The Impact of Metacognitive Instruction on Creative Problem Solving

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Abstract

This study examined the impact of extended metacognitive instruction and reflection on creative thinking abilities. Instruction included a supplemental course focused on encouraging knowledge, understanding, and application of metacognitive concepts upon creative thinking in college students majoring in Design. Thirty first-year students majoring in design were selected by a stratified random approach from a larger section ($N = 122$) and asked to participate in an supplemental metacognitive training course that met for one hour per week over 16 weeks. A new topic related to creative thinking was introduced each week within a metacognitive framework. Results revealed the treatment group to have significantly higher scores on two different measures of creativity compared to their matched peers. In addition, students in the treatment condition performed significantly better on a summative design thought model project that included a metacognitive thinking scale and was judged by external Design experts. Scores on a measure of metacognitive awareness revealed stability over time for the comparison group but not the treatment group indicating an intervention effect. Implications for higher education pedagogy and metacognitive interventions are discussed.

Keywords Creative Thinking • Metacognition

The Impact of Metacognitive Instruction on Creative Problem Solving

The development of creative thinking skills in higher education is often overlooked and undervalued (EAU, 2007; NACCCE, 1999). Yet, in some disciplines it is an essential skill that largely determines one's success in the field. The term creativity elicits the concept of genius and likely conjures up images of eminent artists or scientists such as Michelangelo or Einstein. Historically there has been an assumption that the inclination and ability of a person to respond in novel and useful ways was largely inherited. However, present research refutes this view, and it is now believed that creativity can be learned (Adams, 2001; Davis, 1997; De Bono 1973, 1992; Kvashny, 1982; Nickerson, 1999; Parnes, 1967, 1981; Sternberg & Lubart, 1996; Sternberg & Williams, 1996; Torrance, 1962, 1974) and that it is widely distributed (Beghetto & Kaufman, 2007). Unfortunately, these findings have not transferred to university courses as they are rarely taught in such a way to encourage advanced knowledge acquisition (Spiro, Coulson, Feltovich, & Anderson, 1988). This oft forgotten stage of learning emphasizes a deeper understanding of the material where students are required to engage in problem-solving activities where they must flexibly reason with and apply what they have learned across contexts.

Metacognition, the knowledge and regulation of one's own cognitive processes (Brown, 1987), is a logical conduit for developing creative problem solving approaches in the classroom. Intentional pedagogical approaches that have emphasized practice, automaticity, and conditional understanding of metacognitive strategies have shown powerful results in areas of reading comprehension (Pressley, Gaskins, Solic, & Collins, 2006), monitoring accuracy (Hacker, Bol, Horgan, & Rakow, 2000; Nietfeld, Cao, Osborne, 2005), writing (Harris, Graham, Brindle, & Sandmel, 2009), math (Desoete, Roeyers, & De Clercq, 2003), problem solving (Delclos &

Harrington, 1991), and self-regulatory processes in computer-based learning environments (Azevedo, 2005) just to name a few. However, Hennessey and Amabile (2010) point out in their review of the literature that such investigations aimed at training individuals to be more creative is sparse. It is hardly surprising that in the years since the cognitive revolution began in the late 1950s and early 1960s that cognitive psychologists have concentrated on more tractable cognitive constructs, such as perception, memory, reasoning, and decision making (Sternberg & Lubart, 1996). Moreover, finding "unambiguous cases" of creativity is challenging and these highly creative people are rare and difficult to study in the psychological laboratory. Guilford (1950) recognized the limitations of such approaches and instead proposed that a psychometric approach could be taken to study creativity in everyday people.

The purpose of the present study was to facilitate creative thinking and problem solving through a pedagogical approach that emphasized the development of metacognitive knowledge and skills. Design is one such discipline wherein success relies heavily on creative thinking processes and provides a good test bed for this approach. We posit that metacognitive reflection allows designers to work off of progressively more formal theories (Schraw & Moshman, 1995) that allow for intentional attempts to apply their creative thinking skills to an infinite number of design applications. To date, however, there is little indication that creative strategies are being taught in a deliberate manner in design courses (Cross, 2006). Rather, methods that increase creativity are currently applied on a more informal basis within design education (Kowaltowski, Bianchi, de Paiva, 2010). Therefore this study sought to examine an approach whereby undergraduate students are encouraged over time to develop a greater understanding of their own cognitive processes, how to regulate their problem solving processes, and to increase their ability to generate creative problem solving solutions in design-based problems.

Research on Creativity

Creativity can be described as 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). Creativity has been marginalized to some extent within formal educational contexts but many have long argued that the development of creative talent is not an educational frill but a central issue in the preservation of our culture (Gowan, 1972). It must be emphasized that creativity actually represents a family of skills and processes. Some researchers have concluded that a search for the essence of creativity is overwhelming unless it is studied with a domain specific approach. There is currently a lack of agreement in the extent to which creativity is influenced by domain-specific versus domain-general processes (Baer, 2011) however more likely it is both (Casakin & Kreitler, 2011). Given the complexity of creative processes within individuals it is important to identify the most relevant aspect of creativity for the particular domain under investigation (Taylor, 1987) especially considering that no single test of creativity will accurately represent the entire construct (Hocevar & Bachelor, 1989). By identifying a particular facet of creativity you can increase the reliability and validity in a given study. The focus in the current study was on the generation of ideas within a problem-solving context.

The literature related to creative idea generation and associative thinking dates back to the early part of the 20^{th} century and has continued forward (Koestler 1964, Maltzman 1960, Mednick