be effective, metacognitive instruction should explicitly teach students a variety of creative strategies and also when to use them. The selection of a creative strategy used to work on a problem is critical to how the solution is formed. There are many forms
for solving most problems and it is often difficult to know what approach may be the best choice. The first step is realizing that you have a choice. One should consciously think about the various ways of working the problem and follow through with the most feasible against a set of performance criteria. However, as was mentioned before, most students follow the habit of unconsciously selecting a strategy and then unconsciously switching from one strategy to another.

**Monitoring Strategy Use**

By monitoring their use of creative strategies, students are better able to keep themselves on track to meet their project goals. Once they have selected and begun to implement specific strategies, they need to ask themselves periodically whether or not they are still using those strategies as intended. For example, students may be taught that an effective creative strategy involves free association. Students can be taught that to monitor their use of this strategy; they should pause occasionally asking themselves questions about what they are doing and whether the strategy they are using is most effective in supporting their project goal and users.

**Orchestrating Various Strategies**

Knowing how to orchestrate the use of more than one strategy is an important metacognitive skill. The ability to coordinate, organize, and make associations among the various strategies available are major distinctions between strong and weak problem-solvers. Teachers can assist students by making them aware of the multiple strategies available to them and how to recognize when one strategy isn't working and how to move on to another.

**Evaluating Strategy Use**

Problem-solvers are actively involved in metacognition when they attempt to evaluate whether what they are doing is effective. Teachers can help students evaluate their strategy use by asking them to respond thoughtfully to the following questions: (1) What am I trying to accomplish? (2) What strategies am I using? (3) How well am I using them? (4) What else could I do? Responding to these four questions integrates all of the previous aspects of
metacognition. Preparing and planning relates to identifying what is to be accomplished, while selecting and using particular strategies relates to the question of which strategies are being used. The third question corresponds to monitoring strategy use, while the fourth relates to the orchestration of strategies. The whole cycle is evaluated during this stage of metacognition.

**An Interaction of Skills**

Each of the five metacognitive skills described interacts with the others. Metacognition is not a linear process that moves from planning to evaluating. More than one metacognitive process may be occurring at a time during a problem-solving task. This highlights once again how the orchestration of various strategies is a vital component of any problem-solving activity. Allowing the student opportunities to think about how they combine various strategies facilitates the improvement of strategy use.

Teachers can promote awareness of strategies for thinking by engaging their students in activities that require reflection. Activities that require students to make the sometimes invisible work of thinking visible and explicit help all students to understand that as thinkers, they are in charge. Structured problem-solving strategies can provide novices with mechanisms that promote a more purposeful, flexible, and creative problem-solving. Metacognition is thinking about thinking, knowing "what one knows" and "what one doesn’t know." Just as an executive's job is management of an organization, a thinker's job is management of thinking. Some basic metacognitive strategies are:

1. Connecting new information to former knowledge. (Making associations)
2. Selecting creative thinking strategies deliberately.

(Dirkes, 1985)
When life presents situations that cannot be solved by learned responses (ill-defined problems), metacognitive behavior is brought into play. Metacognitive skills are needed when habitual responses are not successful (e.g. basic retrieval of information). Guidance in recognizing, and practice in applying metacognitive thinking, will help students successfully solve problems with novel and innovative solutions. In this rapidly changing world, the challenge of teaching is to help students develop skills that will not become obsolete. Creative thinking (metacognition) is essential for the twenty-first century. It will enable students to successfully cope with new situations.
3.1 Theoretical Perspective

The relationship between the variables of this study – metacognitive thought and associational creativity- determined the theoretical perspective of this study. This relationship was examined through a constructionist view of human perception and thought processes. In tackling such fundamentally unique problems, Donald Schon has proposed the use of this theoretical position. He sees design as a reflective activity in which the designer has a reflective conversation with the situation. This behavior can be classified as self-regulatory metacognitive thought. Under constructionist theory, reflection reveals the activity of design as experienced by designers. In addition, this extended and systematized version of Schon's theory advances the position of constructionist theory as an application in design practice and education (Dorst & Dijkhuis, 1995).

Schon breaks reflection into two kinds of action: reflection-in-action and reflection-on-action. Reflection-in-action refers to the immediately recursive thought a person puts toward the action at hand--"during which we can still make a difference to the situation at hand--our thinking serves to reshape what we are doing while we are doing it" (Schon, 1987). This behavior relates to self-regulatory planning and monitoring. Schon names reflection-on-action "thinking back on what we have done in order to discover how our knowing-in-action may have contributed to an unexpected outcome" (Schon, 1987), or, post-activity reflection on the activity. This can be described as self-regulatory evaluation.

Schon’s work bolsters the argument that by leading design students in conversation on their projects, educators nurture their concurrent reflection on their creative problem solving skills (reflection-in-action), and that by asking them to re-think what happened and why (reflection-on-action), educators allow them to understand their own cognitive processes. In doing so, educators prepare them for success in a variety of future design situations.
Indeed, it appears that metacognitive ability is the determining factor that enables designers to adjust accordingly to varying task demands and contexts. Not only is metacognitive ability essential for upward movement into more abstract (creative) levels of thinking, it also is a condition for operating at lower response levels. In other words, metacognition facilitates the selection and allocation of creative techniques and strategies for successful problem solving.

In this reflective approach the designer constructs his/her reality rather than serving simply as an information processor in an objective reality. Each design problem is, to a large degree, unique, meaning that it requires the designer to be flexible rather than attacking all problems in the same manner. As mentioned, the design process is a reflective conversation between designer and problem; some aspects of the design problems don’t require a rational search for process. Some design knowledge is viewed as artistry, and designers have an intuitive understanding of when to apply a particular procedures or creative strategies. This is in contradiction to the thought of design knowledge as procedures of scientific law (Dorst & Dijkhuis, 1995). Because of constructionism’s focus on knowledge construction, this theory is of interest to anyone concerned with learning and education. Therefore, it is natural to draw parallels from one’s view of knowledge with one’s view of instruction (Thompson, 2004). Fostering better performance in a creative design is an issue in every design institution. At the heart of this issue is discovering what influences the formation of a students’ design process and what balance among kinds of cognitive processes constitute a healthy design process. In addition, it is important to understand how students should be trained to use cognitive skills, if any, in building up a creative design process of their own (Suwa, 2003). This would put a very extended and systematized version of Schon's theory to good use, and advance its position as an application in design practice and education (Dorst & Dijkhuis, 1995).

In constructionist design education, knowledge is acquired through experience. The design process is a reflective conversation between designer and problem. The design process is expressed as a cycle of self-regulated cognitive processes. Activities and physical artifacts
are presented as promising venues for thinking about design and understanding process. This understanding informs designers about when to apply a particular procedure or creative strategy. Each design problem is thought to be unique, requiring that the designer be flexible (Dorst & Dijkhuis, 1995).

Constructionism moves beyond the construction of meanings and allows learners to create some type of physical artifact that can be shared and discussed. The physical representation of design thinking can be a valuable medium of design education. Through modeling of knowledge structures and the practice of memory strategies the student will gradually develop an enhanced design process. By constructing representations of design thinking, the student gradually becomes advanced in his/her ability to think about and solve problems. This contributes to an understanding of the cognitive processes, which contribute to creative design (Oxman, 1999).

3.2 Conceptual Framework

A model (Pesut, 1984) that conceptualizes creativity as a metacognitive process provided a conceptual framework for the current research effort (Figure 3.1).
In this model creative thinking is conceptualized as a function of regulation of cognition and knowledge of cognition components. When confronted with a design situation that requires a creative solution, it is hypothesized that in a given context the designer can utilize creative strategies such as brainstorming, attribute listing, free association, analogical thinking, synectics, idea checklists, morphological synthesis, etc. to guide his/her thinking and generate associations that are novel and useful.

By utilizing the complementary processes of regulation of cognition (planning, monitoring and evaluation) it is postulated that individuals develop metacognitive knowledge through experience and thus are in a better position to understand and regulate their behavior in the service of a creative goal or outcome.

Such behavior is comparable to Bandura’s (1982) construct of self-efficacy and Rosenbaum’s (1983) construct of learned resourcefulness. This study is interested in the educational implications of this model as the model relates to designer’s creative thinking abilities.
The model has implications for research as well as for curriculum development in design education. There are a variety of ways to develop the theoretical and operational linkages that exist within the model. Another implication of this model is the relevance it has for redefining creative thought as metacognitive verses a cognitive activity or process. To this end, creative thinking can be defined as a metacognitive process of generating novel or useful associations that better solve a problem, produce a plan, or result in a pattern, structure, or product not clearly present before (Pesut 1985).

3.3 Research Questions and Hypothesis

Based on the Conceptual Framework the study asked this main question:
Does an educational intervention focusing on metacognitive thinking and strategy use impact students’ creative thinking?

The study elaborated on these sub-questions:
• Does an educational intervention focusing on metacognitive thinking and strategy use impact students’ metacognitive thinking?
• Will students’ creative and metacognitive thinking change in the period prior to the educational intervention?
• Is there a relationship between self-report metacognitive awareness and students’ creative thinking skills?
• Is there a correlation between students’ metacognitive thinking and creative thinking skills?
• Specifically, what types of creative thinking represent this relationship? (Convergent thinking / Divergent thinking)
• Is there a correlation between various creative thinking skills? (Fluency / Originality)
• How do students from different design disciplines compare on various measures of creativity?
• Would an educational intervention benefit some disciplines more than others?
• Is metacognitive thinking a predictor of students’ convergent or divergent thinking skills?
• Does a student’s design studio instructor influence his/her metacognitive and creative thinking skill development?

_Hypothesis:_ Design students who participate in an educational intervention focusing on enhancing creativity through metacognitive thought will demonstrate higher creative abilities than students who do not participate.

### 3.4 Definition of Key Terms

• **Creativity (Associational)**
  Creativity represents a family of skills and processes that are performed by a designer when attempting to move from design problem to solution. The most relevant cognitive-behavioral dimension of creativity is a matter of utilizing a variety of associations accessible to an individual. Therefore, creativity most appropriately refers to the ability to generate or produce, with some criterion of relevance, many cognitive associates, and many that are unique.

• **Creative Strategies**
  Methods for accessing creative thought using a purposeful cognitive-behavioral approach toward problem solving.

• **Educational Intervention**
  The development of metacognitive knowledge and strategies through a self-regulated education approach. Individuals can learn how to better regulate their cognitive activities. Steps toward such advancement are based on an instructional approach that emphasizes the development of thinking skills and processes as a means to enhance problem solving. The objective is to enable all students to become more strategic, self-reliant, flexible, and productive in their problem-solving endeavors. Programs such as these are based on the
assumption that there are identifiable cognitive strategies, previously believed to be utilized by only expert problem-solvers that can be taught to most students. Therefore, the challenge is for each individual to become aware and consciously explore his/her own cognitive process to determine where strengths and weaknesses exist. Creative strategies then can be appropriately applied to ensure each individual reaches their cognitive potential, and ultimately their design potential.

• Convergent Thinking
It is the ability to bring material from a variety of sources to bear on a problem, in such a way as to produce the single "correct" solution. Convergent thinking often requires taking a novel approach to the problem, seeing the problem from a different perspective or making a unique association between parts of the problem. Convergent thinking (focused, analytical, judgmental and detailed thinking)

• Divergent Thinking
It is the ability to consciously generate new ideas that branch out to many possible solutions for a given problem. Divergent thinking (diffuse, free flowing, associated, perceptual and imaginative).

• Metacognitive Awareness
It is an awareness among learners that metacognition exists, differs from cognition, and increases academic success.

• Metacognitive Thinking
It is the ability to engage in a higher order of thinking that involves actively reflecting on one’s own thinking processes. Thinking about thinking guides people to select, evaluate, revise, or abandon cognitive tasks, goals, and strategies in light of their own abilities and interests.
4.1 Research Design Overview

An experimental approach was used in this study to measure the effects that an educational intervention has on a students’ design thinking/creativity. This study attempted to ascertain and measure the extent that a treatment (educational intervention) caused a clearly measured outcome (level of creativity). The study used different educational experiences (educational intervention/no educational intervention) as treatments (IV), with the output as the level of creativity (measured by multiple tests of creativity and students’ current projects) (DV) (Figure 4.1).

![Diagram of Experimental Research Design](image)

*Figure 4.1: Diagram of Experimental Research Design*
4.2 Data Collection Techniques

The College of Design at North Carolina State University served as the study site due to its wide range of design programs and studio-based education system. The process of the sample selection began by identifying the sample unit. In this study the sample unit was the university design student. All incoming freshman in the College of Design are required to enroll in a Design Fundamentals Studio for the fall semester. At the start of the 2006 fall semester incoming freshman in the College of Design were asked to participate in a research study. Students enrolled in these studios were given informed consent forms regarding the nature of this study and then asked to participate by taking a creativity test. This test included two sections, one for each of the following standardized creativity tests: Similarities Test (Wallach & Kogan 1965), Remotes Association Task (Mednick 1962) (Appendix C-H). These students were then given an equivalent form of the creativity test at the end of the 2006 fall semester. This form of the test was given to track changes that have occurred due to the influence of the Design Fundamental Studio (2006 fall semester). Students were then randomly assigned to treatment and control groups. The control group participated in normal required courses. Students in the treatment group were asked to participate in the educational intervention offered in the 2007 spring semester (Figure 4.2).

Although sampling is a significant issue in other research strategies, it is vital in experimental research due to the fact that randomization or matching is needed. In this study the control of the confounding factors was accomplished through matching. Students were matched based on several criteria including creativity test scores, major and gender. Matching created equivalent groups with the only difference being the independent variable (Figure 5.3).

The subjects recruited for the treatment group had a teacher/student relationship with the researcher. The treatment in this study was an educational intervention created to enhance students’ creativity. The researcher was working with a subgroup of an existing required course, D100-Design Thinking, which freshman design students take in their second semester (spring 2007). This course was developed and taught by Marvin Malecha, dean of
the College of Design. Students attended all regularly scheduled D100 classes and were responsible for all course content. However, by participating in this study that met once a week at a separate time, students received two credit hours under the course title D 292A – Design Thinking Explorations.

The course focused on improving students’ creativity. Specific creative skills were introduced, learned and practiced as action oriented metacognitive skills. At the end of the 2007 spring semester all students from both the treatment and control groups were given an equivalent form of the creativity test for a third and final time. This served as a comparison of students who participated in the educational intervention and those students who did not (Figure 4.2).

In addition to the measure of creativity through the creativity tests students’ metacognitive thinking was assessed through their final design project in D100-Design Thinking. This measure focused on the Design Thought Model that was assigned as a semester long assignment in D100, and comprised the majority of a student’s grade for the class. This project was selected due to its non-discipline specific nature and the fact that the project constraints are such that creative responses are possible and even encouraged. The project was specifically designed for students to practice metacognition and model their design thinking process (Appendix I).

The project asked students how they represent the progression from a way of seeing to a way of doing. The exercise was intended to be a three-dimensional representation of a personal design process. From an educational standpoint, how a person represents themselves is a measure of their understanding of design, both on a cognitive level and the place of design in their life.

This comprehensive exercise spanned the entire semester and was intended to provide the opportunity to construct a personal philosophy of design. As the major project of the course, students were informed of the comprehensive nature of the model and are asked to reflect
throughout the semester in a process of creation. Giving students the opportunity to create a physical artifact made this reflection special and afforded students the opportunity to externalize the cognitive processes of design. Each student was asked to represent his or her own design thought process. This allowed for greater awareness of the role cognition plays in the design process, and the opportunity to consider exactly what cognitive processes and principles exist on a personal level. In addition, students were able to discuss the similarities and differences present in others designer’s process, and reflect on both cognitive strategies and conceptual blocks expressed in a classmate’s thinking.

In addition to the tests of creativity and the evaluation of students’ projects the Metacognitive Awareness Inventory (MAI) (Schraw & Dennison, 1994) was used to measure knowledge and regulation of cognition (Appendix J). The MAI was administered at the same time as the test of creativity on three separate occasions across the 2006 fall and 2007 spring semesters. This inventory served to measure students’ metacognitive awareness and support this study’s conceptual framework of creativity as a metacognitive process. The collection of data from the selection of measures served as strong support for the findings (Figure 4.2).

Also, faculty assessments of each student were conducted at the end of both the 2006 fall and 2007 spring semesters (Appendix K). Design studio faculty were asked to give each student a score based on their judgment of students’ (1) metacognitive thinking, (2) convergent thinking skills, (3) divergent thinking skills. These instructors spent the entire semester with the students as their Design Fundamentals Studio instructor. Students had different instructors for the 2006 fall and 2007 spring semesters (See Figure 4.2).

4.2.1 Cohort – Graduate Student Testing

A cohort group of first year graduate students in Landscape Architecture were given identical measures of creative thinking and metacognitive awareness as the first year undergraduate students represented in this study. These students represented the same discipline (design) and served as a comparable measure for the treatment and control groups in this study. Graduate students in the cohort group were in the College of Design working toward a
Master’s degree in Landscape Architecture. The students in this cohort group held non-design undergraduate degrees and had not taken the D100 – Design Thinking class.

**Figure 4.2: Research Design Overview**
4.3 Educational Intervention – D292A-Design Thinking Explorations

The following served as a framework for the educational intervention in this study (Appendix L). The goal was to enhance students’ creative thinking abilities, particularly the creative skill of association. This framework served to introduce and develop a self-regulated metacognitive approach to design thinking. This approach involved the two aspects of metacognition, knowledge of cognition and regulation of cognition. These aspects were developed collectively in an effort to obtain the goal of enhanced creative thinking abilities.

![Diagram of the framework for educational intervention](image)

*Figure 4.3: Framework for Educational Intervention*
4.4 Cognition

Steps toward the advancement of cognition were based on an instructional approach that emphasized the development of creative thinking strategies and processes as a means to enhance creativity. By making these strategies and principles more explicit, by grounding them in relevant research and practice, and by illustrating them with specific examples, the goal was to make them more accessible and applicable in various design situations.

Figure 4.4: Development of Creative Thinking Strategies
4.5 Metacognition

Steps toward the advancement of metacognition require the development of both knowledge of cognition and regulation of cognition. An examination of the conceptual framework of this study reveals a cycle of building knowledge of cognition that in turn contributes to an advanced regulation of cognition (Figure 4.5). An assumption of this study was that the educational intervention would help support this cycle and foster its growth through instruction.

Figure 4.5: Cycle of Metacognition
4.6 Knowledge of Cognition

Knowledge of cognition includes a metacognitive knowledge base. This knowledge is founded on the understanding of various types of creative thinking strategies. An individuals’ knowledge of these creative strategies consists of three different types of understanding. First, task knowledge (procedural knowledge), represents an understanding of the processing demands placed on the individual. Second, conditional knowledge, represents the understanding of when, where and why to use particular cognitive strategies. Third, individual knowledge (declarative knowledge), represents the knowledge of one’s own thinking processes, or an understanding of the creative strategies that an individual possesses.

![Figure 4.6: Building Metacognitive Knowledge Base](image)

Students were asked to complete a strategy evaluation matrix (SEM) over the course of the semester (Figure 4.7). The SEM was introduced during the first week of the semester and students focused on a new strategy each week. Students were given time to reflect individually and in small groups about strategy use. Talking about how, when and why and also interviewing other students about their
strategy use. Students were expected to revise their SEM’s as if it were a mini portfolio. The SEM served three very important functions:

1. Promoted strategy use
2. Promoted Explicit Metacognitive Awareness
3. Encouraged students to actively construct knowledge

Strategy Evaluation Matrix (SEM)

<table>
<thead>
<tr>
<th>Strategy</th>
<th>How to use</th>
<th>When to use</th>
<th>Why to use</th>
</tr>
</thead>
</table>

![Figure 4.7: Strategy Evaluation Matrix (SEM)](Schraw, 1999)

4.7 Regulation of Cognition

The second part of metacognition is the regulation of cognition. This includes the planning, monitoring and evaluation of various creative strategies. Regulation through the use of these processes contributes to the proper use of creative strategies and more importantly the development of the knowledge of cognition, which serves to improve future creative problem solving.
The teacher/researcher used key operations of metacognition as a structure or guide for helping students to think about their own thinking as their thinking became more self-regulated (Figure 4.9).

I. PLANNING
Stating a goal
Selecting operations to perform
Sequencing operations
Identifying potential obstacles/errors
Identifying ways to recover from obstacles/errors
Predicting results desired and/or anticipated

II. MONITORING
Keeping the goal in mind
Keeping one's place in a sequence
Knowing when a subgoal has been achieved
Deciding when to go on to the next operation
Selecting next appropriate operation
Spotting errors or obstacles
Knowing how to recover from errors, overcome obstacles

III. EVALUATION
Evaluating goal achievement
Judging accuracy and adequately of the results
Evaluating appropriateness of procedures used
Assessing handling of obstacles/errors
Judging efficiency of the plan and its execution

Figure 4.9: Key Operations of Metacognition
The use of a regulatory checklist (RC) provided an overarching heuristic that facilitates the regulation of cognition (Figure 4.10). It enabled novice thinkers to implement a systematic regulatory sequence that helps them control their performance.

Regulatory Checklist (RC)

<table>
<thead>
<tr>
<th>Planning</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. What is the nature of the task?</td>
</tr>
<tr>
<td>2. What is my goal?</td>
</tr>
<tr>
<td>3. What kind of information and strategies do I need?</td>
</tr>
<tr>
<td>4. How much time and resources will I need?</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Monitoring</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Do I have a clear understanding of what I am doing?</td>
</tr>
<tr>
<td>2. Does the task make sense?</td>
</tr>
<tr>
<td>3. Am I reaching my goals?</td>
</tr>
<tr>
<td>4. Do I need to make changes?</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Have I reached my goal?</td>
</tr>
<tr>
<td>2. What strategies worked?</td>
</tr>
<tr>
<td>3. What strategies didn’t work?</td>
</tr>
<tr>
<td>4. Would I do things differently next time?</td>
</tr>
</tbody>
</table>

Figure 4.10: Regulatory Checklist (RC)  Schraw, 1999
4.8 Conceptual Level

The goal up to this point was for student creative thinking to become more rapid, smooth, and self-regulated – ongoing knowledge construction. Because design education should seek to develop proficient creative thinking practices, such teaching involved more than developing technical proficiency in a number of cognitive operations. It also involved helping students become independent thinkers, proficient at self-regulated thinking.

Beyond this level of proficient self-regulated thought was the development of a conceptual level (Level 3). This conceptual level includes theories and mental models of one’s cognition, as well as the task at hand. Mental models are necessary not only to monitor performance, but more important to monitor how well one is self-regulating. There are three basic levels that one can achieve a mental model; the most basic being a tacit model, advancing to an informal model and eventually developing a formal model.

**Tacit model** - implicit understanding. This helps explain why some students can solve incredibly complex design problems but are unable to explain how they reached a solution.

**Informal model** - partially accessible to conscious introspection - scrutiny and revision. This is more advanced than the tacit model and offers the benefit of introspection. This introspection allows for scrutiny and revision of one’s model. Over time this revision leads to a more advanced (formal) model.

**Formal model** - explicit, explanatory, representation of complex phenomenon such as creative thinking.

* This is the ultimate goal of this self-regulated metacognitive approach to design.

4.9 Educational Practices

The following were practices to help students reflect or think about their own thinking. The assumption of this study was that developing metacognitive thinking would enhance student’s creativity.
4.9.1 Direct Instruction

Direct instruction involved the acquisition of essential knowledge that was used to construct higher-level knowledge. It promoted acquisition, which was passive in nature. The direct teaching of creative thinking did not pour into students’ heads a single way of execution. In turn, the modeling procedure provided a takeoff point from which students can gradually construct and develop more personalized but equally effective procedures.

4.9.2 Paired Problem-Solving

Paired problem-solving encouraged students to reflect on their thinking and report to others. It served as a type of “accountability check,” and promoted the active construction of knowledge. The procedure required students to work in pairs to engage in think-aloud tasks, with one student solving a problem and reporting aloud what he or she was thinking.

4.9.3 Journal Keeping

Journal keeping was a form of independent reflection - reflection that led to the restructuring of one’s knowledge in a manner that promoted an increasingly theoretical understanding of one’s metacognitive knowledge. Documentation is important in design. However, it is often that case that students take great care in the documentation of product but do not apply the same approach to the documentation of process. This can be seen in the presentation of design projects; students have a very polished representation of the final product, but often lack the documentation to help explain how they reached a solution. Documentation helped designers reflect on their process and without a record of this process the ability to build metacognitive knowledge would have been greatly reduced.

Writing and illustrating a personal log or project diary throughout a problem solving experience or design project over a period of time caused the students to synthesize thoughts and actions and to translate them into symbolic form. This record also provided an opportunity to revisit initial perceptions, to compare the changes in those perceptions with
additional experience and to recall the success and the failures through the experimentation of cognitive strategies. This took place in conjunction with students studio course for the spring 2007 semester.

4.9.4 Case Studies – Great Thinkers

The teacher also taught about metacognition by giving students opportunities to analyze how numerous expert designers engage in various kinds of thinking operations. Here the subject of the lesson was someone else’s thinking. Students viewed, listened to, or read such examples or case studies of thinking in action, and with teacher assistance identified the kinds of cognitive and metacognitive strategies and skills employed and the key attributes of each.

The Design Thinking (D100) course currently in the NCSU College of Design curriculum does a good job of exposing students to various creative thinkers, both in and outside the profession of design. Creative individuals such as Ben Franklin and Thomas Jefferson are the focus of study, as students examine others’ creative thinking processes. As a part of the educational intervention students were challenged to find new examples of metacognitive thinking in others and various examples of expert thinkers were examined and shared with the class.

4.10 A Framework Toward Effective Pedagogical Practices

This educational approach was based on implementing in the classroom a carefully sequenced curriculum of selected cognitive and metacognitive operations. What stood out was that these practices included a set of basic components that are believed to have made a great difference in the success of the instructional approach. These basic components are as follows:
- Help students develop and learn explicit cognitive strategies that inform and organize the way that they do specific types of creative thinking.  
(Knowledge of Cognition)

- Build into their instruction significant opportunities for students to plan, monitor and evaluate their thinking.  
(Regulation of Cognition)

- Prompt specific engagement by students in the types of skillful creative thinking being taught in the content that they are learning  
(Active Construction of Knowledge)

- Follow-up specific lessons with opportunities for students to get more practice in guiding themselves to apply the same sort of creative thinking in new situations.

- Lessons are conducted in an open learning environment where advanced creative thinking is modeled and where students are given opportunities to reflect on their thinking.  
(Swartz, 2001)

Using this framework of pedagogical practices each of the basic components was examined in relation to the content of the educational intervention.

-Help students develop and learn explicit cognitive strategies that inform and organize the way that they do specific types of creative thinking.

(Knowledge of Cognition) – The educational intervention introduced creative strategies and made an effort to discuss the three different knowledge components (declarative, procedural, conditional) in relation to each. This included individual reflection that led toward the development of each student’s knowledge base. Students were expected to build and modify their SEM portfolios as the semester progresses.

-Build into their instruction significant opportunities for students to plan, monitor and evaluate their thinking.

(Regulation of Cognition) - The educational intervention used various studio projects that students were participating in concurrent to the educational intervention as an opportunity to practice regulation of cognition. Students were asked to reflect on their (regulatory practices)
planning, monitoring, and evaluation of chosen creative strategies. This took place through class or small group discussion, or journal entries into a project diary. A regulatory checklist (RC) helped in the stimulation of these practices. In addition, short design tasks were assigned in class periods to utilize creative strategies and practice the regulation of these strategies.

-Prompt specific engagement by students in the types of skilful creative thinking being taught in the content that they are learning

(*Active Construction of Knowledge*) - During the educational intervention activities such as paired problem solving and case studies allowed for this active construction of knowledge. In paired problem solving students were expected to reflect on their thinking and report to others. This was often based on an in class problem solving activity or a reflection of a student’s studio project. Most important to this educational technique was that students were forced to have an awareness of their thinking processes, both the knowledge of cognitive strategies and the regulation of their use. In addition, this exercise built accountability, as students were required to explain their process to a classmate or small group. This was advantageous for everyone involved. Students reporting were actively reflecting and building a greater understanding, and students listening were exposed to multiple different approaches that may or may not be similar to their own.

Case studies allowed for students to seek out and study others creative individuals who may or may not have a similar process to their own. This included a group of creative strategies or different approaches toward regulating these strategies. Exposure to successful creative individuals from various professions certainly helped build knowledge and perspective.

-Follow-up specific lessons with opportunities for students to get more practice in guiding themselves to apply the same sort of creative thinking in new situations.

- In the educational intervention this practice took place in the classroom with short design problems but also extended into students studio practice. It was important that the creative strategies and regulatory practices that were learned in the educational intervention were
continued and applied to their design projects in studio. This occurred in conjunction with a project diary recording the use and success of these practices. A cycle of building metacognitive knowledge was established through the use of the creative strategies learned (Strategy Evaluation Matrix) and the regulation of these strategies (Regulatory Checklist) in the context of a design problem. Reflection of this process, including in design process journals, proved extremely valuable for knowledge construction and future problem solving.

-They are conducted in an open learning environment where advanced creative thinking is modeled and where students are given opportunities to reflect on their thinking.

- In the educational intervention students were exposed to a new approach to design thinking and problem solving. This approach was a self-regulated metacognitive approach. Each student was exposed to these practices in their design thinking. In addition, students learned the value of this approach and why it is essential to successful design. Reflection was a major component of introducing students to their own thoughts and fostering the realization that their current approach may be enhanced.

4.11 Assessment

What role did assessment play during the educational intervention?

In this study assessment was to be utilized as a tool to create the optimal educational intervention for students. It served to first make students aware of the level of metacognitive thinking that they are practicing, and what was needed to reach a higher level.

Assessment was important for both students and teachers. For students assessment provided feedback and a guide toward improving thinking. Determining what level the students were achieving and how they might approach higher level certainly included making these levels of achievement explicit (a rubric). Also, the teacher needed to have criteria in order to determine which students were reaching higher levels or advancing in their thinking, and which students were struggling. This allowed for more focus on those students who struggled
and also identified those students who were excelling in an effort to provide peer support to other students.

A series of important questions were answered in determining the role of assessment in the educational intervention for this study. How detailed a plan of assessment was used for the teaching of thinking? How many facets were included? And how was assessment determined for each student? Was it enough to make the criteria for assessment explicit and have students and teachers reflect on the level at which each student was performing across the semester, as well as ways in which they might achieve a higher level. These questions are addressed in the following section as the plan for assessment is presented along with a rubric for student awareness and development of metacognitive thinking.

Assessment was an important part of students reaching a conceptual level (Level 3) and building a mental model. Mental models monitor performance and help determine self-regulatory practices through self-assessment. Students should be aware of the different levels that exist and what is needed to advance to a higher level. This process started by making a clearly defined criterion for assessment and providing students with a rubric as a guide toward identifying strengths and weaknesses. Advancement was based on monitoring current performance and understanding what aspects of thinking are desired.

Students were at different levels of thinking and therefore possessed different levels of mental models. An initial step for any student was the awareness that these levels of assessment exist. Making one’s mental model explicit and accessible to conscious introspection was a significant challenge for many students. However, it was this introspection that allowed for scrutiny and revision of ones model over time and ultimately this revision led to a more advanced (formal) model.

From this point students began to assess their own performance through self-regulation, and eventually develop a plan for enhancement of their thinking. Over time students developed an explicit, explanatory, representation of creative thinking. This was the ultimate goal of this self-regulated metacognitive approach to design.
4.11.1 A Plan for Student Assessment

_A Student Who is a Metacognitive Thinker…_

Each of the following facets of metacognitive thinking lends itself to certain assessment tasks. Here are some examples.

**Facet 1. A student who is a metacognitive thinker can explain.** He or she demonstrates sophisticated explanatory power and insight. He or she can

- Provide complex, insightful, and credible reasons – theories and principles, based on good evidence and argument – to explain or illuminate their own thinking process; provide a systematic account using helpful and vivid mental models.
  - Make fine, subtle distinctions in the quality of thinking.
  - See and argue for what is central – big ideas, pivotal moments, decisive evidence, key questions, and so on.
  - Make good predictions of thinking strategies with a clear and justified reasoning.

- Avoid or overcome common misunderstandings and superficial or simplistic views of one’s thinking process – shown, for example, by avoiding overly simplistic, reflexive or imprecise theories or explanations of thought.

- Reveal a personalized, thoughtful, and coherent grasp of one’s thinking process – indicated, for example, by developing a reflective and systematic integration of what he or she knows effectively and cognitively. This integration would therefore be based in part upon significant and apt direct or simulated experience of specific thinking processes. Substantiate or justify his or her views with evidence based on experience.

**Facet 2. A student who is a metacognitive thinker can interpret.** He or she offers powerful, meaningful interpretations, translations, and narratives of his or her own thought process. He or she can

- Effectively and sensitively interpret problem situations – shown, for example, by the ability to “read between the lines” and offer plausible accounts of the many alternative ideas and solutions.

- Offer a meaningful and illuminating account of complex problem solving situations. He or she has the ability, for example, to provide historical and experiential background, thereby helping to make previous cognitive strategies more accessible and relevant to the current situation.
Facet 3. A student who is a metacognitive thinker can apply. He or she uses declarative, procedural, and conditional knowledge of cognitive strategies. He or she can

• Employ his or her knowledge of cognition effectively in diverse, authentic, and realistically challenging contexts.

• Extend or apply what he or she knows in a novel and effective way – that is, how knowledge might be best modified to address current and future problem solving situations.

• Effectively self-adjust by utilizing the self-regulatory processes of planning, monitoring, and evaluation.

Facet 4. A student who is a metacognitive thinker sees in perspective. He or she can

• Critique and justify one’s own thinking processes to see it as an explicit, explanatory mental model; to use skills and dispositions that embody disciplined introspection and the testing of theories.

• Know the history of a cognitive strategy or skill to place discussion and theory in context; know the questions or problem to which the knowledge of cognition helped contribute an answer or solution.

• Infer the past or present assumptions in one’s thinking upon which a cognitive strategy is based.

• Know the limits as well as the power of a cognitive strategy.

• See beyond thinking processes that are reflexive and habitual.

• See and explain the importance or worth of a cognitive strategy; how an idea was conceived through process / action.

Facet 5. A student who is a metacognitive thinker demonstrates empathy. He or she has the ability to sensitively perceive. He or she can

• Project himself or herself into, feel, and appreciate another’s problem solving situation, affect, or thinking process.

• Operate on the assumption that even an apparently odd or obscure approach to thinking may contain insights that justify working to understand it. That there is value in all cognitive
skills and that any approach may lead or contribute to something entirely new and worthwhile.

- See when incomplete or flawed cognitive strategies are plausible, even insightful, though perhaps somewhat incorrect or outdated. Draw from all experience and build toward the future.

- See and explain how cognitive strategies or processes can be all too easily misunderstood by others.

- Listen – and hear what others often do not; find value in others cognitive process.

**Facet 6. A student who is a metacognitive thinker reveals self-knowledge.** He or she can

- Recognize his or her own prejudices and style in thinking, and how they color perception and understanding; see and get beyond a single way of knowing and either-or-thinking.

- Recognize strengths and weaknesses in one’s thinking process.

- Question his or her own convictions; like Socrates, able to sort out mere strong belief and habit from warranted knowledge. Be intellectually honest, and admit ignorance; work to overcome conceptual blocks.

- Accurately self-assess and effectively self-regulate one’s own thinking process.

- Accept feedback and criticism without defensiveness.
4.11.2 Two Basic Questions

Thinking like an assessor boils down to two basic questions. Where should one look to find characteristics of metacognitive thinking, and what should one look for in determining and distinguishing degrees of metacognitive thinking? The first question asks us to consider the necessary evidence in general – the kinds of performance and behavior indicative of metacognitive thinking, the second question asks us to focus on the most salient and revealing levels or degrees of metacognitive thinking – using criteria and rubrics to sort thinking by quality along a continuum (Figure 4.11).

![Figure 4.11: Rubrics: Learning Outcomes & Measures](image)

The first set of questions in Figure 4.12 ensures that the eventual activities and instructional strategies simultaneously derive from and point toward the appropriate final assessments. The second set of questions, though logical from the perspective of activity design, makes it far less likely that the instruction will culminate in metacognitive thinking or that one will have the evidence one needs to judge whether such metacognitive thinking has occurred. In effect, when one only thinks like an activity designer, one ends up lacking a learning
outcome and a measure to determine this outcome. Even though some students may develop important metacognitive skills through the various activities comprising this approach, this does not consider, at the design stage, how to build the activities around the need for evidence of metacognitive thinking.

<table>
<thead>
<tr>
<th>Thinking Like an Assessor</th>
<th>Thinking Like an Activity Designer</th>
</tr>
</thead>
<tbody>
<tr>
<td>What would be sufficient and revealing evidence of understanding?</td>
<td>What would be interesting and engaging activities on this topic?</td>
</tr>
<tr>
<td>What performance tasks anchor the unit and focus the instructional work?</td>
<td>What resources and materials are available on this topic?</td>
</tr>
<tr>
<td>How will I be able to distinguish between those who really understand and those who don’t (though they may seem to)?</td>
<td>What will students be doing in and out of class? What assignments will be given?</td>
</tr>
<tr>
<td>Against what criteria will I distinguish work?</td>
<td>How will I give students a grade?</td>
</tr>
<tr>
<td>What misunderstandings are likely? How will I check for those?</td>
<td>Did the activities work? Why or why not?</td>
</tr>
</tbody>
</table>

**Figure 4.12: Thinking Like an Assessor**

(Wiggins & McTighe, 2005)

### 4.11.3 Criteria and Indicators

Having clarified the kinds of evidence needed to assess for metacognitive thinking, the focus shifts to the second phase of thinking like an assessor, asking, against what criteria will one judge such evidence? What are the kinds of things to look for? These questions challenge educators to clarify the criteria for judging performance. One asks, given the right kinds of evidence, what is the difference between successful and unsuccessful metacognitive thinking?

Presumably, for example, a high level metacognitive thinker displays “systematic” and “justified” explanation – two criteria seemingly central to the first facet, explanation (Figure
And what distinguishes metacognitive thinking from the absence or lesser degrees of metacognitive thinking? A rubric makes clear all of the relevant criteria as well as helped differentiate levels of understanding. Figure 4.13 provides a partial list of applicable criteria.

<table>
<thead>
<tr>
<th>Facet 1 Explanation</th>
<th>Facet 2 Interpretation</th>
<th>Facet 3 Application</th>
<th>Facet 4 Perspective</th>
<th>Facet 5 Empathy</th>
<th>Facet 6 Self-Knowledge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accurate</td>
<td>Meaningful</td>
<td>Effective</td>
<td>Credible</td>
<td>Sensitive</td>
<td>Self-aware</td>
</tr>
<tr>
<td>Coherent</td>
<td>Insightful</td>
<td>Efficient</td>
<td>Revealing</td>
<td>Open</td>
<td>Meta-cognitive</td>
</tr>
<tr>
<td>Justified</td>
<td>Significant</td>
<td>Fluent</td>
<td>Insightful</td>
<td>Receptive</td>
<td>Self-adjusting</td>
</tr>
<tr>
<td>Systematic</td>
<td>Illustrative</td>
<td>Adaptive</td>
<td>Plausible</td>
<td>Perceptive</td>
<td>Reflective</td>
</tr>
<tr>
<td>Predictive</td>
<td>Illuminating</td>
<td>Graceful</td>
<td>Unusual</td>
<td>Tactful</td>
<td>Wise</td>
</tr>
</tbody>
</table>

Figure 4.13: Facets and Levels of Metacognitive Thinking (Wiggins & McTighe, 2005)

4.11.4 Naïve Versus Sophisticated Metacognitive Thinking

Sophistication: Of a person: free from naiveté, experienced, worldly-wise, subtle, discriminating, refined, cultured, aware of, versed in the complexities of a subject or pursuit. Of equipment, techniques, theories, etc.; employing advanced or refined methods or concepts; highly developed or complicated.

--Oxford English Dictionary

This definition of sophistication is good, but to develop a sound and comprehensive assessment of metacognitive thinking, one needs more than this picture of what metacognitive thinkers do. One needs some way to more precisely, validly, and reliably distinguish between degrees of metacognitive thinking. Assessment is about judging relative strengths and weaknesses with increasing precision. Which actions, responses, or performances are most characteristic of metacognitive thinking? Figure 4.14 provides a comprehensive list of applicable criteria along with a detailed explanation of each.
<table>
<thead>
<tr>
<th>Explanation</th>
<th>Interpretation</th>
<th>Application</th>
<th>Perspective</th>
<th>Empathy</th>
<th>Self-Knowledge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sophisticated: an unusually thorough, explanatory, and inventive account (mental model); fully supported, verified, and justified; deep and broad: goes well beyond a basic understanding and awareness of one’s thought process.</td>
<td>Profound: a powerful and illuminating interpretation and analysis of the importance/meaning/significance of cognitive strategies; tells a rich and insightful account of cognition through reflection; provides a rich history or context from which to build future knowledge; sees deeply and incisively any ironies in different interpretations of the thinking.</td>
<td>Masterful: fluent, flexible, and efficient use of cognitive strategies and skills; also able to use knowledge and skill and adjust understandings to address novel, diverse, and difficult problem solving contexts.</td>
<td>Insightful: a penetrating and novel viewpoint of one’s own thinking processes; effectively critiques and encompasses other plausible perspectives in a disciplined introspection of one’s thinking process; infers the past or present assumptions in one’s thinking upon which a cognitive strategy is based.</td>
<td>Mature: disposed and able to see and feel another’s problem solving situation, affect, or thinking process; unusually open to and willing to seek out the odd, alien, or different approaches to thinking.</td>
<td>Wise: deeply aware of the boundaries of one’s own and others thinking; able to recognize his or her own prejudices and approach to thinking, and how they color perception and understanding; able to recognize strengths and weaknesses in one’s thinking process and willing to act on what is revealed (self-regulate).</td>
</tr>
<tr>
<td>In-depth: an atypical and revealing account, going beyond what is obvious, or what is explicitly taught; makes subtle connections; well supported by experience and evidence; novel thinking displayed.</td>
<td>Revealing: a nuanced interpretation and analysis of the importance/meaning/significance of cognitive strategies; tells an insightful account of cognition; provides a telling history or context of knowledge; sees subtle differences, levels, and ironies in diverse interpretations of the thinking.</td>
<td>Skilled: competent in using knowledge and skill and adapting understandings in a variety of appropriate and demanding problem solving contexts</td>
<td>Thoughtful: a revealing and coordinated viewpoint of one’s own thinking processes; makes own thinking processes more plausible by considering the plausibility of other approaches/ perspectives; makes apt criticisms and qualifications of one’s own cognitive strategy use.</td>
<td>Sensitive: disposed to see and feel another’s problem solving situation, or thinking process; open to unfamiliar and different approaches to thinking.</td>
<td>Circumspect: aware of one’s ignorance; intellectually honest, and will work to overcome conceptual blocks; aware of one’s prejudices, knows the strengths and limits of one’s thinking process and the self-regulatory operations to improve.</td>
</tr>
<tr>
<td>Developed: an account that reflects some in-depth and personalized reflection; the student is making a thinking process that is his or her own; going beyond the given—there is supported theory here, but insufficient or unsupported evidence and experience.</td>
<td>Perceptive: a helpful interpretation or analysis of the importance/meaning/significance of cognitive strategies; tells a clear and instructive account of cognition; provides a useful history or context of knowledge; sees different levels of interpretation of the thinking.</td>
<td>Able: able to perform well with knowledge and skill in a few key contexts, with a limited set of cognitive strategies, flexibility or adaptability to address diverse contexts is minimal.</td>
<td>Considered: a reasonably critical and comprehensive look at others thinking processes in the context of one’s own; makes clear that there is plausibility to other approaches to cognition and problem solving.</td>
<td>Aware: knows and feels that others see and approach thinking differently; somewhat able to empathize with others explanation of thinking processes; has difficulty making sense of odd or alien approaches to thinking.</td>
<td>Thoughtful: generally aware of what is and what is not a part of one’s thinking capacity; aware of how prejudices and projection can occur without awareness and self-regulation of one’s thinking processes.</td>
</tr>
<tr>
<td>Intuitive: an incomplete account that is insightful reflection; extends and depends on what was learned through experience; some “reading between the lines”; account has limited support/experience data or sweeping generalizations. There is theory but with one limited testing and evidence.</td>
<td>Interpreted: a plausible interpretation or analysis of the importance/meaning/significance of cognitive strategies; a sense of an account of cognition; provides a history and context of knowledge.</td>
<td>Apprentice: relies on limited repertoire of cognitive strategies and skills; able to perform well in familiar or simple problem solving contexts, with perhaps some need for coaching; limited use of personal judgment and responsiveness to specifics of feedback or a problem solving situation.</td>
<td>Aware: knows the different approaches to thinking and somewhat able to place one’s own cognitive strategies in perspective; but weakness in considering worth of each differing approach or critiquing each approach, especially one’s own; uncritical about tacit assumptions.</td>
<td>Developing: has some capacity and self-discipline to see thinking through another’s eyes, but is still primarily limited to one’s own reactions and attitudes; puzzled or put off by different feelings or attitudes toward thinking processes.</td>
<td>Unreflective: generally unaware of one’s specific lack of self-reflection; generally unaware of how one’s own knowledge of cognition determines their thinking process / cognitive strategy use.</td>
</tr>
<tr>
<td>Novice: a superficial account but with apt and insightful thinking; a fragmentary or sketchy account of experience using cognitive strategies; less a theory than an unexamined hunch or borrowed idea.</td>
<td>Literal: a simplistic or superficial reading of cognitive strategies; explaining and translation; a decoding with little or no interpretation; no sense of wider importance or significance; a restatement of what is habitual or stereotyped.</td>
<td>Novice: can perform only with coaching or relies on highly scripted, singular “plug-in” (stereotypical) cognitive strategies, procedures, or approaches.</td>
<td>Uncritical: unaware of differing approaches to thinking; prone to overlook other approaches; has difficulty imagining other ways of seeing things; prone to egocentric argument and either-or thinking.</td>
<td>Ego-centric: has little or no empathy beyond intellectual awareness of others; sees cognitive tasks in the context of one’s own thoughts and beliefs, ignores or is threatened or puzzled by opposing outlooks or approaches to thinking.</td>
<td>Immoral: completely unaware of the bounds of one’s thinking and of the role of reflection and self-regulation in the development of cognition.</td>
</tr>
</tbody>
</table>
4.12 Steps Toward a Successful Intervention

The educational intervention began with an introduction of purpose, content and goals. This included an outline of the course for the semester. The metacognitive framework (Figure 4.15) served as a guideline for student advancement throughout the semester.

![Metacognitive Framework](image)

**Figure 4.14: Metacognitive Framework**

Before the focus of the instruction was placed on the metacognitive framework it was critical to clearly identify the meaning of metacognition and how it applies to design. Thus, making students aware of their value and building relevance on a personal level.

First, a goal was to obtain a sense of where students currently stand in terms of cognitive (creative) strategies. This determined what strategies students currently use explicitly in design thinking. After establishing a baseline for the class, instruction began by introducing a single creative strategy and discussing it in detail. This included all three types of knowledge of cognition (procedural, declarative and conditional). The addition of creative strategies continued in the subsequent weeks of class by learning a new strategy each week in class. This was incorporated into a SEM portfolio and aided in the use of the RC. Students
started in a cycle of building knowledge of cognition that contributed to an advanced level of regulation of cognition (in class as well as in studio work) and continued this cycle throughout the semester, building metacognitive knowledge.

Second, in addition to learning a new creative strategy each week, students learned about metacognitive thinking and the relationship between cognition and metacognition. When new strategies were introduced it was critical to discuss all three knowledge components (conditional, procedural, declarative) as they apply to metacognitive thinking. Metacognition was broken down into knowledge of cognition and regulation of cognition. Tools such as the Strategy Evaluation Matrix and the Regulatory Checklist served to aid in this process. Teaching techniques such as direct instruction served in providing basic knowledge of metacognitive thinking. Paired problem solving, case studies and journals (project diary) served as experience, practice and reflection on both knowledge and regulation of cognition. Finally, in-class design problem-solving exercises provided students with multiple opportunities to practice and reflect on their strategy use as well as regulate the use of these strategies.

Third, reflection with students on their mental models took place in the last portion of the semester. Utilizing the assessment rubric students became aware of their current abilities in relation to multiple facets of metacognitive thinking. Mental models were necessary not only to monitor performance, but more important to monitor how well students were self-regulating. It was critical to help students form these models by making them aware of their function and value in design thinking. In addition, it was important to formulate a plan to help students move from implicit to informal to formal models, or at least make them aware that these different stages existed and why one should strive toward a formal model. The goal being that each student was able to monitor their own performance of cognitive and metacognitive processes in relation to clearly understood assessment standards.
4.13 Strategies For Analysis

4.13.1 Wallach & Kogan Similarities Test – Divergent Thinking

The Similarities Test of associational creativity that was administered to the participating students was based on the definition of creativity as defined in this study (Appendix F-H). It is possible through the imposition of task constraints to structure a situation where only associations that are appropriate – that meet certain requirements – are given. For example, the individual may be asked to generate ways that different objects are similar. In such situations, the person’s associational behavior possesses a general orientation toward some given requirement that guides the nature of his/her responses. Under such conditions, where appropriateness of associations is assured, two variables should reflect individual differences in creativity as presently defined in this study: the total number of associations that a person is capable, and the relative uniqueness that his/her associations possess.

The total number is scored by adding up the number of responses given for each question. Uniqueness of uses is scored by totaling the number responses a participant generates that are given by no more than 5 percent of all respondents. This is not to assert that these two variables necessarily would be independent of each other; rather, it is quite possible that more frequent associations will occur earlier and more unique associations later in a sequence, so that individuals who are able to produce a large number of associations also should be able to produce a greater number of unique ones. It is suggested, then, that if a situation is arranged in such a manner that only appropriate associations are provided by the individual, greater creativity should be indicated by the ability to produce more associations and to produce more that are unique.

Also of importance is the fact that if responses of greater stereotypy are likely to come early in a sequence even in the case of a creative persons, then it will not be possible to detect the persons if insufficient time is permitted for the more unique responses to emerge. An environment in which short time limits are placed on individuals for the performance of a given task thus would hardly be appropriate in an attempt to measure creativity.
Using the Spearman-Brown split-half reliability coefficient, (Wallach & Kogan, 1965) found that the uniqueness score had a .87 reliability score and that the number of instances had a .93 reliability score. Additionally, the test showed high correlations with Wallach and Kogan's other measures of creativity and no correlation with a variety of intelligence measures.

4.13.2 Remote Associates Test – Convergent Thinking

Unlike the Wallach & Kogan Similarities Test the Remote Associates Test is a measure of convergent thinking as it applies to creativity (Appendix C-E). In convergent thinking there is a single right answer or best answer while in divergent thinking there is not. While the generation of the production of associates remains relatively hidden from view, based on the definition of creativity as it is presently defined in the study it is appropriate that one may infer process from product in this case. Although the experimenter defines the product or correct solution before the fact, and then assesses whether or not the subject is able to attain it, the process of creating infers that the ability to make the appropriate associational links in order to obtain the single best response is valued and essential to creative thinking.

In the Remote Associates Test a single term must be provided by the subject as an associational bridge to unite the three given words. Only one word constitutes the correct answer to a given problem. For example, “cheese” would be the correct response to the triad, “rat,” “blue,” and “cottage.” The quantity measured in this procedure, then, is number of test problems correctly answered. The RAT has shown promising reliability and validity in a number of studies (Mednick, 1962). In two separate studies, Spearman-Brown reliability for the RAT was .92 and .91. In comparison with expert ratings of the creativity of a group of practicing architects, the RAT showed a high positive correlation (r = .70, p < .01).
4.13.3 D100 – Design Thinking – Design Thought Model

There was a required exhibit of the final D100 projects for a general review (Appendix I). Similar to a formal design studio critique projects were reviewed by the course instructor, teaching assistants, and other invited design faculty from other institutions. The invited faculty included eight well-respected professionals from the various disciplines represented in the college of design. The final review session was scheduled across three days with each student given the opportunity to present their model to several different reviewers while engaging in a one-on-one discourse. A student’s grade was based on a number of categories that are described in detail for the reviewers in a comprehensive scoring rubric (Appendix M). These categories represent a measure of students’ metacognitive thinking ability, but are most simply described as the clarity of idea and depth of thought and reflection, an awareness and understanding of one’s own cognitive processes.

4.13.4 Metacognitive Awareness Inventory (MAI)

The MAI is a 52-item self-report instrument of adolescent and adult metacognitive awareness (Appendix J). The items are based on the Brown (1987) two-component model of metacognition, Knowledge of Cognition and Regulation of Cognition. Items load on two scales: Knowledge of Cognition and Regulation of Cognition. The Knowledge of Cognition scale is designed to reflect what students are aware of about their individual thinking processes. A typical item is “I am a good judge of how well I understand something.” The Regulation of Cognition scale indicates learners’ awareness of control of their learning processes, with items such as “I think of several ways to solve a problem and choose the best one.” Students respond to these items by indicating degrees of agreement with each statement on a Likert-type scale, ranging from a score of one (Never True) to a score of five (Always True). Students' scores for each factor were determined by the loading scores from Schraw & Dennison (1994). The MAI has been demonstrated to have high internal consistency of the two factors that are highly correlated and is a "reliable initial test of metacognitive awareness" (Schraw & Dennison, 1994, p. 472). Internal consistency statistics range from $r =$
.90-.95 (Dennison, 1997). Furthermore, Hammann (2005) found the MAI to have strong predictive validity for test performance and self-monitoring in academic tasks. Subsequent studies with the MAI have supported these findings, including a test-retest reliability of about .85 (Dennison, 1997).

4.13.5 Faculty Assessment

The faculty assessment served as an additional measure of students’ creative abilities. This measure was based on the instructors’ observation and interaction with students throughout the semester (Appendix K). Design studio instructors were given a definition for each of the following measures: (1) convergent thinking, (2) divergent thinking, (3) metacognitive thinking. Instructors responded to these items by indicating level of proficiency on a five-point Likert-type scale, ranging from a score of one (Very Poor) to a score of five (Very Good). The different forms of the creativity testing required students to apply convergent thinking (Remote Associates Test) and divergent thinking (Similarities Test). The faculty assessment served to compare students’ test scores with instructors’ evaluation of these skills. In addition, the faculty assessment of students’ metacognitive thinking served as a comparison to students’ scores on the Metacognitive Awareness Inventory (MAI) and Design Thought Model.

4.14 Rationale

Components of both divergent and convergent thinking are involved in creative work. Divergent thinking, the production of multiple possible solutions, appears to be one important factor in the study of creative ability, since it includes the production of ideas in quality and quantity along with the ability to redefine. These skills are tested in tests such as Wallach and Kogan’s Similarities Test. Undoubtedly, convergent thinking, the type of thinking that narrows down the possibilities and focuses on producing a single solution, also has a role in creative work. These skills are tested in tests such as Mednick’s Remote Associates Test. Many useful things can be accomplished with structured questions and
responses. The selection among a number of alternatives of that one judged to be best and the rejection of other alternatives is involved in the later stages of the divergent-convergent sequence found in creative problem-solving (Figure 4.16). Compactness of thinking and expression is related to the elegance of the final product.

![Design Process Diagram](image.png)

**Figure 4.15: Divergent / Convergent Design Process**

Creativity tests that are widely used today are measures of ideational fluency (i.e., the ability to generate many ideas, many responses to a stimulus, many solutions to a problem). Admittedly there is widespread predictor/criterion misunderstanding in the field. Ideational fluency has been erroneously regarded as a criterion for creative behavior rather than a predictor of it, as an end in itself rather than a means to an end. However, this confusion is not sufficient basis for abandoning the use of ideational fluency based tests. Ideational fluency is to be viewed as one among a number of cognitive and other abilities that have been cited as being involved in creative or original thinking (e.g. Barron & Harrington, 1981).
4.15 Quality Considerations

4.15.1 Internal Validity

Internal validity is the first objective of any experimental research design. Experimental researchers must identify threats to the internal validity of the experiment and addresses these threats in the design of the research study. Internal validity threats include anything that might threaten the researcher’s ability to draw correct inferences from the data in an experiment. Important issues of internal validity concern the truth value of the findings. These threats might involve inadequate procedures or problems in applying the treatment. Threats can also arise from characteristics of the participants (Creswell, 2003).

This study addressed internal validity in several ways. First, both independent and dependent variables were clearly specified, while other factors are controlled. In this study variables were controlled using a matching strategy to establish comparison groups. Students were matched based on several criteria including creativity test scores, major and gender. The faculty assessment served as an additional measure to help rank students for equivalent groups. Matching created equivalent groups with the only difference being the independent variable (participation in educational intervention). There are factors that cannot be controlled such as differing university educational experiences. This was one reason why incoming freshman were selected for the study, preceding any variation from the common required courses in the college of design.

4.15.2 External Validity

External validity, a second objective of experimental design, deals with the representativeness of findings, and the degree that the results may be generalized to similar circumstances and subjects. In this experiment steps were taken to ensure that incorrect inferences are not made from the data to other persons or settings. The study was limiting in its examination of creativity in design, and did not make inferences to other disciplines.
However, it does have strength in its applicability to the selected discipline (design), and its theoretical generalizability to principles of design pedagogy.

4.15.3 Construct Validity

Construct validity ensures that the measurement that will be used actually measures the outcome accurately. Particularly important to this study are the definitions of key terms, the use of both convergent and divergent thinking measures, as well as the use of process and product as a measure of design creativity. The clear definition of creativity in this study ensured that valid measures were selected for assessment.

Previous work in the area of creativity by Wallach & Kogan (1965) and Mednick (1962) helped formulate the measures for this study. In their work both posed new questions about creative thinking and outlined some promising paths for the study of creativity. Numerous aspects of creativity and design thinking were explored before identifying the facet of association as primary in creative thinking in design.

As mentioned previously creative thinking is both convergent and divergent behavior, often in collaboration or sequence (Figure 4.15). Therefore, it was absolutely necessary to consider both convergent and divergent thinking when assessing an individual’s creative ability. Problem solving and more specifically design thinking require both of these thinking processes and for that reason this study accounted for both. This study has carefully considered both of these thinking processes and how each relates to creativity as defined in the study. By including tests of both convergent and divergent thinking a valid measure of creative ability was reached.

The distinction between creative process and creative product is widely recognized. Indicators of potential in both process and product were sought and used for assessment purposes. Such indicators are of practical value as well. In developing criteria for the evaluation of creative thinking the assessment of product is important and acceptable for
several reasons. One main reason is the fact that it is far more tangible. However, in order to fully understand any facet of creative thinking an assessment of process must be included as well. Ideally a measure of both process and product would serve as the best evaluation of creative ability. By measuring both creative process and product this study evaluated both sides in the creativity testing debate while capturing a valid assessment of an individual’s creative skill.

4.15.4 Reliability

The concept of reliability involves the consistency of the measurements or findings. It is important that the results of the study are based solely on the experiment and not on the bias of the researcher.

The scoring of students’ Design Thought Models in this study was done by a group of multiple (8) independent design professionals. The group of design professionals selected to review the subjects’ design projects was representative of the various design disciplines in the NCSU College of Design. The goal of the initial scoring was agreement across all reviewers. Once completed the scoring was reviewed for internal reliability and any discrepancies in the scoring across the individual professionals was discussed so an agreement can be reached and the score finalized. In addition, the use of digital photography and personal notes provided some insurance for reliability. If needed these were used to review material or clarify information from the verbal and graphic presentations. If no agreement could be reached the final score was based on an average of revised individual scores after the group discussion.
CHAPTER 5
RESEARCH METHODOLOGY II

5.1 Data Analysis

In statistics, one often relies on a sample that is, a small subset of a larger set of data --- to draw inferences about the larger set. The larger set is known as the population from which the sample is drawn. The mathematical procedures used to convert information about the sample into intelligent guesses about the population fall under the category of inferential statistics. The goal is to generalize to a large population. This study makes inference to (freshman) undergraduate design students.

Specific procedures used to make inferences about an unknown population or unknown score vary depending on the type of data used and the purpose of making the inference. There are a number of main categories of inferential procedures that include t-test, one and two-way ANOVA, correlation and regression analysis.

For this study a number of variables were analyzed using various statistical procedures. Primary among the statistical inferential procedures for this study was the determination if students that participate in an educational intervention focusing on enhancing creativity through metacognitive thought demonstrated higher creativity measures than those students who do not participate.

5.1.1 T-test

A t-test was used to determine if a difference exists between the means of two groups. To compare these groups, the t-test statistical formula includes the means, standard deviations, and number of subjects for each group. Each of these sets of data can be derived by using descriptive statistics.
As mentioned, the t-test is a useful technique for comparing mean values of two sets of numbers. The comparison provides a statistic for evaluating whether the difference between two means is statistically significant. T-tests are used to compare two independent groups (independent-samples t-test) and to compare observations from two measurement occasions for the same group (paired-samples t-test). Paired t-tests are designed to address dependence between samples and are commonly used in before/after (pre and post-test) studies. While each of these t-tests compares mean values of two sets of numbers, they are designed for distinctly different situations:

• The independent-sample t-test is used to compare two groups' scores on the same variable. For example, it could be used to compare pre-or post-test scores of students participating in an educational intervention and students who are not participating to evaluate whether there is a significant difference in their pre-or post-test scores.

• The paired-sample t-test is used to compare the means of two variables within a single group. For example, it could be used to see if there is a significant difference between pre-and post-test scores of students in either the control (no educational intervention) or treatment (educational intervention) groups.

For this study the variables that were used for the t-tests include scores of students that participated in the educational intervention and scores of those who did not. The mean values of these scores determined the statistical significance. These scores include the two components of the creativity test given to the students (RAT - Remote Associates Test, SIM - Similarities Test) as well as scores on the MAI - Metacognitive Awareness Inventory. In addition, the scores on the DTM (Design Thought Model) at the conclusion of the spring 2007 semester were compared using an independent-sample t-test to determine if a difference existed between the two groups.
5.1.2 Correlation

Correlation is one of the most common forms of data analysis both because it can provide an analysis that stands on its own, and also because it underlies many other analyses, and can be a good way to support conclusions after primary analyses have been completed. Correlations measure the strength of the linear relationship between two quantitative variables. A correlation coefficient is used to measure the strength of the relationship between numeric variables. In this study the numeric variables that were examined include the multiple relationships between the following: Remote Associate Test, Similarities Test, Metacognitive Awareness Inventory, Design Studio grade, and Design Thought Model. This analysis served to answer many of the sub-questions in this study. A correlation matrix was used to examine all possible relationships between the following:

- Remote Associates Test
- Similarities Test - Fluency
- Similarities Test - Originality
- Similarities Test - Total
- Metacognitive Awareness Inventory
- Design Thought Model
- 2006 Fall Design Studio grade
- 2007 Spring Studio grade

The most common correlation coefficient is Pearson's $r$. The Pearson $r$, also known as the Pearson product-moment correlation coefficient, was used to calculate the degree to which two variables are linearly related, either inversely or directly. An inverse relationship means that high values on one variable tend to occur with low values on the other variable. A direct relationship means that high values on one variable tend to occur with high levels on the other variable. For example, high scores on the Remote Associate Test would occur with high levels on the Similarities Test.
Once calculated, $r$ ranges from -1 to +1. An $r$ of -1 means there is a perfect inverse relationship between the two variables. An $r$ of +1 means there is a perfect direct relationship. A value of -1 or +1 means that if you know the value of variable 1, you can know the exact value of variable 2. An $r$ of 0 indicates the complete absence of a relationship. The closer an $r$ is to -1 or +1, the stronger the relationship. The value of correlation (i.e., correlation coefficient) does not depend on the specific measurement units used; for example, the correlation between the Remote Associates Test and Similarities Test will be identical regardless of the measurement units. Proportionality is represented by a linear relationship; that is, the correlation is high if it can be “summarized” by a straight line (sloped upwards or downwards).

As mentioned previously, the correlation coefficient ($r$) represents the linear relationship between two variables. If the correlation coefficient is squared, then the resulting value $r^2$ – the coefficient of determination – will represent the proportion of common variation in the two variables (i.e., the "strength" or "magnitude" of the relationship). In order to evaluate the correlation between variables, it is important to know this strength of the correlation. However, the interpretation of $r$ depends a lot on the research design; $r$ is not a percentage or proportion—an $r$ of .50 does not mean it is half of anything. If two variables were correlated at +1.0 or -1.0 (perfect correlations) this prediction would be extremely accurate. If the correlation coefficient was +/-0.9, the prediction would be good but less accurate than a perfect correlation. The farther from a perfect correlation, the less accurate the results of the prediction. Subsequently, all $r$ does is show a correlational relationship, not a causal one. Just because two variables are linked together does not mean that one causes the other.

5.2 Findings

5.2.1 T-test
The t-test served as the primary analysis for this study by comparing mean values of control and treatment groups. This comparison provided a statistic for determining whether the difference between the two means was statistically significant. Two types of t-tests were
used to compare groups (Figure 5.1). An independent-sample t-test was used to compare the two groups’ scores on the same variable. A paired-sample t-test was used to compare the means of two variables within a group.

![Independent-sample vs. Paired-sample T-test](image)

*Figure 5.1: Independent-sample vs. Paired-sample T-test*
Independent-sample t-test

Hypothesis:

Design students who participate in an educational intervention focusing on enhancing creativity through metacognitive thought will demonstrate higher creative abilities than students who do not participate.

Due to the large number of variables being compared sub-sets were made based on the period in which that data was collected. In addition metacognitive thinking scores based on student Design Thought Models were compared across the control and treatment groups. These subsets are summarized in Figure 5.2.

Pre-Test 1 -- Beginning of 2006 Fall Semester
Pre-Test 2 -- End of 2006 Fall Semester
Post-Test -- End of 2007 Spring Semester

An independent t-test was used to test the variables scored on the creativity tests. This test determined if a significant difference existed between the control and treatment groups in the study. The t-tests for each of the testing periods prior to the educational intervention (pre-test 1 and pre-test 2) revealed that scores of all variables were determined not to be statistically significant (Figure 5.3). These results were expected due to the fact that matching was used following pre-test 2 in order to create equivalent groups for the control and treatment groups.
The matching was based on several of the same variables used in the t-tests. Primary among the variables used in matching were the results of the creativity test during the first two testings in the 2006 fall semester.

An independent t-test was used to test the effect of the educational intervention on the same variables. This test was comparing the scores of control and treatment groups following the educational intervention. It was the primary test in determining if the educational intervention (treatment) had a significant effect on the students in the treatment group. The results revealed a significant difference between all creative thinking variables (Figure 5.4). On average students in the educational intervention scored higher on the Similarities Test.
(fluency and originality) and the Remote Associates Test than did students who did not participate in the intervention.

An independent groups t-test (Similarities-fluency) revealed that the treatment group \((M=102.97, SD=40.16)\) differed from the control group \((M=52.98, SD=19.85)\) as predicted, \(p < .0001\). A t-test (Similarities-originality) revealed that the treatment group \((M=48.4, SD=22.294)\) differed from the control group \((M=15.422, SD=9.181)\) as predicted, \(p < .0001\).

In addition, student scores from the final testing (2007 spring semester) of Remote Associate Test (RAT) were determined to be significant. An independent groups t-test revealed that the treatment group \((M=22.767, SD=5.9462)\) differed from the control group \((M=17.124, SD=7.1316)\) as predicted, \(p < .0001\).

Scores on the Metacognitive Awareness Inventory (MAI) were not determined to be statistically significant, however, it is noteworthy that the mean of the treatment group \((M=208.27)\) was higher than the control group \((M=202.45)\). This marks an improvement from a lower mean in both the first testing at the beginning of the 2006 fall semester (Treatment – \(M=191.87\) / Control – \(M=193.86\)) and the second testing at the end of the 2006 fall semester (Treatment – \(M=192.73\) / Control – \(M=193.34\)).

![Table: Independent T-test – Post-test](image)

**Figure 5.4: Independent T-test – Post-test**
Results from the final independent t-test comparing an assessment of students’ metacognitive thinking represented in their Design Thought Models were determined to be statistically significant (Figure 5.5). A t-test revealed that the treatment group (\(M=37.596, SD=1.7288\)) differed from the control group (\(M=34.32, SD=2.8624\)) as predicted, \(p < .0001\). This result supports the other independent t-test findings by revealing that scores of metacognitive thinking improved along with creative thinking skills. In addition, this comprehensive measure of students’ metacognitive thinking builds on the finding that students’ self-assessment MAI scores differed based on treatment and control groups.

| Variable | Method             | Variances | DF   | t Value | Pr > |t| |
|----------|--------------------|-----------|------|---------|------|---|
| SP07_DTM | Pooled             | Equal     | 114  | -4.73   | <.0001 |
| SP07_DTM | Satterthwaite      | Unequal   | 84.6 | -5.96   | <.0001 |

Figure 5.5. Independent T-test – Design Thought Models

Paired-sample t-test

Key question:

- *Over the course of the entire school year at what stages will advancement in creative thinking abilities and metacognitive awareness take place?*
The paired-sample t-tests compared mean scores of variables on the creativity test across different testing periods. This comparison was made within the control and treatment groups separately. The three tests that were compared (pre-test 1, pre-test 2, post-test) represent a progression across the 2006-2007 school year (Figure 5.6). The first test compares scores at the beginning of the 2006 fall semester with the end of the 2006 fall semester. This period is prior to the educational intervention. The second test compares the first and third testing periods and serves as a cross-section of the entire study, including the educational intervention. The final test served as the most important comparison because it examined test scores that framed the intervention period (2007 spring semester), and included the end of the 2006 fall and 2007 spring semesters.

The MAI was the first measure compared across the three periods. The results determined that there was a significant difference in MAI scores for both the control and treatment groups (Figure 5.7). Results comparing scores across the entire 2006-2007 school year determined that the MAI scores improved significantly for both control and treatment groups, (treatment: $t$ (30) = 2.76, $p < .01$; control: $t$ (89) = 2.35, $p < .0211$). Students in both groups scored higher on average at the end of the 2007 spring semester (treatment: $M=202.27$, $SD=16.075$; control: $M=197.81$, $SD=22.151$) than at the beginning of the 2006 fall semester (treatment: $M=197.81$, $SD=18.407$; control: $M=198.08$, $SD=20.376$).
The results comparing scores at the end of the 2006 fall semester to the end of the 2007 spring semester were shown to be highly significant for both groups, (treatment: $t(30) = 2.76, p < .0098$; control: $t(86) = 3.27, p < .0015$). Students in both groups scored higher at the end of the 2007 spring semester (treatment: $M=202.27$, $SD=16.075$; control: $M=197.81$, $SD=22.151$) than at the end of the 2006 fall semester (treatment: $M=192.73$, $SD=16.942$; control: $M=193.34$, $SD=21.587$).

![Metacognitive Awareness Inventory – Treatment Group](image)

![Metacognitive Awareness Inventory – Control Group](image)

Figure 5.7: Paired-sample T-test – Metacognitive Awareness Inventory
The second paired-sample t-test compared scores on both forms of the Similarities Test within the control and treatment groups (Figure 5.8). Again, the comparisons were made across each of the three testing periods. Students in the treatment group followed a similar pattern as the control group during the first testing period. This was expressed by a significant decrease in scores for both forms of the test: Similarities Fluency (treatment: \( t(30) = -2.84, p < .0081 \); control: \( t(88) = -6.64, p < .0001 \)) Similarities Originality (treatment: \( t(30) = -2.98, p < .0058 \); control: \( t(88) = -6.10, p < .0001 \)).

The test period that includes the entire 2006-2007 school year including the educational intervention showed a sharp contrast in the scores of the two groups. The treatment group showed a highly significant improvement in scores while the control group showed a significant to highly significant decrease in scores: Similarities Fluency (treatment: \( t(30) = 5.12, p < .0001 \); control: \( t(88) = -7.34, p < .0001 \)) Similarities Originality (treatment: \( t(30) = 7.07, p < .0001 \); control: \( t(88) = -2.11, p < .0374 \)).

Of particular note, the final testing period that framed the educational intervention (2007 spring semester) the treatment group showed significant to highly significant improvement of scores on both forms of the Similarities Test: Similarities Fluency (treatment: \( t(30) = 7.22, p < .0001 \); control: \( t(86) = -0.99, p < .3226 \)) Similarities Originality (treatment: \( t(30) = 9.38, p < .0001 \); control: \( t(86) = 3.84, p < .0002 \)). These results confirm the original hypothesis regarding the potential impact of an educational intervention on student’s creative thinking skills and reiterate the independent-sample t-test results in support of the role the intervention played.
### Similarities Test – Treatment Group

#### Similarities – Fluency

<table>
<thead>
<tr>
<th>Year</th>
<th>Group</th>
<th>N</th>
<th>M</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006 Fall Beg. – 2006 Fall End</td>
<td>N=30</td>
<td>M= 74.133, 59.367</td>
<td>SD= 28.154, 24.678</td>
<td></td>
</tr>
<tr>
<td>2006 Fall Beg. – 2007 Sp. End</td>
<td>N=30</td>
<td>M= 74.133, 102.97</td>
<td>SD= 28.154, 40.16</td>
<td></td>
</tr>
<tr>
<td>2006 Fall End – 2007 Sp. End</td>
<td>N=30</td>
<td>M= 59.367, 102.97</td>
<td>SD= 24.678, 40.16</td>
<td></td>
</tr>
</tbody>
</table>

**Table 5.8:** Paired-sample T-test – Similarities Test – Treatment Group

| Difference | DF | t Value | Pr > |t| |
|------------|----|---------|------|---|
| F06_E_SIM_FL - F06_B_SIM_FL | 29 | -2.84 | 0.0081 |
| SP_07_SIM_FL - F06_B_SIM_FL | 29 | 5.12 | <.0001 |
| SP_07_SIM_FL - F06_E_SIM_FL | 29 | 7.22 | <.0001 |

#### Similarities – Originality

<table>
<thead>
<tr>
<th>Year</th>
<th>Group</th>
<th>N</th>
<th>M</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006 Fall Beg. – 2006 Fall End</td>
<td>N=30</td>
<td>M= 21.733, 14.167</td>
<td>SD= 14.849, 7.796</td>
<td></td>
</tr>
</tbody>
</table>

| Difference | DF | t Value | Pr > |t| |
|------------|----|---------|------|---|
| F06_E_SIM_ORIG - F06_B_SIM_ORIG | 29 | -2.98 | 0.0058 |
| SP_07_SIM_ORIG - F06_B_SIM_ORIG | 29 | 7.07 | <.0001 |
| SP_07_SIM_ORIG - F06_E_SIM_ORIG | 29 | 9.38 | <.0001 |

### Similarities Test – Control Group

#### Similarities – Fluency

<table>
<thead>
<tr>
<th>Year</th>
<th>Group</th>
<th>N</th>
<th>M</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006 Fall Beg. – 2006 Fall End</td>
<td>N=89</td>
<td>M= 71.261, 55.573</td>
<td>SD= 29.225, 22.516</td>
<td></td>
</tr>
</tbody>
</table>

| Difference | DF | t Value | Pr > |t| |
|------------|----|---------|------|---|
| F06_E_SIM_FL - F06_B_SIM_FL | 88 | -6.64 | <.0001 |
| SP_07_SIM_FL - F06_B_SIM_FL | 89 | -7.34 | <.0001 |
| SP_07_SIM_FL - F06_E_SIM_FL | 86 | -0.99 | 0.3226 |

#### Similarities – Originality

<table>
<thead>
<tr>
<th>Year</th>
<th>Group</th>
<th>N</th>
<th>M</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006 Fall Beg. – 2006 Fall End</td>
<td>N=88</td>
<td>M= 18.87, 11.629</td>
<td>SD= 13.995, 7.9019</td>
<td></td>
</tr>
</tbody>
</table>

| Difference | DF | t Value | Pr > |t| |
|------------|----|---------|------|---|
| F06_E_SIM_ORIG - F06_B_SIM_ORIG | 88 | -6.10 | <.0001 |
| SP_07_SIM_ORIG - F06_B_SIM_ORIG | 89 | -2.11 | 0.0374 |
| SP_07_SIM_ORIG - F06_E_SIM_ORIG | 86 | 3.84  | 0.0002 |

**Figure 5.8:** Paired-sample T-test – Similarities Test – Treatment and Control Group
The third paired-sample t-test compared control and treatment group scores on the Remote Associates Test across the three testing periods. The results for the control group revealed that students’ scores significantly decreased over the entire testing period (control: $t(87) = -5.58, p < .0001$) with the most significant decrease occurring in the final testing at the end of the 2007 spring semester (control: $t(84) = -7.70, p < .0001$). In contrast the treatment group demonstrated an improvement during each period of testing with a significant improvement in scores occurring across the entire testing period (treatment: $t(30) = 2.37, p < .0248$). The increase in scores during the intervention period (2007 spring semester) were not at a significant level (treatment: $t(30) = 0.71, p < .4827$), however, they did stand in sharp contrast to scores of the control group that showed an extremely significant decrease in scores over that same time period.

![Remote Associates Test – Treatment Group](image)

| Difference | DF | t Value | Pr > |t| |
|------------|----|---------|------|---|
| F06_E_RAT - F06_B_RAT | 29 | 1.41 | 0.1704 |
| SP07_RAT - F06_B_RAT | 29 | 2.37 | 0.0248 |
| SP07_RAT - F06_E_RAT | 29 | 0.71 | 0.4827 |

![Remote Associates Test – Control Group](image)

| Difference | DF | t Value | Pr > |t| |
|------------|----|---------|------|---|
| F06_E_RAT - F06_B_RAT | 86 | 0.13 | 0.8936 |
| SP07_RAT - F06_B_RAT | 87 | -5.88 | <.0001 |
| SP07_RAT - F06_E_RAT | 84 | -7.70 | <.0001 |

Figure 5.9: Paired-sample T-test – Remote Associates Test – Treatment and Control group
5.2.2 Correlation

Key questions:

- Is there a correlation between various creative thinking skills (Fluency / Originality)?
- Is there a correlation between metacognitive thinking and creative thinking skills?
- Specifically, what measures of creativity represent this relationship?
- Is metacognitive thinking a predictor of students’ convergent or divergent thinking skills?

As a secondary analysis in this study correlation served to support conclusions after the primary analyses had been completed. Several quantitative numeric variables were examined to measure the strength of their relationship (Appendix N). The majority of these variables represented different measures of creative thinking. Included were students’ scores on the different forms of the creativity tests. In addition, scores from the Design Thought Models were included as a measure of metacognitive thinking.

A correlation quantifies the degree to which two variables are linearly related and vary together. Using correlation was extremely efficient in examining the strength of all possible relationships among the variables. The output matrix containing all of the relationships and information regarding their strength was displayed together and significant relationships could be determined and examined in detail (Figure 5.10).
Examining those significant relationships allowed for several questions to be answered. Among those was determining if a relationship existed between the different types of creative thinking skills that were tested. This involved examining the relationship of student scores on the different forms of the creativity test (Remote Associates Test, Similarities Test--Fluency, Similarities Test—Originality). A significant positive correlation was found to exist between the fluency and originality scores on the Similarities test (Figure 5.11). This indicates that students with high fluency scores also have high originality scores. Although the strength of this relationship is high for each testing it reaches its highest level in the 2007 spring semester. This was very encouraging because it supports the assertion that before
students can generate truly original responses to problems they must first concentrate on generating as many alternative solutions as possible. It is this process of generating alternatives that allows for the original responses to emerge.

There was not a linear relationship between scores on the RAT and either part of the SIM test. This can be attributed to the fact that the tests were measuring two completely different types of thinking (RAT – convergent thinking / SIM – divergent thinking). While both types of thinking are critical to design thinking and the design process the level of skill an individual possesses in one type of thinking was found to be largely independent of the other.

Another important relationship was discovered between students’ metacognitive thinking and creative thinking. Students’ level of metacognitive thinking measured in the assessment of their Design Thought Models had a strong relationship to their level of divergent thinking represented by scores on both forms the Similarities Test (Figure 5.12).

The study examined the relationship between metacognitive thinking and creative thinking in greater detail by looking at the relationship separately for treatment and control groups (Appendix O). By examining the groups separately an important disparity in the strength of this relationship was revealed. A correlation including the treatment group only revealed a very strong relationship between metacognitive thinking and divergent thinking. Metacognitive thinking scores on the Design Thought Model and fluency scores on the Similarities test were highly correlated, \( r (30) = .87111, p < .0001 \). Also, metacognitive
thinking scores on the Design Thought Model and originality scores on the Similarities Test were highly correlated, $r (30) = .86657$, $p < .0001$. Finally, metacognitive scores on the Design Thought Model and a total score of fluency and originality on the Similarities Test were highly correlated, $r (30) = .88811$, $p < .0001$.

A correlation including the control group only revealed that metacognitive thinking scores on the Design Thought Model and fluency scores on the Similarities test were weakly correlated, $r (86) = .06865$, $p < .0001$. Also, metacognitive thinking scores on the Design Thought Model and originality scores on the Similarities Test were weakly correlated, $r (86) = .02258$, $p < .0001$. Finally, metacognitive scores on the Design Thought Model and a total score of fluency and originality on the Similarities Test were weakly correlated, $r (86) = .05652$, $p < .0001$.

\[
\begin{array}{ll}
\text{Metacognitive Thinking / Creative Thinking} \\
\text{--- All students---} \\
\text{Design Thought Model / Similarities – Fluency} & r (116) = 0.38686 \quad p < .0001 \\
\text{Design Thought Model / Similarities – Originality} & r (116) = 0.37556 \quad p < .0001 \\
\text{Design Thought Model / Similarities – Total} & r (116) = 0.38985 \quad p < .0001 \\
\text{---Treatment---} \\
\text{Design Thought Model / Similarities – Fluency} & r (30) = 0.87111 \quad p < .0001 \\
\text{Design Thought Model / Similarities – Originality} & r (30) = 0.86657 \quad p < .0001 \\
\text{Design Thought Model / Similarities – Total} & r (30) = 0.88811 \quad p < .0001 \\
\text{---Control---} \\
\text{Design Thought Model / Similarities – Fluency} & r (86) = 0.06865 \quad p < .0001 \\
\text{Design Thought Model / Similarities – Originality} & r (86) = 0.02258 \quad p < .0001 \\
\text{Design Thought Model / Similarities – Total} & r (86) = 0.05652 \quad p < .0001 \\
\end{array}
\]

Figure 5.12: Pearson Product-Moment Correlation – Metacognitive Thinking / Creative Thinking
6.0 Conclusions

The findings in this study support the main hypothesis. Students who participated in an educational intervention focusing on enhancing creativity through metacognitive thought demonstrated higher creativity measures than those students who did not participate. A significant difference in scores was found in several key variables measuring creative thinking. In addition to an increase in creative thinking abilities students who participated in the educational intervention were found to have significantly higher metacognitive thinking skills represented in their Design Thought Models (Appendix P-S). This is an important result due to the fact that the Design Thought Model is a physical manifestation of one’s thinking process. It can be described as a detailed exercise in metacognition, revealing an awareness and understanding of one’s personal cognitive process in design.

In support of these primary findings the study examined scores across the entire 2006-2007 school year and compared scores within control and treatment groups at various points both pre and post intervention. This allowed for the scores of control and treatment groups following the educational intervention to be placed in context along with multiple pre-test measures. The results not only provided additional support of the hypothesis by revealing significantly improved scores of the treatment group following the educational intervention, but also indicated that this contrast in scores did not exist at any point prior to the treatment. While students in the treatment group demonstrated significantly increased scores on both forms of the creativity test this was not the case for the control group. Of particular concern is the fact that the students in the control group demonstrated a significant decrease in creativity scores across the testing period. This may be due to the fact that students in the treatment group were more motivated to enhance their thinking processes as a result of their participation in educational intervention. Therefore, students in the treatment group may have placed a greater value on design process while students in the control group may have
reflected a design approach valuing product at the expense of process. The decline in creative thinking abilities of students in the control group represents an area that needs further exploration and continued testing.

A goal of the educational intervention was to increase students’ awareness and appreciation of metacognitive and creative thinking skills. The intervention focused on understanding the importance of process and made clear that the best way to generate creative solutions is to build knowledge of creative thinking processes and strategies through reflection. Therefore, when presented with an opportunity to exercise these creative strategies in a testing situation students were not only more prepared to use various strategies but also more motivated to do so having experienced their value.

Students who participated in the educational intervention were aware that the course was designed to improve their creative thinking abilities. This knowledge provided motivation to improve and work toward their potential. Students believed that a progression in thinking could take place and were encouraged to plan, monitor and evaluate their thinking through regulation of cognition. This progression of thinking was aided by self-assessment throughout the semester. Students were presented a self-assessment rubric and asked to continually reference it for setting goals and making evaluation. Presently in design education creative thinking is often considered to be predetermined (Oxman, 1999); an innate ability that students either possess or do not possess. In many design studio settings discussion and explanation of creative processes and improving one’s creative thinking ability is not addressed, or not to the degree that is most constructive. Metacognition should be a foundation for design education, guiding students to think about and strive to improve their own thinking processes is essential to design education.

Two critical correlations were revealed in the findings for this study. The first established a strong relationship between metacognitive thinking as measured by the Design Thought Models and divergent thinking. Taking these results a step further a correlation examining the treatment and control groups separately discovered that this relationship was stronger for
the treatment group. The fact that students with higher level metacognitive thinking (awareness and understanding of their own thinking process) possessed higher level of divergent thinking supports a fundamental aspect of the study. This conclusion meets the goals and initiates that were a part of the educational intervention, and supports the fact that the educational intervention helped build this relationship through an educational approach conceptualizing creativity as a metacognitive process. Building students’ metacognitive skills allowed them to most effectively utilize creative thinking strategies and abilities. By having a strong awareness and understanding of their own creative thinking process students in the treatment group were best able to utilize their creative thinking strategies when tested.

The educational intervention (treatment) introduced and practiced the model of creative thinking as a metacognitive process. Students were made aware of the importance of metacognition and their emergent understanding of their own thinking process was related to creative thinking in design. Beyond building students’ basic awareness, activities and exercises were used to strengthen each students’ metacognitive skills while focusing on how these skills attribute to advanced creative thinking. Establishing this connection in the classroom translated into students exercising the connection in their own thinking when challenged or tested.

This study conceptualized metacognition as requiring knowledge of cognition and regulation of cognition. Students who experienced the educational intervention and worked to build higher levels of both knowledge and regulation of cognition also had higher levels of creative thinking. Knowledge of cognition provided students with a knowledge base consisting of conditional knowledge (when, where and why to use specific creative strategies), individual knowledge (which creative strategies work best for you) and task knowledge (steps to perform each creative strategy). Regulation of cognition provided students the ability to plan, monitor and evaluate the use of creative strategies. Students were able to plan which strategies to use on a specific problem, monitor their use of strategies to gauge their effectiveness, and evaluate and change strategies if one was not working. As a students’ level of metacognitive thinking increases so does their capacity to utilize their creative thinking. By becoming more aware and having a greater understanding of thinking process
this clarity and comprehension allow for new and more complex modes of creative thinking and strategy use.

The second important correlation that was reported occurred across all students. It was revealed that students with higher fluency (total number of responses) scores on the Similarities Test also possessed higher originality scores. A response was deemed original if it was given by no more than 5 percent of all respondents. This suggested that in order to generate truly innovative and unique solutions to creative problems a person must first generate numerous alternatives. It was not the case that a student was able to generate a large number of original responses without also generating a large number of alternative responses. By generating numerous alternatives students were able to consider infinitely greater possibilities of how these common responses could be combined, modified or juxtaposed to generate new responses that were unique. In the process of generating alternatives a person evokes many common responses that are reflexive and frees the mind to consider how these common responses may lead to new responses that are reflective in nature; that is, they required a new way of looking at the available information occupying the problem state.

This relationship points to the associationistic approach to creativity adopted in this study, and represents a theory many scholars have presented that the ability to think creatively is a matter of utilizing a variety of associations accessible to an individual (Ribot 1900, Spearman 1931, Mednick 1962, Wallach & Kogan 1965, Koestler 1964, Maltzman 1960). Unusual recombination of these bonds results in creativity. One such theory is Mednick’s (1962) associationistic theory of creativity in which creativity is characterized by the combining of mutually distant associative elements of thought. In his view creative individuals solve problems by juxtaposing a number of ideas not previously related to one another. It can be suggested that students who scored highly on the Similarites Test practiced a similar pattern. The generation of numerous alternatives (fluency) allowed them to combine, modify and generate new ideas (originality) based on the relationship of existing alternatives. In this view creativity is a matter of novel arrangement of temporarily contiguous, unusual associations to a given stimulus. In addition, Spearman (1931) has presented the Principle
of Correlates – “When any item and a relation to it are present to mind, then the mind can generate in itself another item so related.” Spearman’s basic model (Figure 2) involves an active process in which associations with an initial idea can be freed from their relation to it and thus lead to something entirely new.

6.1 Generalizing Findings

This study was performed using subjects from the College of Design at North Carolina State University. The College of Design at NCSU has several attributes that make it unique in terms of design education. First, the college is comprised of five distinct design disciplines (Architecture, Landscape Architecture, Industrial Design, Graphic Design and Art & Design) all of which were represented in the study. While this diversity makes for a healthy design community the college requires that all freshman take an interdisciplinary Design Fundamentals studio their first semester. These studios build a strong foundation from which students can advance toward achieving academic and personal success. In addition, students are required to enroll in a two-credit course entitled D100 –Design Thinking during their second semester. This course is taught by Marvin Malecha, dean of the College of Design. The course is instrumental in introducing students to various concepts and models associated with design cognition and process. Along with the D100 course the college seeks to experiment with new approaches to design education and often promotes advancement in design pedagogy as evidence by the special topics course that served as an educational intervention for this study. Most importantly, there is support throughout the administration to continue taking steps toward the advancement of students’ education, and to ensure that graduates are best prepared to contribute to a challenging and evolving professional workplace. For all of these reasons freshman design students at NCSU were a perfect sample population. However, in order for these findings to be highly generalizable to other design institutions similar academic approaches may need to be in place.

In this study freshman design students served as the study population. Therefore, the results and conclusions apply only to this level of education. Future research should assess if similar
results are repeated throughout all levels of education and beyond. The educational approach practiced in the treatment is based on the advancement of metacognitive skills in creative thinking and represents a progression in a designer’s approach to design. This is not something that is mastered over a semester or even a year. Rather it is an approach that a person develops over a lifetime of experience and reflection, and is limited only by one’s lack of motivation or support.

As freshman design students the participants in this study had no previous university education. However, as a limitation of the generalizability of this study there is no guarantee that students don’t develop creative and metacognitive skills through other means in parallel curricular experiences.

This study did examine a group of first-year graduate students as a cohort to the freshman undergraduate students. Although the students were unable to participate in the educational intervention they served as a comparison to the control group of freshman designers. Unfortunately due to the small number of students participating valid statistical comparisons could not be made. In the future an effort should be made to study not only graduate students but also designers at all levels of education and beyond.

6.2 Application to Design Education

As a part of the responsibility associated with organizing and administering the education intervention for this study I maintained a weekly reflection journal throughout the spring semester. The entries in the journal correspond with each class period and are comprised of my thoughts following each session. The goal was to use this experience to gather insight on the strengths and weaknesses of the course and how best to improve the course to the point that it can be integrated on a larger scale across the design curriculum and in other design educational settings. In conjunction with the weekly reflections recorded in the journal students were asked to participate in an instructor and course evaluation at the end of the semester. The feedback from students who participated in the educational intervention along
with reflections recorded in the teaching journal served as guidance toward the applicability
to design education. A summary of the reflection journal is provided below. For a complete
record of each see (Appendix T).

6.2.1 Weekly Reflection Journal:

The core of the educational intervention was interactive and involved activities and exercises
allowing students to experience using the creative strategies for themselves. An open
learning environment and planned group sessions helped generate energy as all of the
students were very active participants in activities planned for the class.

At the beginning of the semester a practice was established of presenting information and
participating in exercises without allowing students to offer perspective. It was discovered
that students need the opportunity to express their thoughts. An effort was then made to
incorporate student feedback on their personal use of creative strategies. The most
appropriate time for this was at the beginning of the class period. It served as a way to
review past strategies and generated class participation. Although many of the students were
initially reluctant to speak aloud, with some prompting and the creation of an open
environment for discussion dialogue was created and flourished.

Only one creative strategy was introduced at a time. While a metacognitive approach to
creative thinking remained constant, various creative strategies were first introduced and
learned individually and then practiced as a skill set. The focus of the entire class time was
centered on exercises and examples that encouraged student involvement and offered
perspective. This class format was class much smoother for the students, not having to take
in so much information, and being able to concentrate on one specific strategy.

Ideally having multiple classes devoted to each of the creative strategies would allow for
follow-up lessons where advancement in complexity could be practiced and monitored. This
would also lend itself to reflection and discussion of each strategy in the context of design
using specific design problems from students studio work. The ideas that were presented in
class were best realized when allowed to blossom through practice and experience in the
design setting. Therefore the concepts presented in this educational intervention need to be a
part of the core of design education and intergraded into studio practice in both teaching and
discussion. In the case of the educational intervention for this study once students left the
classroom it was up to them to utilize the strategies in their studio work and other design
endeavors. This highlighted the importance of making creative thinking a part of every
aspect of a design students’ education. Introducing metacognitive thinking is a key in this
process and ultimately should be paramount in all aspect of a designer’s life.

Some of the creative strategies are similar in their approach and in many cases can be utilized
together. A point was made to mention this fact and review of past strategies proved helpful
to reinforce the main objectives and aid students in making this connection. It was critical to
continue to build on what was introduced in previous classes. An effort was made to
encourage the combination and modification of strategies. Posting lectures and handouts on a
website for student access helped facilitate student review and documentation of the material.

Students were prompted to reflect on their thinking to help ensure that a metacognitive
approach is being utilized. Are they planning, monitoring and evaluating? It proved
valuable to incorporate case study examples of each creative strategy in design along with
discussions on how designers utilized metacognition in their process of design. The
exposure to these examples helped reinforce their importance and gave students tangible
examples in the design profession. Examples and exercises began to allow students to see
how these strategies may be utilized, but it is important to take this a step further and give
them specific cases in which designers have and continue to use these strategies in design
thinking.

The practice of keeping a strategy log was introduced to students and they were encouraged
to begin as part of their studio work. Eventually the class began with an open discussion of
students’ strategy logs, what strategies they had experimented with outside of class along
with feedback on what they learned in using these strategies. As the semester progressed and
students learned additional creative strategies they were able to find many opportunities to
utilize these strategies in their design work, and had numerous experiences to discuss in class.

It was important that students understand that these strategies provide a solid base for their design thinking, but only to the degree that they practice metacognitive thinking when utilizing the strategies. Simply having the knowledge of how to use the strategies is only one type of knowledge. Conditional, individual and task knowledge are dependent upon students’ regulation of cognition. The act of taking control – planning, monitoring, and evaluating their own thinking is the ultimate goal. This point was continually reinforced throughout the semester. There is no doubt that this experience led to a clearer vision about the importance of metacognition in education, particularly design.

Students seemed to understand the entire concept of metacognition – both knowledge and regulation components. More importantly I feel as though they understood the significance of this approach in creative thinking and the cycle of building knowledge through self-regulated thinking.

There was a need to incorporate more group activities along with any individual exercises during class. Students seemed to become more active and articulate after participating in activities as a group. The exercise of students reporting their use of creative strategies is a good example. Asking students to report to one another in groups allowed them to reflect on their own practice and learn from others experiences. Open discussion was encouraged and the sharing of experience and knowledge was valued. Students representing various design disciplines indicated that this type of discussion did not occur in studio.

At times some of the exercises in class were very general and did not apply newly introduced strategies into a specific design context. Certainly in learning about a new strategy it was wise to start with a basic exercise to help students understand the nature of the process, however, this was followed with design specific examples and exercises. When possible exercises were related to work that students were currently undertaking in their own studio
projects. Ideally students’ current problems and projects should foster in-class exercises and discussion.

A primary goal of this educational intervention was that each student have an understanding of where they currently stand as metacognitive thinkers; where their strengths exist and what they need to improve on to become proficient and reach their creative potential. In this intervention the process of reflection was aided by the introduction of a self-assessment rubric. Students used this to assess themselves and worked in the second half of the semester to improve in areas where they were the weakest. Using the rubric students were able to assess their metacognitive thinking in several (6) different facets and rate themselves along a continuum. This served as a tool to help students understand at what level they were currently utilizing metacognitive thinking, and more importantly what was needed in order to improve incrementally and reach proficiency in all facets. As students continued in the second half of this semester the class focused on each on the these metacognitive facets and discussed how to best advance to a higher level. The challenges and mental blocks associated with each of these facets were explored using individual reflection and discourse to lead in-class discussion. By introducing one aspect of metacognitive thinking in each class period the focus was on what each of these aspects entails and how students may first rate themselves along a performance continuum for a particular aspect. The focus then shifted to how students may improve upon their current level of thinking and achieve a more proficient level of metacognitive thinking for each aspect. By breaking metacognition down into singular aspects students were able to better comprehend how metacognition applied to their creative process as designers. In addition, students were able to guide themselves in a process of enhancing their own design thinking by setting attainable goals for improved thinking. The self-assessment metacognitive thinking rubric served to guide students along a path to reaching their creative potential as designers.

The activities in class were a mix of small group and large group size. Each activity lends itself to an optimal size group. Still, the use of these strategies by students outside of class will be practiced primarily individually. The nature of design work remains largely an individual endeavor. Students were encouraged to seek out their peers and allow for a
discourse and sharing of ideas. Encouraging the interplay of ideas and viewpoints particularly in the ideation phase of a project helped everyone involved realize their creative potential. This is not to say that students should rely on others for ideas, it is encouraging an openness of thought in order to foster innovative ideas and solutions.

The creative strategies introduced in the educational intervention allowed students to examine their problem state by diverging into as many possible areas relating to the problem. This allowed students to view the problem in a more comprehensive manner and allowed critical associations to be made. Making these associations is critical to creative thinking, and teaching students to make these associations involves introducing them to various creative strategies that encourage and aid in this process. It is largely about a way of seeing. These strategies allowed students to organize, present, and view their ideas in a manner that associations could be made. All of these strategies allowed students to see their thinking/ideas in a slightly different way. The key for students was trying these strategies in their own design work and finding out which ones allowed them to make the most associations and lead to creative ideas/solutions.

The majority of the students who participated in the educational intervention seemed to be juggling a large amount of course work that included non-design courses for their general education requirements. Witnessing this trend prompted the question of how this course might be best introduced to students. Would it be best as a part of their studio courses, or perhaps it should be a required course that all design students take every year. A definitive answer to this question remains unclear, however, the concepts that students learned in this class should be utilized in their design work, and the separation that existed between this educational intervention and design studio work was an obstacle. Students seemed to view their studio work as primary and all other courses as something that must be completed, but with far less time and focus. It might be best to offer a general class for all first year students followed by advanced discipline specific courses as students’ progress in their education. This way it could be assured that discipline specific problems are addressed regularly in the context of the class.
As a class the entire semester was a progression in thought, complexity, and ideas. Each week involved an introduction of something new, in most cases a new creative strategy. However, with each new strategy there was a layering of though and ideas as they apply to design thinking. Each of the strategies was based on common approaches to creative thinking. In particular there was a focus on the use of association in both divergent and convergent thinking. The significance of this approach is that as the semester progressed students were forced to consider each of these strategies individually as well as in conjunction with one another. Each week students were practicing the skill of association and returning to their studio projects with a renewed and enhanced approach to creative thinking. As students built an appreciation and understanding for the skill of association in the form of various strategies their overall ability to utilize their thinking in design blossomed. It was very rewarding to see students make this progression and work to realize their creative potential on a weekly basis. In the future there needs to be some action to ensure that information learned in this class will be reinforced in the design studio. This study relied on the students’ motivation and willingness to explore these strategies on their own.

Another interesting aspect of this semester was the interaction between what was learned in D100 – Design Thinking and the material introduced in this course. Design Thinking was based on a more general introduction of the design process and various related issues. As students experienced both classes on a weekly basis throughout the semester areas of intersection were noted. At these moments the educational intervention capitalized on the opportunity to reinforce the content and build upon what was introduced in D100. This interaction was very beneficial for both students and instructors. The simple fact that students were forced to think more about their thinking in a focused classroom setting and share in discussions was invaluable. There is enormous value in both design courses. This interaction should continue beyond one semester in students first year of study. Based on the experiences and conclusions of this study the content and focus represented in the educational intervention should be a part of the entire design curriculum, especially the reinforcement of ideas in design studio. Unfortunately at this point students are left on their
own to transfer what is introduced in the classroom into the studio. There is little doubt that for most freshmen this challenge along with other new responsibilities is overwhelming and requires more guidance and support. By assuming that students will utilize and build these cognitive thinking skills without support in the core of the curriculum educators are letting students down and not serving their best interest as future design professionals.

What was learned in this educational intervention was just a start, the beginning of a collection of cognitive strategies that they will continue to grow as designers continue to gain insight through experience. Each student was encouraged to take time and reflect on what was introduced and practiced this semester. The course made an attempt to establish an awareness and understanding of a way of thinking, designing and living. Design for college students is a way of life and many of them are just beginning to come to this realization. At the same time the majority of these students were unaware of the concept of metacognition and had spent very little time considering, reflecting and thinking about their own thought process. Asking them to do so at this early stage of their design education was a challenging but essential step toward the realization of their creative potential.

For most design students creativity was something that was valued but rarely discussed or conceptualized in terms of thinking. The idea of creative thinking was viewed as an innate ability that most design students possess and will naturally surface in their work, seemingly without explanation. This educational intervention made an effort to change this perception and make students aware of the role metacognition plays in creative thinking and the design process. Forcing students to think about their own thinking allowed many to realize and ultimately value process and growth through reflection. Design is no different than any intellectual endeavor in that cognitive growth is determined by a conscious and lucid account of one’s own thinking. Watching students come to this realization was very rewarding. This class in conjunction with their design studio and D100- Design Thinking provided an optimal environment for this growth and understanding to occur. A goal is that this environment can be maintained and strengthened in the future allowing each design student to work most efficiently toward realizing his or her creative potential.
6.3 Limitations

One major limitation of this study was the interaction with students in the treatment group. The treatment for the study involved a semester long education intervention that was realized in the form of a two-credit hour course. This elective course met once a week for one hour. The course was independent of students’ design studio and any involvement between the two was voluntary in terms of student participation. Students were encouraged to utilize what was learned and practiced in the educational intervention during studio; however, this was not a part of the studio instruction or teaching approach. While this educational intervention was a very important first step toward the realization of incorporating this content across the design curriculum the fact that interaction, discussion and extended support was limited to the classroom and not in the studio setting serves as a major limiting factor in the advancement of the study and its results. The content introduced and advanced in the educational intervention should be implemented and supported across the design curriculum and throughout students’ design life in order to maximize its meaning, purpose and effectiveness.

6.4 Future Research Directions

Future research should build upon this study by taking what was learned and applying it in a studio setting, fostering more interaction with students and applying principles of thinking to discipline specific problems. Ideally the educational intervention would include a more comprehensive treatment that encompasses all design classes. This would allow for an extended and content specific focus as well as an opportunity to directly apply the creative strategies that are introduced. Integration into the design studio would ensure that students have a guidance and support system in place to allow the advancement of creative thinking through a metacognitive approach. In addition, an effort should be made to extend the educational experience throughout a student’s education and observe how metacognitive and creative skills progress as they advance toward a professional career. This could be extended into professional practice as well to examine how these skills benefit designers as they enter different design professions.
Although the cohort group of first year graduate students did not play a significant role in this results of this study a more comprehensive large-scale attempt at incorporating similar studies into graduate design education is needed. First year graduate students are often faced with many of the same challenges as their undergraduate counterparts. Many of these students have a non-design background and have very little awareness or understanding of the cognitive processes associated with creative thinking. Metacognition is not an inherited skill or one that students naturally develop with age. It is equally important to address this in graduate design education and continue it’s development throughout a student’s education. The goal is to establish an approach to design thinking that student’s will continue to develop throughout their design lives.

This study examines the creative skill of association. Future research could expand the study to examine other aspects of creativity as it applies to design. This focus could be discipline specific as different design disciplines may examine aspects of creativity deemed to be important. A metacognitive approach utilizing these creative thinking skills may be constructed and practiced in the studio. Approaching creative thinking as a metacognitive process allows for any aspect of creativity to become the focus of an educational approach to design. Moreover, this approach could be expanded to include numerous aspects of creativity and these could be integrated across a designers’ education.

This study gathered faculty assessments of students’ creative and metacognitive thinking skills for the 2006 fall and 2007 spring semesters. Design studio instructors were asked to indicate the level of proficiency of students’ convergent, divergent and metacognitive thinking based on the instructors’ observation and interaction with students throughout the semester. The faculty assessment served to compare students’ test scores with instructors’ evaluation of these skills. In addition, the faculty assessment of students’ metacognitive thinking served as a comparison to students’ scores on the Metacognitive Awareness Inventory (MAI) and Design Thought Model. After collecting these assessments of students for both semesters it was discovered through statistical analysis that scoring was highly inconsistent across the various instructors each semester. Due to the large number of
students multiple sections were used for both the 2006 fall and 2007 spring semesters. With different instructors for each section and semester the number of instructors rating the students was large. In addition, different instructors demonstrated a pattern of high or low ratings across their entire section of students. To eliminate this problem multiple raters are typically used to ensure that each student receives numerous assessments of each measure. Unfortunately this was not possible in the studio setting as it is presently conformed. The instructor is the only person qualified to make these assessments of the students and currently each section has only one instructor.

In future studies faculty assessments of various creative and metacognitive skills should certainly be included, but only if multiple qualified raters are available to the study population. Studio classes with adjunct professors or teaching assistants would be ideal. Also, co-teaching or swing studios in which multiple instructors have access to the students are viable possibilities. The faculty assessment is a promising measurement tool and an effort needs to be made to ensure that this type of assessment is strongly considered in future studies.

A final direction of research would examine the current state of design education including how creative thinking is taught and developed in the studio environment. Also studying how studio instructors are supporting the notion of creativity as a metacognitive approach. Using a more qualitative approach future research might attempt to examine design instructors and students conception of creative thinking. Important questions might investigate if their understanding of creative thinking includes metacognitive activities and how this understanding changes or differs with experience and or other factors.
REFERENCES


Davis, Meredith; Hawley, Peter; McMullan, Bernard; Spilka, Gertrude. (1997). *Design as a Catalyst Fro Learning*. Association for Supervision and Curriculum Development. Alexandria, VA.


Appendix A. Informed Consent Form for Research – General

North Carolina State University
INFORMED CONSENT FORM for RESEARCH

Title of Study: Enhancing Creativity Through Self-regulated Metacognitive Thought

Ryan Hargrove PhD student in Design

Art Rice – Associate Dean for Graduate Studies
College of Design

We are asking you to participate in a research study. The purpose of this study is to measure creative behavior that may be used in future problem solving.

INFORMATION
If you agree to participate in this study, you will complete a creative skills test on three separate occasions during the next two semesters of school. The first test will be administered at the start of the 2006 fall semester. The second test will be administered at the completion of the 2006 fall semester, and the third test will be administered at the completion of the spring 2007 semester. These tests will not require any additional time outside of class.

RISKS
There are no risks to the subjects involved in this research. Students will be fully informed as to the purpose of this study.

BENEFITS
Promoting the creative abilities of designers is crucial to the advancement of design scholarship. As culture grows more complex, science more all-encompassing, and choices more diverse there exists a growing need for creative solutions that will address these challenges and provide a framework for continued innovation. By participating in this research study you are assisting in the examination of how creative thinking can best be integrated into the design curriculum.

CONFIDENTIALITY
The information in the study records will be kept strictly confidential. Data will be stored securely in locked file cabinets. No reference will be made in oral or written reports which could link you to the study. A confidential identification number will identify subjects in the data.

CONTACT
If you have questions at any time about the study or the procedures, you may contact the researcher, Ryan Hargrove, at ryanuofk@aol.com or 502.938.1308. If you feel you have not been treated according to the descriptions in this form, or your rights as a participant in research have been violated during the course of this project, you may contact Dr. Matthew Zingraff, Chair of the NCSU IRB for the Use of Human Subjects in Research Committee, Box 7514, NCSU Campus (919/513-1834) or Mr. Matthew Ronning, Assistant Vice Chancellor, Research Administration, Box 7514, NCSU Campus (919/513-2148)

PARTICIPATION
A decision to participate or not participate will not affect students' grades; your participation in this study is voluntary and you may decline to participate without penalty. If you decide to participate, you may withdraw from the study at any time without penalty and without loss of benefits to which you are otherwise entitled. If you withdraw from the study before data collection is completed your data will be returned to you or destroyed at your request.

CONSENT
“I have read and understand the above information. I have received a copy of this form. I agree to participate in this study with the understanding that I may withdraw at any time.”

Subject's signature_______________________________________ Date _________________

Investigator's signature__________________________________ Date _________________
Appendix B. Informed Consent Form for Research – Treatment

North Carolina State University
INFORMED CONSENT FORM for RESEARCH

Title of Study: Enhancing Creativity Through Self-regulated Metacognitive Thought

Ryan Hargrove PhD student in Design  Art Rice –Associate Dean for Graduate Studies
College of Design

We are asking you to participate in a research study. The purpose of this study is to enhance students understanding and awareness of creative strategies that may be used in future problem solving. These creative strategies would help encourage creative thinking that will lead to more innovative and novel solutions. Students will practice (self-regulated) metacognitive thought; planning, monitoring and evaluating thinking in an effort to enhance attention and awareness and ultimately realize creative potential.

INFORMATION
If you agree to participate in this study, you will be a part of an educational intervention for the 2007 spring semester. This educational intervention is worth two credit hours and is listed as D 292A – Design Thinking Explorations in the university registration system. The intervention will focus on improving students’ creativity. In an effort to encourage students to regulate (plan, monitor, evaluate) their own thinking processes specific creative skills will be introduced, learned and practiced. Students that agree to participate will meet once a week for one hour. Audio and videotaping will be used to document daily activities that may be used for future professional development associated with the project. This will serve as a record for review and template for larger scale implementation into a design curriculum.

RISKS
There are no risks to the subjects involved in this research. Students will be fully informed as to the purpose of this study.

BENEFITS
Students that participate in the educational intervention will gain an understanding and awareness of creative strategies that may be used in future problem solving. These creative strategies help encourage creative thinking that will lead to more innovative and novel solutions. Students will practice a metacognitive approach by reflecting on their own thinking in an effort to enhance a self-regulation and ultimately realize creative potential.

Promoting the creative abilities of designers is crucial to the advancement of design scholarship. As culture grows more complex, science more all-encompassing, and choices more diverse there exists a growing need for creative solutions that will address these challenges and provide a framework for continued innovation.

CONFIDENTIALITY
The information in the study records will be kept strictly confidential. Data will be stored securely in locked file cabinets. No reference will be made in oral or written reports which could link you to the study. A confidential identification number will identify subjects in the data.

COMPENSATION
By participating in this study you will receive two credit hours under the course title of D292A – Design Thinking Explorations.

CONTACT
If you have questions at any time about the study or the procedures, you may contact the researcher, Ryan Hargrove, at ryanuofl@aol.com, or 502.938.1308. If you feel you have not been treated according to the descriptions in this form, or your rights as a participant in research have been violated during the course of this project, you may contact Dr. Matthew Zingraff, Chair of the NCSU IRB for the Use of Human Subjects in Research Committee, Box 7514, NCSU Campus (919/513-1834) or Mr. Matthew Ronning, Assistant Vice Chancellor, Research Administration, Box 7514, NCSU Campus (919/513-2148)
PARTICIPATION
A decision to participate or not participate will not affect students' grades in D100; your participation in this study is voluntary and you may decline to participate without penalty. If you decide to participate, you may withdraw from the study at any time. If you withdraw from the study before data collection is completed your data will be returned to you or destroyed at your request. All that is required of a student in order to receive credit for the course is their attendance and weekly participation in the educational intervention. If a student does not meet the requirement for attendance or participation or decides for whatever reason to withdraw from the study he or she will not receive credit for the course.

CONSENT
“I have read and understand the above information. I have received a copy of this form. I agree to participate in this study with the understanding that I may withdraw at any time.”

Subject's signature_______________________________________ Date _________________

Investigator's signature__________________________________ Date _________________
Appendix C. Similarities Test – Form A

NAME___________________________

Similarities

In this section you will be given the name of two objects, and you will then be asked to think of all the ways that these two objects are alike. Any two objects may be named – like apple and orange. But whatever is listed, it will be your job to think of all the ways that the two objects are alike. For example, if you are asked “List all the ways in which a apple and an orange are alike” you might write that they both are round, and they both are sweet, they both have seeds, they both are fruits, they both have skins, they both grow on trees, etc.

Printed below are 10 questions, take as much time as needed to provide as many possible answers for each question. List all the ways that each two objects are alike. If you require additional space for a response use the extra pages provided at the end of the packet.

List all the ways in which a carrot and a potato are alike

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List all the ways in which a cat and a mouse are alike
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List all the ways in which a train and a tractor are alike
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List all the ways in which milk and meat are alike

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List all the ways in which a grocery store and a restaurant are alike

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List all the ways in which a violin and a piano are alike

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List all the ways in which a radio and a telephone are alike

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List all the ways in which a watch and a typewriter are alike

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List all the ways in which a curtain and a rug are alike

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List all the ways in which a desk and a table are alike
Appendix D. Similarities Test – Form B

NAME__________________________________________

Part 2 Form B

Similarities

In this section you will be given the name of two objects, and you will then be asked to think of all the ways that these two objects are alike. Any two objects may be named – like apple and orange. But whatever is listed, it will be your job to think of all the ways that the two objects are alike. For example, if you are asked “List all the ways in which a apple and an orange are alike” you might write that they both are round, and they both are sweet, they both have seeds, they both are fruits, they both have skins, they both grow on trees, etc.

Printed below are 10 questions, take as much time as needed to provide as many possible answers for each question. List all the ways that each two objects are alike. If you require additional space for a response use the extra pages provided at the end of the packet.

List all the ways in which a tree and a table are alike

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List all the ways in which a desert and a mountain are alike
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List all the ways in which a factory and a school are alike
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List all the ways in which a shoe and a hat are alike

List all the ways in which a hair and a blade of grass are alike
List all the ways in which a bowl and a bathtub are alike

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List all the ways in which eyeglasses and a telescope are alike

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List all the ways in which a camera and a paintbrush are alike

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List all the ways in which a knee and an elbow are alike

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List all the ways in which a door and a window are alike
Appendix E. Similarities Test – Form C

NAME___________________________

Similarities

In this section you will be given the name of two objects, and you will then be asked to think of all the ways that these two objects are alike. Any two objects may be named – like apple and orange. But whatever is listed, it will be your job to think of all the ways that the two objects are alike. For example, if you are asked “List all the ways in which a apple and an orange are alike” you might write that they both are round, and they both are sweet, they both have seeds, they both are fruits, they both have skins, they both grow on trees, etc.

Printed below are 10 questions, take as much time as needed to provide as many possible answers for each question. List all the ways that each two objects are alike. If you require additional space for a response use the extra pages provided at the end of the packet.

List all the ways in which a river and a railroad are alike
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List all the ways in which a bridge and a tunnel are alike

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List all the ways in which an earthquake and a hurricane are alike

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List all the ways in which a tattoo and a scar are alike

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List all the ways in which fog and rain are alike

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List all the ways in which a belt and a shoelace are alike

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List all the ways in which a bank and a library are alike

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List all the ways in which a cave and an ocean are alike

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List all the ways in which a compass and a map are alike

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List all the ways in which a sunset and a rainbow are alike
Appendix F. Remote Associates Test – Form A

NAME___________________________

Remote Associates Test

INSTRUCTIONS: In this test you are presented with three words and asked to find a fourth word that is related to all three. Each set of three words can be associated with the solution word in a number of ways. For example, the three words SAME / TENNIS / HEAD are associated with the solution MATCH by synonymy (same = match), by formation of a compound word (matchhead), and by semantic association (tennis match). Please write the solution to each problem in the space to the right.

<table>
<thead>
<tr>
<th>Same / Tennis / Head</th>
<th>Match</th>
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<tbody>
<tr>
<td>Falling / Actor / Dust</td>
<td></td>
</tr>
<tr>
<td>Broken / Clear / Eye</td>
<td></td>
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<tr>
<td>Bass / Complex / Sleep</td>
<td></td>
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<tr>
<td>Coin / Quick / Spoon</td>
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<tr>
<td>Gold / Stool / Tender</td>
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<tr>
<td>Time / Hair / Stretch</td>
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<tr>
<td>Bald / Screech / Emblem</td>
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<tr>
<td>Manners / Round / Tennis</td>
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<tr>
<td>Playing / Credit / Report</td>
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<tr>
<td>Rabbit / Cloud / House</td>
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<tr>
<td>Salt / Deep / Foam</td>
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<td>Square / Cardboard / Open</td>
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<td>Water / Tobacco / Stove</td>
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<td>Ache / Hunter / Cabbage</td>
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<td>High / Book / Sour</td>
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<td>Lick / Sprinkle / Mines</td>
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<td>Snack / Line / Birthday</td>
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<td>Square / Telephone / Club</td>
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<td>Surprise / Wrap / Care</td>
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<td>Ticket / Shop / Broker</td>
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<td>Barrel / Root / Belly</td>
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<td>Blade / Witted / Weary</td>
<td></td>
</tr>
<tr>
<td>Notch / Flight / Spin</td>
<td></td>
</tr>
<tr>
<td>Walker / Main / Sweeper</td>
<td></td>
</tr>
<tr>
<td>Chocolate / Fortune / Tin</td>
<td></td>
</tr>
<tr>
<td>Color / Numbers / Oil</td>
<td></td>
</tr>
<tr>
<td>Mouse / Sharp / Blue</td>
<td></td>
</tr>
<tr>
<td>Sandwich / Golf / Foot</td>
<td></td>
</tr>
<tr>
<td>Silk / Cream / Even</td>
<td></td>
</tr>
<tr>
<td>Speak / Money / Street</td>
<td></td>
</tr>
<tr>
<td>Big /Leaf/ Shade</td>
<td></td>
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<tr>
<td>------------------</td>
<td></td>
</tr>
<tr>
<td>Envy /Golf/ Beans</td>
<td></td>
</tr>
<tr>
<td>Hall /Car/ Swimming</td>
<td></td>
</tr>
<tr>
<td>Ink /Herring/ Neck</td>
<td></td>
</tr>
<tr>
<td>Measure /Desk/ Scotch</td>
<td></td>
</tr>
<tr>
<td>Athletes /Web/ Rabbit</td>
<td></td>
</tr>
<tr>
<td>Board /Magic/ Death</td>
<td></td>
</tr>
<tr>
<td>Lapse /Vivid/ Elephant</td>
<td></td>
</tr>
<tr>
<td>Puss /Tart/ Spoiled</td>
<td></td>
</tr>
<tr>
<td>Rock /Times/ Steel</td>
<td></td>
</tr>
<tr>
<td>Thread /Pine/ Pain</td>
<td></td>
</tr>
<tr>
<td>Zone /Still/ Noise</td>
<td></td>
</tr>
<tr>
<td>Jump /Kill/ Bliss</td>
<td></td>
</tr>
<tr>
<td>Magic /Plush/ Floor</td>
<td></td>
</tr>
<tr>
<td>Note /Dive/ Chair</td>
<td></td>
</tr>
<tr>
<td>Stalk /Trainer/ King</td>
<td></td>
</tr>
<tr>
<td>Bump /Throat/ Sum</td>
<td></td>
</tr>
<tr>
<td>Blank /White/ Lines</td>
<td></td>
</tr>
<tr>
<td>Stick /Light/ Birthday</td>
<td></td>
</tr>
<tr>
<td>Sore /Shoulder/ Sweat</td>
<td></td>
</tr>
</tbody>
</table>
### Remote Associates Test

**INSTRUCTIONS:** In this test you are presented with three words and asked to find a fourth word that is related to all three. Each set of three words can be associated with the solution word in a number of ways. For example, the three words SAME / TENNIS / HEAD are associated with the solution MATCH by synonymy (same = match), by formation of a compound word (matchhead), and by semantic association (tennis match). Please write the solution to each problem in the space to the right.

<table>
<thead>
<tr>
<th>Same /Tennis /Head</th>
<th>Match</th>
</tr>
</thead>
<tbody>
<tr>
<td>cottage/swiss/cake</td>
<td></td>
</tr>
<tr>
<td>loser/throat/spot</td>
<td></td>
</tr>
<tr>
<td>night/wrist/stop</td>
<td></td>
</tr>
<tr>
<td>rocking/wheel/high</td>
<td></td>
</tr>
<tr>
<td>fountain/baking/pop</td>
<td></td>
</tr>
<tr>
<td>aid/rubber/wagon</td>
<td></td>
</tr>
<tr>
<td>cracker/fly/fighter</td>
<td></td>
</tr>
<tr>
<td>fish/mine/rush</td>
<td></td>
</tr>
<tr>
<td>measure/worm/video</td>
<td></td>
</tr>
<tr>
<td>sense/courtesy/place</td>
<td></td>
</tr>
<tr>
<td>pie/luck/belly</td>
<td></td>
</tr>
<tr>
<td>---------------</td>
<td>----------</td>
</tr>
<tr>
<td>opera/hand/dish</td>
<td></td>
</tr>
<tr>
<td>fur/rack/tail</td>
<td></td>
</tr>
<tr>
<td>hound/pressure/shot</td>
<td></td>
</tr>
<tr>
<td>sleeping/bean/trash</td>
<td></td>
</tr>
<tr>
<td>water/mine/shaker</td>
<td></td>
</tr>
<tr>
<td>right/cat/carbon</td>
<td></td>
</tr>
<tr>
<td>nuclear/feud/album</td>
<td></td>
</tr>
<tr>
<td>cross/rain/tie</td>
<td></td>
</tr>
<tr>
<td>french/car/shoe</td>
<td></td>
</tr>
<tr>
<td>chamber/mask/natural</td>
<td></td>
</tr>
<tr>
<td>age/mile/sand</td>
<td></td>
</tr>
<tr>
<td>health/taker/less</td>
<td></td>
</tr>
<tr>
<td>dress/dial/flower</td>
<td></td>
</tr>
<tr>
<td>guy/rain/down</td>
<td></td>
</tr>
<tr>
<td>down/question/check</td>
<td></td>
</tr>
<tr>
<td>house/thumb/pepper</td>
<td></td>
</tr>
<tr>
<td>master/toss/finger</td>
<td></td>
</tr>
<tr>
<td>change/circuit/cake</td>
<td></td>
</tr>
<tr>
<td>blank/list/mate</td>
<td></td>
</tr>
<tr>
<td>marshal/child/piano</td>
<td></td>
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<tr>
<td>---------------------</td>
<td>---</td>
</tr>
<tr>
<td>pile/market/room</td>
<td></td>
</tr>
<tr>
<td>fence/card/master</td>
<td></td>
</tr>
<tr>
<td>dive/light/rocket</td>
<td></td>
</tr>
<tr>
<td>tooth/potato/heart</td>
<td></td>
</tr>
<tr>
<td>teeth/arrest/start</td>
<td></td>
</tr>
<tr>
<td>wet/law/business</td>
<td></td>
</tr>
<tr>
<td>off/military/first</td>
<td></td>
</tr>
<tr>
<td>cut/cream/war</td>
<td></td>
</tr>
<tr>
<td>shock/shave/taste</td>
<td></td>
</tr>
<tr>
<td>break/bean/cake</td>
<td></td>
</tr>
<tr>
<td>bottom/curve/hop</td>
<td></td>
</tr>
<tr>
<td>pea/shell/chest</td>
<td></td>
</tr>
<tr>
<td>home/arm/room</td>
<td></td>
</tr>
<tr>
<td>nose/stone/bear</td>
<td></td>
</tr>
<tr>
<td>control/place/rate</td>
<td></td>
</tr>
<tr>
<td>artist/hatch/route</td>
<td></td>
</tr>
<tr>
<td>mate/shoes/total</td>
<td></td>
</tr>
<tr>
<td>shadow/chart/drop</td>
<td></td>
</tr>
<tr>
<td>reading/service/stick</td>
<td></td>
</tr>
</tbody>
</table>
Appendix H. Remote Associates Test – Form C

NAME___________________________

Remote Associates Test

INSTRUCTIONS: In this test you are presented with three words and asked to find a fourth word that is related to all three. Each set of three words can be associated with the solution word in a number of ways. For example, the three words SAME / TENNIS / HEAD are associated with the solution MATCH by synonymy (same = match), by formation of a compound word (matchhead), and by semantic association (tennis match). Please write the solution to each problem in the space to the right.

<table>
<thead>
<tr>
<th>Same / Tennis / Head</th>
<th>Match</th>
</tr>
</thead>
<tbody>
<tr>
<td>cream / skate / water</td>
<td></td>
</tr>
<tr>
<td>show / life / row</td>
<td></td>
</tr>
<tr>
<td>duck / fold / dollar</td>
<td></td>
</tr>
<tr>
<td>preserve / ranger / tropical</td>
<td></td>
</tr>
<tr>
<td>flake / mobile / cone</td>
<td></td>
</tr>
<tr>
<td>safety / cushion / point</td>
<td></td>
</tr>
<tr>
<td>dream / break / light</td>
<td></td>
</tr>
<tr>
<td>high / district / house</td>
<td></td>
</tr>
<tr>
<td>worm / shelf / end</td>
<td></td>
</tr>
<tr>
<td>flower / friend / scout</td>
<td></td>
</tr>
<tr>
<td>print/berry/bird</td>
<td></td>
</tr>
<tr>
<td>--------------------------</td>
<td></td>
</tr>
<tr>
<td>date/alley/fold</td>
<td></td>
</tr>
<tr>
<td>fox/man/peep</td>
<td></td>
</tr>
<tr>
<td>dust/cereal/fish</td>
<td></td>
</tr>
<tr>
<td>peach/arm/tar</td>
<td></td>
</tr>
<tr>
<td>palm/shoe/house</td>
<td></td>
</tr>
<tr>
<td>home/sea/bed</td>
<td></td>
</tr>
<tr>
<td>sage/paint/hair</td>
<td></td>
</tr>
<tr>
<td>boot/summer/ground</td>
<td></td>
</tr>
<tr>
<td>fly/clip/wall</td>
<td></td>
</tr>
<tr>
<td>catcher/food/hot</td>
<td></td>
</tr>
<tr>
<td>tank/hill/secret</td>
<td></td>
</tr>
<tr>
<td>lift/card/mask</td>
<td></td>
</tr>
<tr>
<td>force/line/mail</td>
<td></td>
</tr>
<tr>
<td>eight/skate/stick</td>
<td></td>
</tr>
<tr>
<td>pine/crab/sauce</td>
<td></td>
</tr>
<tr>
<td>foul/ground/mate</td>
<td></td>
</tr>
<tr>
<td>way/board/sleep</td>
<td></td>
</tr>
<tr>
<td>tail/water/flood</td>
<td></td>
</tr>
<tr>
<td>cover/arm/wear</td>
<td></td>
</tr>
<tr>
<td>mouse/bear/sand</td>
<td></td>
</tr>
<tr>
<td>------------------------</td>
<td></td>
</tr>
<tr>
<td>keg/puff/room</td>
<td></td>
</tr>
<tr>
<td>test/runer/map</td>
<td></td>
</tr>
<tr>
<td>man/glue/star</td>
<td></td>
</tr>
<tr>
<td>illness/bus/computer</td>
<td></td>
</tr>
<tr>
<td>iron/shovel/engine</td>
<td></td>
</tr>
<tr>
<td>rope/truck/line</td>
<td></td>
</tr>
<tr>
<td>spoon/cloth/card</td>
<td></td>
</tr>
<tr>
<td>note/chain/master</td>
<td></td>
</tr>
<tr>
<td>wise/work/tower</td>
<td></td>
</tr>
<tr>
<td>cry/front/ship</td>
<td></td>
</tr>
<tr>
<td>roll/bean/fish</td>
<td></td>
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<tr>
<td>oil/bar/tuna</td>
<td></td>
</tr>
<tr>
<td>fight/control/machine</td>
<td></td>
</tr>
<tr>
<td>child/san/wash</td>
<td></td>
</tr>
<tr>
<td>end/line/lock</td>
<td></td>
</tr>
<tr>
<td>self/attorney/spending</td>
<td></td>
</tr>
<tr>
<td>land/hand/house</td>
<td></td>
</tr>
<tr>
<td>back/step/screen</td>
<td></td>
</tr>
<tr>
<td>over/plant/horse</td>
<td></td>
</tr>
</tbody>
</table>
Appendix I. Design Thought Model Program

Spring Semester 2007
Design Thinking (D 100)

Design Thought Final Project Assignment
Critical

NC State University College of Design
Professor Marvin J. Malecha

A Personal Design Thought Model

Project Introduction
As a student of design you have inherited a remarkable legacy of craft and professional accomplishment. The question that this comprehensive exercise poses is what is the mental map you would construct to connect the two points. How you represent the progression from a way of seeing to a way of doing is entirely up to you. This exercise is intended to be a three-dimensional representation of a personal design process. How you represent your design thinking process is a measure of your understanding of design and the place of design in your life. It is important that once you have constructed this representation your process must be obvious to others.

A Three-Part Presentation

Physical
You are asked to create a physical representation of your design thought process. The final project should not exceed Thirty (30) inches in any dimension. A variance is possible with the permission of the course instructor. The model may be made of any non-toxic material.

Written
You will supplement the physical artifact representing your design thought process with a written narrative. This part of the assignment was issued as Contemplation Exercise 6 – The Critical Manifesto. You were asked to clearly articulate the cognitive processes (strategies and skills) that make up your process of design. The addition of this exercise will serve to strengthen the physical representation by clarifying the intention in your thought process.

Verbal
There will be a required exhibit of the final project for the general review of class members, the course instructor, teaching assistants and invited guests from outside the university. This exhibit of the Design Thought Model will be scheduled individually across a three day time
period to facilitate a personal response as well as to adjust to personal study and class
schedule requirements.
You will be asked to verbally express the operations and meaning expressed in both your written and
physical representations. Each student will communicate their process to a sequence of jurors in one-on-
one presentations. The goal is to clearly convey your understanding of your own design thinking
process.

Project Issue and Submission
The Design Thought Model Project will be issued following lecture 9 (February 15; it is due during the
period (April 30 – May 2). Excellent Examples of the Design Thought Model may be held by the
instructor for future use in the class and exhibition in the College.

Teaching Assistant Discussion Sessions
The Teaching Assistants will be available to assist with the Contemplation Exercises and the evolution
of the Design Thought Model Project. Specific class periods throughout the semester will be devoted to
individual critiques, guidance and discussion. Meetings outside of regularly scheduled class time may
be arranged by contacting a teaching assistant.

Project Reference
A monograph, Design in Life, Life in Design, was distributed during the introductory class lecture as a
reference to the Design Thought Model Project.

Design Thought Model Project Examples
Ellison Sieck : Architecture Major, Spring 2003
Project Grading

Each student will be expected to have at least one mid-semester review of the progress toward completing the Design Thought Model Project with either a teaching assistant or the course instructor. The late submission of the project will result in a twenty-five (25) percent reduction from the total possible score. The following categories will be graded and assessed points. The Design Thought Model Exercise comprises 40% of the semester grade.

The Design Thought Model Exercise (40 pts)

Craft of the Model (10pts) – construction and representation of the physical artifact.

Rigor of the Concept: precision of thinking (10pts) – exploration and articulation of the concept, refinement and detailed representation of thinking.

Communication: accurate representation of the idea (10pts) – congruence between verbal and physical representations, physical model serves to communicate ideas above and beyond the verbal presentation.

Metacognitive Thinking (10pts) – an awareness and understanding of one’s own thinking process. Metacognition begins with an awareness among thinkers that metacognition exists, differs from cognition, and enhances creative thinking. Beyond this basic awareness metacognition requires knowledge of cognition and regulation of cognition.

• Knowledge of cognition includes what students know about themselves, thinking strategies, and conditions under which strategies are most useful.

• Regulation of cognition corresponds to knowledge about the way students plan and implement thinking strategies, monitor and correct errors, and evaluate their thinking.
Appendix J. Metacognitive Awareness Inventory

NAME____________________________________

Metacognitive Awareness Inventory

Please indicate your level of agreement or disagreement to the following statements. If you strongly agree, for example, write the number 5 in the blank provided to the left.

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Neutral</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>

1. I ask myself periodically if I am meeting my goals.
2. I consider several alternatives to a problem before I answer.
3. I try to use strategies that have worked in the past.
4. I pace myself while learning in order to have enough time.
5. I understand my intellectual strengths and weaknesses.
6. I think about what I really need to learn before I begin a task.
7. I know how well I did once I finish a test.
8. I set specific goals before I begin a task.
9. I slow down when I encounter important information.
10. I know what kind of information is most important to learn.
11. I ask myself if I have considered all options when solving a problem.
12. I am good at organizing information.
13. I consciously focus my attention on important information.
14. I have a specific purpose for each strategy I use.
15. I learn best when I know something about the topic.
16. I know what the teacher expects me to learn.
17. I am good at remembering information.
18. I use different learning strategies depending on the situation.
19. I ask myself if there was an easier way to do things after I finish a task.
20. I have control over how well I learn.
21. I periodically review to help me understand important relationships.
22. I ask myself questions about the material before I begin.
23. I think of several ways to solve a problem and choose the best one.
25. I ask others for help when I don’t understand something.
<table>
<thead>
<tr>
<th></th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Neutral</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>2</td>
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<td>5</td>
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</tr>
</tbody>
</table>

26. I can motivate myself to learn when I need to.
27. I am aware of what strategies I use when I study.
28. I find myself analyzing the usefulness of strategies while I study.
29. I use my intellectual strengths to compensate for my weaknesses.
30. I focus on the meaning and significance of new information.
31. I create my own examples to make information more meaningful.
32. I am a good judge of how well I understand something.
33. I find myself using helpful learning strategies automatically.
34. I find myself pausing regularly to check my comprehension.
35. I know when each strategy I use will be most effective.
36. I ask myself how well I accomplished my goals once I’m finished.
37. I draw pictures or diagrams to help me understand while learning.
38. I ask myself if I have considered all options after I solve a problem.
39. I try to translate new information into my own words.
40. I change strategies when I fail to understand.
41. I use the organizational structure of the text to help me learn.
42. I read instructions carefully before I begin a task.
43. I ask myself if what I’m reading is related to what I already know.
44. I reevaluate my assumptions when I get confused.
45. I organize my time to best accomplish my goals.
46. I learn more when I am interested in the topic.
47. I try to break studying down into smaller steps.
48. I focus on overall meaning rather than specifics.
49. I ask myself questions about how well I am doing while I am learning something new.
50. I ask myself if I learned as much as I could have once I finish a task.
51. I stop and go back over new information that is not clear.
52. I stop and reread when I get confused.
Appendix K. Faculty Assessment Form

NAME___________________________

Faculty Assessment of Creative Thinking

Based on the definition provided please indicate the level at which (student) has demonstrated this type of thinking in studio. If a student has demonstrated a very high level of this type of thinking, for example, circle the number 5.

• Divergent Thinking

It is the ability to consciously generate new ideas that branch out to many possible solutions for a given problem. Divergent thinking (diffuse, free flowing, associated, perceptual and imaginative).

Figure 1: Divergent Thinking

Thinking that moves away in diverging directions so as to involve a variety of aspects involved tearing a topic apart to explore its various component parts. Thinking that produces many ideas or alternatives; many possibilities are developed from one starting point. Divergence is the process of thinking broadly, of expanding one's mind, of going places where one does not normally go. Divergent thinking is very important in creativity as the process whereby ideas are generated. Although everyone can do it, some take to it more easily and find idea creation (sometimes called ideation) both natural and fun.

<table>
<thead>
<tr>
<th>Very Low</th>
<th>Low</th>
<th>Average</th>
<th>High</th>
<th>Very High</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>
Convergent Thinking

It is the ability to bring material from a variety of sources to bear on a problem, in such a way as to produce the single "correct" solution. Convergent thinking often requires taking a novel approach to the problem, seeing the problem from a different perspective or making a unique association between parts of the problem. Convergent thinking (focused, analytical, judgmental and detailed thinking)

Figure 2: Convergent Thinking

Thinking that brings together information focused on solving a problem. It involves combining or joining different ideas together based on elements these ideas have in common along with the ability to narrow all possible alternatives down to a single solution. When you have created a big pile of ideas, the creative activity does not stop there. The next stage, which can be very difficult, seeks to thin down the idea set into a very small set of ideas (maybe one) that will be taken forward for further development. This approach requires skills of selection, evaluation and judgment to whittle down the list to the most useful ideas. Convergent thought (lines of thought converge on the correct answer).

<table>
<thead>
<tr>
<th>Very Low</th>
<th>Low</th>
<th>Average</th>
<th>High</th>
<th>Very High</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>
**Metacognitive Thinking**

Metacognition is essential to successful design thinking because it enables individuals to better manage their cognitive skills and to determine weaknesses that can be corrected by constructing new cognitive skills. Almost anyone who can perform a thinking skill is capable of metacognition – that is, thinking about one’s own thought process. Metacognition begins with an awareness among thinkers that metacognition exists, differs from cognition, and enhances creative thinking. Beyond this basic awareness metacognition requires **knowledge of cognition** and **regulation of cognition**.

- Knowledge of cognition includes what students know about themselves, thinking strategies, and conditions under which strategies are most useful.

- Regulation of cognition corresponds to knowledge about the way students plan, implement thinking strategies, monitor, correct errors, and evaluate their thinking.

Please review the model and indicate the level at which (student) has demonstrated this type of thinking in studio.

<table>
<thead>
<tr>
<th>Very Low</th>
<th>Low</th>
<th>Average</th>
<th>High</th>
<th>Very High</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1</strong></td>
<td><strong>2</strong></td>
<td><strong>3</strong></td>
<td><strong>4</strong></td>
<td><strong>5</strong></td>
</tr>
</tbody>
</table>
Appendix L.  D 292A – Design Thinking Explorations Course Syllabus

Spring Semester 2007
Design Thinking Explorations (D 292A)

Course Syllabus
NC State University College of Design

A. Course Instructor and Contact Information

Faculty:  Ryan Hargrove, PhD Candidate, College of Design
ryanuofk@aol.com

Office:  College of Design, Brooks Hall, Studio Suite 212 A

Office Hours:  By Appointment

B. Course prerequisites or restrictive statements.

Prerequisite:  DF 101
Corequisites:  D100 and ADN102 or ARC102 or GD102 or ID102 or LAR102

C. Student learning outcomes for the course.

Learning Outcomes:  Students that participate in the course will gain an understanding and
awareness of creative strategies that may be used in future problem solving.  These
creative strategies help encourage creative thinking that will lead to more innovative and
novel solutions.  Students will practice a metacognitive approach by reflecting on
their own thinking in an effort to enhance self-regulation and ultimately realize creative
potential.

D. Textbook and Handouts

Textbook:  No textbook is required for this course.
Handouts:  Handouts will be periodically provided to the students throughout the semester.
E. Course organization and scope.

This course is being offered on an experimental basis, and is part of a research study examining the creative abilities of design students. The role of teacher/researcher is based upon in-class interaction with students in weekly class meetings. Issues of cognition and metacognition emerge as we negotiate and develop a process where the students act as observers of their own thinking processes. Reflection in weekly group meetings provide a framework to challenge individual students' assumptions about their approach to design thinking, and to explore the advancement of metacognitive thinking. Participation in this course will have no effect on students’ grades in D100 – Design Thinking. All that is required in order to receive credit for the course is regular attendance and weekly participation during class time. If a student does not meet the requirement for attendance or classroom participation or decides for whatever reason to withdraw from the study he or she will not receive credit for the course.

Course Expectations: Students will be exposed to modes of thinking including the discovery, application, integration, and the sharing of knowledge. This will be accomplished in discussion sessions, group activities and in-class exercises.

Course Requirements: Each student will be expected to attend each class session. Participation is essential to the success of the course. In addition to in-class participation each student is required to keep a strategy log outside of class. This will reflect content from in-class activities as well as work in students’ design studio course. Unexcused absences or lack of participation will result in a student being dropped from the course.

F. Daily plan of work

The following is an outline for the typical class period:

1. Review creative strategy introduced in previous class period. Talk about how this strategy worked in a design situation outside of class (Strategy Log). (5-10 min.)

2. Introduce a new creative strategy and build knowledge through discussion. (10-15 min.)

3. In-class activity/exercise focusing on the practice of the creative strategy that was most recently introduced. (15-20 min.)

4. Reflection / Discussion of exercise as a class or in small groups. (5-10 min.)

5. Short lesson on one aspect of metacognitive thinking. (5-10 min.)
G. Projected schedule

See attached planned schedule
Please note that because of the complexity of the academic calendar schedule adjustments may be made to this schedule over the course of the semester. Students will be given ample warning of any changes.

H. Explanation of Grading

Attendance and participation will compose 100% of students’ final grade for the course. Students are asked to attend all classes and participate in activities, exercises and discussions. **Due to the nature of the course students' attendance is critical toward obtaining the educational objectives. Because students’ grades are solely based on their attendance and participation no absences are encouraged. Beyond two (2) University excused absences a failure to attend class will result in the removal of a student from the course.

I. Academic Integrity Statement

University Academic Integrity Policy: Students are expected to:

Comply with the University policy on academic integrity found in the Code of Student Conduct: http://www.ncsu.edu/policies/student_services/student_conduct/POL445.00.1.htm

J. Statement for students with disabilities

"Reasonable accommodations will be made for students with verifiable disabilities. In order to take advantage of available accommodations, students must register with Disability Services for Students at 1900 Student Health Center, Campus Box 7509, 515-7653.
http://www.ncsu.edu/provost/offices/affirm_action/dss/ For more information on NC State's policy on working with students with disabilities, please see http://www.ncsu.edu/provost/hat/current/appendix/appendix_k.html
Projected Schedule for the Semester

Class 1: Activity
   Introduction
   Discussion of class purpose and objectives

Class 2: Introduction to creative strategies
   Creative Strategy 1 – Brainstorming / Reverse Brainstorming
   Framework for effective metacognitive practices

Class 3: Lateral Thinking Lesson
   Knowledge of cognition

Class 4: Creative Strategy 2 – Random Input
   Regulation of cognition

Class 5: Creative Strategy 3 – Analogy Technique / Forced Analogy / Mind Mapping
   Cycle of knowledge and regulation of cognition

Class 6: Creative Strategy 4 – Metaphorical Thinking
   Key operations of metacognition

Class 7: Synectics Lesson
   Importance of practice

Class 8: Creative Strategy 5 – The Discontinuity Principle
   Conceptual level

Class 9: Creative Strategy 6 – Storyboarding
   Rubric for self-assessment

------------------------SELF-ASSESSMENT --------------------------------

Class 10: Creative Strategy 7 – Lotus Blossom Technique
   Metacognitive Facet 1 - Explanation

Class 11: Creative Strategy 8 – Assumption Smashing
   Metacognitive Facet 2 - Interpretation

Class 12: Creative Strategy 9 – Escapism Technique
   Metacognitive Facet 3 - Application

Class 13: Creative Strategy 10 – Search and Reapply Technique
   Metacognitive Facet 4 - Perspective

Class 14: Creative Strategy 11 – Idea Checklist / SCAMPER
   Metacognitive Facet 5 - Empathy

Class 15: Creative Strategy 12 – Attribute Listing / Morphological Charts / Morphological Forced Connections
   Metacognitive Facet 6 – Self-Knowledge

Class 16: Conclusion and Wrap-up
Appendix M. Design Thought Model Scoring Rubric

D100 – Design Thinking
Design Thought Model
Spring 2007

Grade Categories – Total 40 points

Craft of the Model (10pts) – construction and representation of the physical artifact

Rigor of the Concept: precision of thinking (10pts) – exploration and articulation of the concept, refinement and detailed representation of thinking.

Communication: accurate representation of the idea (10pts) – congruence between verbal and physical representations, physical model serves to communicate ideas above and beyond the verbal presentation.

Metacognitive Thinking (10pts) – an awareness and understanding of one’s own thinking process. Metacognition begins with an awareness among thinkers that metacognition exists, differs from cognition, and enhances creative thinking. Beyond this basic awareness metacognition requires knowledge of cognition and regulation of cognition.

• Knowledge of cognition includes what students know about themselves, thinking strategies, and conditions under which strategies are most useful.

• Regulation of cognition corresponds to knowledge about the way students plan and implement thinking strategies, monitor and correct errors, and evaluate their thinking.
Appendix N. Correlation Matrix

The SAS System

The CORR Procedure

16 Variables: F06_B_RAT F06_B_SIM_FL F06_B_SIM_ORIG F06_B_SIM_TOTAL F06_B_MAI F06_E_RAT F06_E_SIM_FL F06_E_SIM_ORIG F06_E_SIM_TOTAL F06_E_MAI SP07_RAT SP07_DTM_MA SP07_SIM_FL SP07_SIM.ORIG SP07_SIM_TOTAL SP07_MAI

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## The SAS System

### The CORR Procedure

#### Pearson Correlation Coefficients

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The SAS System

The CORR Procedure

Pearson Correlation Coefficients
Prob > |r| under H0: Rho=0
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Appendix O. Correlation – Metacognitive Thinking / Creative Thinking

The SAS System

The CORR Procedure

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Variable N Mean Std Dev Sum Minimum Maximum Label

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The CORR Procedure

4 Variables:  SP_07_SIM_FL  SP_07_SIM_ORIG  SP07_SIM_TOTAL  SP07_DTM_MA

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THOUGHTS BEHIND THE THOUGHT
: A PERSONAL DESIGN MANIFESTO

TO VIEW PROCESS FROM ABOVE
IS NOT ENOUGH. FROM ABOVE,
PROCESS IS AN EMPTY SERIES
VOID OF MEANING - AN UNTRODDEN PATH

TO VIEW PROCESS FROM ABOVE
GIVES IT NO JUSTICE, BECAUSE
IT IS MORE THAN JUST A PROCESS
IT IS AN EVOLUTION OF THOUGHT

THE EVOLUTION BEGINS WITH A
MOTIVE FORCE, A PUSH FROM
THE ORIGIN POINT
FROM HERE THE PROCESS BEGINS

NO LONGER IS THE PROCESS SEEN FROM
A SINGLE PERSPECTIVE
I SEE ITS ELEMENTS
FROM INSIDE
Elements fall in sequence one step compelling the next.

With each step taken and decision made, I learn something new.

With each step something is left behind - something to be left with me. The remnant is not visible from the origin, but only acquired once the process has begun.

If two elements stand alone, they are not triggered by the elements before them.

If two elements are displaced a new path is created.
 THESE DEVIATIONS ARE NOT CURSES
 BUT BLESSINGS TO THE PROCESS.
 THESE DEVIATIONS REVEAL
 ONLY MORE REMNANTS
 TO BE COLLECTED ALONG THE WAY.

 THROUGH THE IMPERFECT PROCESS
 THAT SEEMED SO ALIGNED AND
 PRECISE FROM ITS BEGINNING.
 I WILL FIND A WAY OF ORGANIZING
 MY THOUGHT.

 I WILL FIND THE PROPER SETUP
 AS IT COMPOSES A
 BEAUTIFUL RHYTHM.
Appendix Q. Design Thought Model Example – Student B

Manifesto

My first semester fundamentals class was the first class in which I was challenged to think about my design process. Since then, my awareness of process has grown exponentially, fuelled by D100 and the Thought Model Project. I have also given much thought to how I approach life. Until assigned this reflection, I did not realize how closely my design process and my approach to life (and life in design) parallel each other. They are nearly identical in most regards.

My initial response to a problem is carried out in my mind, where I gather all the information I can (personal experience, research, thoughts and works of others) and process it in a turbulent and unpredictable manner. Picking and ripping apart everything like a tornado. I feel like this part of this process is quite violent and chaotic, and I constantly find myself fighting my own thoughts in order to focus. Like a tornado, the environment I am in is critical in shaping the brainstorming process; it has the power to either smother...
My thoughts or contribute to the momentum of my ideas. I think, at some level, this storm of thoughts has an inner serenity and an organized and logical structure. I will always strive to discover the rules and logic behind this structure, keeping in mind that I may never get to the bottom of it.

When the ideas become narrowed and focused enough, I funnel them into a tangible form—such as a sketch. Still struggling with many uncertainties, I explore many alternatives and variations, following a path that wanders, but slowly becomes more definite. New thoughts and influences being sucked into the mix insure that I will change directions many times. Ideas lead to new ideas, merge with other ones, and sometimes dead end.

Near the end of the process, the general direction of design becomes more clear, conflicting ideas are abandoned, and the final design becomes evident. Now all that remains is to clean up the remnants of chaotic thinking, produce a polished final product, and reveal it to the world. This final product is like air; it initially
APPEARS PURE AND PERFECT, AND THE FINAL PRODUCT MUST BE EVALUATED AND IMPROVED UPON IN A FUTURE PROJECT. AND THE IDEAS START WHIRLING AGAIN.

CHURNING.
THEY WILL NEVER STOP TURNING.
MANIFESTO

SHE CAN READ THE BIBLE AS AN INTELLECT OR SHE CAN KNOW IT IN HER HEART. IT IS IN MY HEART, THEREFORE FELT IN MY PROCESS.

SHE CAN LISTEN TO OTHERS FEEDBACK, OR SHE CAN HEAR IT. I HEAR IT, & THEREFORE IT IS HEARD IN MY PROCESS.

SHE CAN GENERATE IDEAS ALL ON THE SAME LEVEL, OR SHE CAN ALLOW PREVIOUS IDEAS TO BRING NEW IDEAS TO THE NEXT LEVEL. I STRIVE FOR GREATER LEVELS, & THEREFORE SHOW DEPTH IN MY PROCESS.

SHE CAN LET THE LIMITATIONS CAUSE HER IDEAS TO BECOME CONCAVE, OR SHE CAN EXPAND HER IDEA AROUND THE LIMITATIONS. I EXPAND MY IDEAS, & THEREFORE ADD CONVEX IDEAS TO MY PROCESS.

SHE CAN REACH AN OBSTACLE, OR REACH A TEST OF FAITH. I RELY ON FAITH, & THEREFORE TURN MY OBSTACLES INTO AN ESSENTIAL COMPONENT OF MY PROCESS.
She can simply experiment with available resources, or she can grow in her understanding of new found talent & craft. I reach new conclusions as I grow, & therefore allow my experimenting to exponentially influence my process.

She can work through an assignment for a grad in design, or she can complete it with a passion in design. My main motivation is passion, & therefore it is evident in my process.

As a designer, I attribute my satisfaction & success, not to the finished product, but how I challenged myself to grow in the process of "getting there."
Appendix S. Design Thought Model Example – Student D

The mind is well-known for being a realm or device or ______ of infinite possibility, as long as it is tapped into.

I believe that earning the title “designer” is accomplished by learning to effectively use all the brainpower possible to solve a problem.

So in order to become a designer, you have to learn to tap into your own mind—something that comes naturally to most of us in the college of design.

I love exploring possibilities, which is what I wanted to accomplish with my design thought model.

I created a constantly shifting book of abstractions that take only a few of the infinite combinations of forms possible.
Basic elements lead to an exploration of quality, and why stop there? The fusing of three or more complex elements.

Going through the book is a sort of stream-of-consciousness trip through the design process—emphasizing quantity of ideas.

Basically, this path is too complex to ever be mapped—just explored.
Design Inspiration // Chemical flurry in the mind

Thought
Appendix T.  D292 A – Weekly Reflection Journal

Weekly Reflection Journal
D292A – Design Thinking Explorations
2007 Spring Semester

Class 1 - January 18, 2007

The first class was a combination of introducing students to the class content and objectives. The first part of class involved bookkeeping. I thought that starting off the class with an introductory activity was an excellent way of breaking the ice. More importantly it served as an example that I was able to reference throughout the class. The transcript of my thought process was very valuable and I think students were able to see and better understand what was discussed in the lecture by having this example. The introduction of the goal and purpose of the course seemed to be grasped by the students although I do not think that they will truly understand the benefits of a metacognitive approach until they are able to built and utilize this approach for themselves in their own work. The daily plan of work that I have proposed for each class seems to be a good approach. It will be important to monitor the use of lecture and Power Point to ensure that the core of the class remains interactive and involves activities and exercises allowing students to experience using the creative strategies for themselves. However, I think that finishing each class focusing on metacognition is extremely important. It is crucial that the students are reminded that the strategies that we are learning in class should be used with a metacognitive approach to design in order to build knowledge and ensure that they are best utilized. It is the combination of both creative strategies and metacognitive thinking that will allow students to reach their creative potential.

As the class progresses I must concentrate on making sure that students are comfortable interacting with one another as well as myself. Open discussion should be encouraged and the sharing of experience and knowledge must be valued. I am hopeful that open dialogue and feedback will be fostered in group exercises and weekly reflections by students. In the future I think some examples of designers utilizing a selected creative strategy would be
beneficial. Along with a discussion of how the designer utilized metacognition in their process of design.

Overall I think that the first class was a great start to the semester. We have started down the path of cognitive awareness and understanding and as the semester progresses we will continue to build knowledge through experience and reflection in and outside of class. This approach to design is a lifestyle, an outlook, a type of thinking in general. It is not something that can or should be turned on and off for class.

Other notes:
Request for posting of lectures on website for student access

Class 2 – January 25, 2007

The second class focused on building upon the foundation of ideas that were introduced during the first class period. Prior to new content there was a brief review of the core ideas that were introduced in the previous week. The new content began with a focus on conceptual blocks that student might face during creative thinking in design. These conceptual blocks are a part of every designer’s process and what this course seeks to overcome and avoid through a metacognitive approach utilizing creative strategies. Some of these conceptual blocks were introduced and examples were provided to make them more realistic in the design setting.

After these blocks were brought to the forefront of discussion the focus shifted to the approach for the remainder of the semester. These blocks will be attacked through the use of creative strategies. Starting in this class one new creative strategy will be introduced every class and practiced through a series of activities and exercises. These strategies fall into some very broad categories that were introduced before beginning with the first creative strategy.
The creative strategy for this class was brainstorming and it built upon a fundamental activity of students, list making. Students embraced this portion of the class and were enthusiastic about learning creative strategies for use in design. The open learning environment and group session that was planned helped foster this energy and all of the students were very active participants in the brainstorming activity planned for the class. The students seemed to thrive in this environment and in the short amount of time some very strong ideas were generated. In addition, the idea of strategy logs was proposed and I promised to bring in examples for students to reference and build upon in their own journals. The Strategy Evaluation Matrix (SEM) and Regulatory Checklist (RC) will be introduced separately in the next to class periods to help students in beginning to create their own log throughout the semester in both this class and in their studio work. I plan to check up on student progress throughout the semester and reflect on their experiences together at the beginning of class. This will hopefully promote the sharing of knowledge and continue to foster an open environment for the sharing of knowledge and experience.

Following the exercises associated with brainstorming I concluded the class as planned with a reinforcement of principles associated with metacognitive thinking. This will take place at the conclusion of every class in order to reinforce the idea that we are learning creative strategies, but they should be practiced using this metacognitive approach that relies on self-regulation and the processes of planning, monitoring and evaluating one’s own strategy use.

Notes:
- A priority should be kept on activities reinforcing the creative strategies presented in class.
- I need to post the lecture slides online for student review and retrieval.
- It will be critical to continue to build on what was introduced in previous classes. An effort should be made to encourage the combination and modification of strategies.
- Students should be prompted to reflect on their thinking to help ensure that a metacognitive approach is being utilized. Are they planning? Monitoring? Evaluating?
- Reinforce the concepts of fluency and flexibility of ideas.
Class 3 – February 1, 2007

In the third class the concentration has started to shift from introduction and explanation of the class and core concepts to the creative strategies. This week the second creative strategy was introduced, and the focus of the entire class time was centered on exercises and examples that encourage student involvement and offer perspective. I found the format of this class to be much smoother for the students, not having to take in so much information, and being able to concentrate on one specific strategy.

Lateral thinking in this case was presented as a single strategy while its underlying concepts were the focus of the class. Students seemed to follow the content and examples very well and participated in the exercises. I think that I need to spend more time letting students talk and express their thoughts. At times I get in a pattern of presenting information and participating in the exercises with students, without allowing students to offer their perspective. Although many of the students might initially be reluctant to speak aloud, with some prompting I think an open environment for discussion could be created and flourish.

I have introduced a strategy log to students and encouraged them to start keeping their own strategy log during their studio work. I am not sure how many students have taken this opportunity. In the future I am going to begin each class with an open discussion of their strategy logs, what strategies they have tried outside of class along with some feedback on what they learned in using these strategies. As the semester progresses and we learn more strategies I hope that the students will seek and find many opportunities to utilize these strategies in their design work, and have many experiences to discuss in class.

The end of class has been reserved for a brief review of one aspect of metacognitive thinking. I think that this is critical to the success of the class. It is important that students understand that these strategies will provide a solid base for their design thinking, but only to the degree that they practice metacognitive thinking when utilizing the strategies. Simply having the knowledge of how to use the strategies is only one type of knowledge. Conditional and individual knowledge are dependent upon students regulation of cognition. The act of taking
control – planning, monitoring, and evaluating their own thinking is the ultimate goal. I will continue to reinforce this point throughout the semester.

Overall the class is going very well. I hope that attendance continues to stay strong and students being to see the class as an enjoyable time.

Class 4 – February 8, 2007

The classes are starting to flow much smoother now that we have settled into a routine. I need to incorporate more feedback at the beginning of the class having students comment on their experiences using the strategies in studio. I think that the students are starting to enjoy the presentation of each new strategy and how each one may apply to their own design thinking. Some of the strategies are similar in their approach and in many cases can be used in unison. I have made a point to mention this fact although I think a review of past strategies would be helpful to reinforce the main objectives.

I am continuing to review very briefly the concepts of metacognitive thinking at the end of each class. Although I am not devoting a large portion of the class to this I feel as though the ideas are being reinforced adequately. Students seem to understand the entire concept of metacognition – both knowledge and regulation components. More importantly I feel as though they understand the significance of this approach in creative thinking and the cycle of building knowledge through self-regulated thinking.

I would like to incorporate some case study examples of each creative strategies in design. I will make an attempt to start incorporating this into the lectures. The exposure to these examples will help reinforce their importance and give students some tangible examples in the design profession. The examples and exercises begin to allow students to see how these strategies may be utilized, but I want to give them specific cases in which designers have and continue to use these strategies in design thinking.
I think it would be a great idea to ask for some feedback from students as to how they think the class is going. I want to know what they find most beneficial as well as areas in which they are confused or may need additional guidance. The format and sequence of the class is not set in stone and I think this feedback could help guide me in making the experience better with each class period. In addition, I would like to know if the manner in which the information is being presented is effective. I would anticipate that the students might have some great ideas for how to improve the class.

Class 5 – February 15, 2007

The structure for class has been established and we are in a regular routine. The students are beginning to anticipate what strategy will be introduced each week and many have stayed after class to ask additional questions. Several students have requested that the information in class be made available to copy. I have suggested that I will post the information online for their reproduction and records.

This class was the first time I have given students an example of a designer and their use of a particular creative strategy. The students were very interested in the example and responded well with questions and comments. Giving them a concrete example of a designer along with a design project that utilized a particular strategy is something that should be continued throughout the semester.

I need to incorporate more group activities along with any individual exercises during class. Students seem to become more active and articulate after participating in activities as a group. For next class I am going to ask that they report their use of some of the strategies that we have learned up to this point in the semester. I want them to report to one another in groups, allowing them to reflect on their own practice and learn from others' experiences. Many of the students are in the same studios and have indicated that this type of discussion does not occur in studio.
I am considering asking students to bring in examples of design work that is the result of creative strategies use. I may have them present their examples in class and build toward discourse as a class. I am curious as to how many students are thinking about these strategies outside of class. Are they taking what they are learning and applying it to studio work? If so, what are they learning? This is a discussion that needs to be open and a part of future classes. As a class we could talk about the different projects that students are working on in their design studios and suggest how these strategies may be utilized in their design thinking.

Another issue that needs to be discussed is the adopting of a strategy log. I am not optimistic about the number of students who are currently keeping a record of their process and creative thinking. I may announce to students that each week a randomly selected person will be responsible for sharing a page out of their strategy log at the end of each class. I do not want to force students to keep a log if they do not want to, but I would at least like for them to try it for a short period of time in order to understand its benefits.

Class 6 – February 22, 2007

I started the class with a short lesson on metaphorical thinking. This built upon what was discussed last week with analogy. I wanted to cover these before starting the lesson on Synectics and in the future I think that analogy and metaphor should be covered in the same class period. They are very similar and both are the major tools used in Synectic thinking.

The majority of the class was spent explaining Synectics and how it applies to creative thinking. The class split up in several small groups of 3-4 people and we walked through the stages of Synectics with each group exploring a different word. Although the content was not design specific I think that the students were able to understand the value in this process. Following the exercise we discussed some of the student’s current studio projects and how Synectics might apply to their design process / thinking. This was something that I need to really concentrate more on as the semester progresses. At times some of the exercises in class are very general and do not directly apply newly introduced strategies in a specific
design context. Certainly in learning about a new strategy it is wise to start with a basic exercise to help students understand the nature of the process, however, this needs to be followed with design specific examples and exercises. I will make a concerted effort to incorporate more of these exercises and examples for the remainder of the semester. This can be lead by the work that students are currently undertaking in their own studio projects. I would like for their problems and projects to foster in-class exercises and discussion.

I need to make certain that I incorporate student feedback on their personal use of the strategies that we have learned so far. Occasionally the class flows naturally in the pattern that has been established and I forget to incorporate these discussions into the class. I think that the most appropriate time for this would be at the beginning of the class period. It would serve as a way to review past strategies and generate class participation/discussion.

In addition, I think that a period of time at the end of class should be reserved for talking about students initial thoughts concerning the strategy that was introduced that class period. This would serve as a review and give students an opportunity to talk about experiences with certain strategies as well as how they might apply to their design work. This discussion could include points about how new strategies might be used in conjunction with other strategies introduced throughout the semester. Currently this time is reserved for a short discussion of one aspect of metacognition. Although this is certainly important, students seem to have grasped the meaning and implications of metacognition and how it relates to creative thinking. We are approaching the midway point in the semester and the time when students are asked to self-evaluate themselves in terms of being a metacognitive thinker. So, the focus at the end of each class will shift toward this reflection. Still, there is plenty of time to hold a review of strategies prior to this at the final part of each class.

Class 7 – March 1, 2007

This week’s class was a departure from the class schedule that has been followed up to this point in the semester. While there was a new creative strategy introduced, the majority of the class was devoted to an in-class activity. This activity was based on the Synectics process
from the previous class along with the principle of discontinuity that was introduced in this class period. In addition, the lesson on metacognition typically reserved for the end of each class period was omitted to allow more time for the activity. Although this change in the class schedule is not permanent, I feel as though the change was good for the students and helped reinforce some of the principles that we have discussed in recent weeks.

The activity allowed students to work with one other partner in the process of synectics. However, this activity included the added element of design and creation. In essence students were learning in the act of making. Students were asked to use the Synectic process as a tool for understanding and a catalyst for creation. Each group was given a word and then asked to create a space that best expressed the word that they were given using various shaped wooden blocks. Following the building of these spaces each student voted on what word they thought other groups had created.

I think that the students enjoyed working hands on in the process and giving them the opportunity to create an artifact was very beneficial. Students were able to see how to apply this process directly to a design situation and how this strategy might help them in future projects. The groups seemed to interact well and having another person to communicate with in the process is preferred.

The students have a week off for spring break and the break will give me a chance to review some of my reflections up to this point in the semester. I will try and incorporate these ideas into the second half of the semester and create an experience that is most beneficial for the students. I want to start off with a self-assessment and let that guide us through the second half of the semester. It is my goal that each student will have an understanding of where they currently stand as metacognitive thinkers; where their strengths exist, and what they need to improve on to become proficient and reach their creative potential. This process of reflection will take place with the aid of a self-assessment rubric. Students will use this to assess themselves and work in the second half of the semester to improve in areas where they are weakest.
The attendance has been good throughout the first part of the semester with the exception of one or two individuals who have missed 2 classes. However, most of these students have made an effort to meet with me individually to review the material that they missed. Although this has been very time consuming for me at times, especially when more than one student is absent from class. I want to ensure that every student receives all of the material presented throughout the semester and receive the same experience.

**Class 8 – March 15, 2007**

This week marked the halfway point in the curriculum. Students were given a self-assessment form at the end of class. They were asked to take time out of class and reflect on their own level of metacognitive thinking. Using a rubric students were able to assess their metacognitive thinking in several (6) different facets and rate themselves along a continuum. This will serve as a tool to help students understand at what level they are currently utilizing metacognitive thinking, and more importantly what is needed in order to improve incrementally and reach proficiency in all facets.

As we continue in the second half of this semester I will be focusing on each on the these metacognitive facets and discussing how to best advance to a higher level. We will discuss the challenges and mental blocks associated with each of these facets using individual reflection and discourse to lead in-class discussion.

The class structure remained primarily the same, with a creative strategy being introduced and being accompanied with an activity. This week the strategy was storyboarding and many students were familiar with this activity, but not as a creative thinking strategy. The student’s familiarity helped make the group activity very successful and I think they were able to relate well with the use of the strategy in a new way. Again, I question how design specific the in-class exercises should be. I think that when introducing strategies that are new to the students using a very general problem that is not design specific aids in their understanding of the process and intent. However, in the case of other strategies that are
more familiar to students, the activity might allow for a more advanced problem and solution. Ideally I would like to have multiple classes for each of the strategies to allow for follow-up lessons where advancement in complexity could be practiced and monitored. This would also lend itself to reflection and discussion of each strategy in the context of design using specific design problems from students studio work. This is exactly how these lessons should be carried into studio education and incorporated into the entire design education. As the semester progresses students are becoming more comfortable with the presentation of the information and with their classmates. This fact supports my assertion that this class should be a part of every design student’s education, not a single class but an element of their entire education and design life.

The activities in class have been a mix of small group and large group size. I think the activity itself lends itself to a certain size group. Still, the use of these strategies by students outside of class will be practiced primarily individually. The nature of design work remains largely an individual endeavor. I am encouraging students to seek out their peers and allow for a discourse and sharing of ideas. Encouraging the interplay of ideas and viewpoints particularly in the ideation phase of a project help lead the creative potential of everyone involved. This is not to say that students should rely on others for ideas, it is encouraging an openness of thought in order to foster innovative ideas and solutions.

Class 9 – March 22, 2007

The creative strategy presented in class followed some of the same principles of past lectures. The Lotus Blossom strategy provides another way for students to examine a problem or theme by pulling it apart and examining all of its associations. It is a process of extraction and then association. Going along with the divergent / convergent thinking that is a part of design thinking these strategies allow students to examine their problem state by diverging into as many possible areas relating to the problem. This allows students to view the problem in a more comprehensive manner and allows critical associations to be made. The subsequent process of association can be described as a convergent process where more in-
depth thoughts and ideas are formed by the association. Making these associations is critical to creative thinking, and teaching students to make these associations involves introducing them to various creative strategies that encourage and aid in this process. It is largely about a way of seeing. These strategies allow students to organize, present, and view their ideas in a manner that associations can be made. All of these strategies allow students to see their thinking/ideas in a slightly different way. The key for students is trying these strategies in their own design work and finding out which ones allow them to make the most associations and lead to creative ideas/solutions.

At the end of class the focus shifted toward the self-evaluation rubric that was introduced in the previous class. I have decided to dedicate class time to discuss one facet of metacognitive thinking that was presented in the rubric. For the next six lectures each of the six facets will be discussed in detail with a focus on relating each of these to design. We will explore what it means to be proficient in each facet in terms of design. In addition, we will discuss the differences along the performance continuum that way established within each facet. This includes how to advance to a higher level, and common blocks that prohibit this advancement.

This class focused on the first facet and students seemed to appreciate the discussion. I want to get them to offer more feedback and participate more in future classes. For next week I asked them to review the second facet and think about how they are currently performing. I hope to let students guide the discussion and share experiences and personal approaches to design.

To this point in the semester attendance and participation has been excellent. Only one student has missed multiple classes. Very few students have missed class outside of illness and other excused absences. I have made an effort to meet individually with students who miss class in order to review the material. It is critical for students to not only attend class but to participate in the activities. Once students leave the classroom it is up to them to utilize the strategies in their studio work and other design endeavors. This brings into light the importance of making creative thinking a part of every aspect of a design students
education. Introducing metacognitive thinking is a key in this process and ultimately should be paramount in all aspect of a designer’s life.

Class 10 – March 29, 2007

The creative strategy for this week was assumption smashing. The basic principle behind this approach is to identify all of the assumptions that you bring to a particular situation/problem and then one by one eliminate each assumption. This allows a person to see a problem in a new way and often allows for more creative ideas to occur. Ideas that normally would have been blocked/undiscovered due to constraints formed by assumptions of the individual. Students seemed to relate to this approach very well, and were able to see how assumptions are inherent in a problem state. Some of these assumptions are based on the situation, but others are unique to an individual. I tried to stress the importance of understanding that assumptions that you as an individual might bring to a problem, and learn how to recognize then eliminate their influence on your thinking.

The second part of the class was dedicated to focusing on the second facet of metacognition (interpretation). I purposely selected interpretation for this week due to the upcoming critiques of students Design Thought Models. I explained to students that interpretation is the exact skill that is being called upon for this assignment. The Design Thought Model asks students to interpret their own thinking process. This interpretation is realized only through reflection and thinking about one’s own process with intense focus. I would expect that the students in this class might have a slight advantage in some way due to the fact that I have been drilling the concepts associated with metacognition throughout the semester. Ideally they all would be aware and understanding of these processes and might find it easier to being the process of representing their own thinking process. I am not sure that this will be the case, however, I am curious to see if the students in this class struggle with the process or find it easier than other students not in the class.
I am not sure how to generate maximum class participation. I have tried to engage students through in class activities, and this seems to work during the activity, but many students are reluctant to offer feedback outside of structured activities. Many students seem very tired in class, and when asked about their energy level they all agree that studio work has them running on very little sleep. Most of the students seem to be juggling a large amount of coursework that includes non-design courses for their general education requirements. Witnessing this behavior in class I have begun to question how this course might be best introduced to students. Would it be best as a part of their studio courses, or perhaps it should be a required course that all design students take every year. I am uncertain at this point, but I would say that the concepts that students are learning in this class should be utilized in their design work, and the separation between this class and their studio work may be an obstacle. Students seem to view their studio work as primary and all other courses as something that must be done, but with far less time and focus. In addition, it might be best to offer a class for all first year students, and then for each discipline as students’ progress in their education. This way it could be assured that discipline specific problems are addressed regularly in the context of the class.

Class 11 – April 5, 2007

Up to this point in the semester students have been introduced to a number of creative strategies. As these strategies begin to associate and overlap in meaningful ways an interesting dynamic has begun to take place in the classroom. Students are starting to realize and contemplate how each of the strategies may relate to strategies learned in past classes. This has added an unexpected but very meaningful dynamic to the class discussions. These connections have enhanced the class in two important ways. First, students are able to use their experience and knowledge of other strategies to build a greater understanding of a new strategy. Learning meaningful similarities and differences that in turn will aid in their conditional knowledge. Second, having learned previous strategies students are more adept at how best to absorb, judge and experience each new strategy. Each student learns how best
to soak up what is being presented in the form of a thinking strategy. Their experience and knowledge aids in their ability to absorb and process new information effectively.

The shift toward focusing more on examples and activities in design has certainly contributed to new discussions in class. After introducing a strategy each week I have focused on applying this strategy in a design context. This transition might sometimes be accompanied first by a more general example, but ultimately the focus returns to the context of design. Students seem to appreciate the introduction of design in the lesson and interject more based on their current experiences in design studio. This focus has also expanded discussion on how these strategies might be applied in future work. By keeping design in the student’s problem state I believe they are able to think more clearly and draw more effectively from their existing knowledge base.

The series of focus exercises at the end of each class appear to be going well. As mentioned in previous reflections I have been introducing one aspect of metacognitive thinking at the end of each class period. The focus remains on what each of these aspects entails and how students may first rate themselves along a performance continuum for a particular aspect. The focus then shifts to how students may improve upon their current level of thinking and achieve a more proficient level of metacognitive thinking for each aspect. By breaking metacognition down into singular aspects students are able to better comprehend how metacognition applies to their creative process as designers. In addition, students are able to guide themselves in a process of enhancing their own design thinking by setting attainable goals for improved thinking. The self-assessment metacognitive thinking rubric was constructed to guide students along this path to reaching their creative potential as designers.

**Class 12 – April 12, 2007**

As a class the entire semester has been a progression in thought, complexity, and ideas. Each week has involved an introduction of something new, in most cases a new creative strategy. However, with each new strategy there becomes a layering of thought and ideas as they apply
to design thinking. Each of the strategies that have been introduced are based on common approaches to creative thinking. In particular there has been a focus on the use of association in both divergent and convergent thinking. The significance of this approach is that as the semester progresses students are forced to consider each of these strategies individually as well as in conjunction with one another. Each week students are practicing the skill of association and returning to their studio projects with a renewed and enhanced approach to creative thinking. As students build an appreciation and understanding for the skill of association in the form of various strategies their overall ability to utilize their thinking in design blossoms. It has been very rewarding to see students make this progression and work to realize their creative potential on a weekly basis. I wish that there were some way to ensure that information learned in this class will be reinforced in the design studio; however, I am left to rely on the students’ motivation and willingness to explore these strategies on their own.

Another interesting aspect of this semester has been the interaction between what is learned in D100 – Design Thinking and the material introduced in this course. Design Thinking is based on a more general introduction of the design process and various related issues. As students have experienced both classes on a weekly basis throughout the semester I have noted areas of intersection. At these moments I have taken the opportunity to reinforce the content and build upon what was introduced in D100. This interaction has been very beneficial for both students and instructors. The simple fact that students are forced to think more about their thinking in a focused classroom setting and share in discussions is invaluable. I cannot express how strongly I feel about the value of both courses in a design curriculum. There interaction is mutually beneficial and I would encourage this interaction to continue beyond one semester in students first year of study. In addition I would promote this content and focus to be a part of the entire design curriculum, especially the reinforcement of ideas in design studio. Unfortunately at this point students are left on their own to take what is introduced in the classroom into the studio. I am quite certain that for many freshmen this along with their other responsibilities is overwhelming and requires more guidance and support. I think that by assuming that students will utilize and build these
cognitive thinking skills without a support in the core of the curriculum we are letting them
down and not serving their best interest as future design professionals.

Class 13 – April 19, 2007

Only two classes remain and the students have demonstrated a tremendous amount of growth
throughout the semester. I am extremely pleased with their progress and truly believe that
each student has benefited from the experience. This has been my first opportunity teaching
a class on my own and I have learned a great deal about myself as a communicator and
teacher. I consider this semester to be more valuable than any time to this point of my
academic journey. It has been very rewarding to know that I am helping students realize
their potential both in design and life. I hope that this experience will lead to a clearer vision
about the importance of metacognition in education, particularly design. On a personal level
it has brought clarity to my aspirations as an academic and begun to establish a future area of
important research.

I have been amazed at how well the students have accepted my presence in the classroom and
embraced what I have introduced as a valuable part of their lives as designers. They all seem
to have grown along with the concepts and built a rich sense of purpose in continuing to
explore their own design thinking. I only wish that I could continue to push them after they
leave the classroom and offer a support/supplementary aspect across their education,
particularly in their studio. The ideas that have been presented in class are best realized
when allowed to blossom through practice and experience in the design setting. Therefore
the concepts leaned this semester need to be a part of the core of design education and
intergraded into studio practice in both teaching and discussion.

I introduced to students the fact that class and instructor evaluations are critical to the future
of this course and content. Due to the fact that this course is listed as special topics, it is at
this stage very much experimental and preliminary to design education in the College of
Design at North Carolina State University. I have expressed my desire to grow this course
across the design curriculum and measures such as these course evaluations are important
steps to ensure that this remains a strong possibility. In order to build this course into a major component of design education many steps are needed. This semester was a first step toward a very detailed and well-established core content and set of learning objectives.

As this semester comes to a conclusion it is my goal that this course contributes in every way possible to the knowledge base that currently exists in design pedagogy. The students that are participating in the course will help make this possible and have played an important role in this initial phase of development. I owe them a great deal of thanks for their willingness to participate and continually open their mind to new ideas and ways of thinking. As the results of my study are more clearly stated the future of this content will take on the next phase of development and others will be called upon to embrace the initiative.

**Class 14 – April 26, 2007**

It is hard to believe that this was the final class of the semester. Over the course of 14 weeks I have presented what I hope will be a beneficial asset to these students over the next few years of school and beyond. I explained to them that what we learned this semester is just a start, the beginning of a collection of cognitive strategies that they will continue to grow as designers. I urged each student to take time and reflect on what was introduced and practiced this semester. I have tried to establish an awareness and understanding of a way of thinking, designing and living. Design for these students is now a way of life and they are just beginning to come to this realization. At the same time the majority of these students were unaware of the concept of metacognition and had spent very little time considering, reflecting and thinking about their own thought process. Asking them to do so at this early stage of their design education was a challenging but essential step toward the realization of their creative potential.

I found that for most design students creativity is something that is valued but rarely discussed or conceptualized in terms of thinking. For the most part the idea of creative thinking was viewed as an innate ability that most design students possess and will naturally
surface in their work, seemingly without explanation. I have tried this semester to change this perception and make students aware of the role metacognition plays in creative thinking and the design process. Forcing students to think about their own thinking has allowed many to realize and ultimately value process and growth through reflection. Design is no different than any intellectual endeavor in that growth in that cognitive growth is determined by a conscious and lucid account of one’s own thinking. Watching students come to this realization this semester has been very rewarding. This class in conjunction with their design studio and D100- Design Thinking has provided an optimal environment for this growth and understanding to occur. It is my hope that this environment can be maintained and strengthened in the future. This would allow each design student to work most efficiently toward realizing his or her creative potential.

As I reflect on the past semester I can identify numerous future opportunities for design education that have surfaced in light of this course. When I started the semester I was optimistic that the students would respond to the course that I had created any most importantly find value and applicability to their design life. As I write this reflection I can report that this objective has been met and in the process confirmed my beliefs about the importance of the content. Experiencing this with students on a weekly basis has allowed me to gather information about how the course could be improved and grow into an integral part of the design curriculum. The College of Design at North Carolina State University is perhaps ahead of many other design institutions in that they offer a mandatory design thinking course and the importance of design cognition is supported at the highest level of administration. However, even with this in place and the addition of special topics courses such as the one I offered this semester additional steps need to occur to ensure that design cognition becomes a focus across all design courses, particularly in the studio. In addition, teaching and discussing design thinking should occur across a student’s education not only as an introductory course. I hope that the finding of this study can help pave the way to future consideration and realization of these important advancements in design education.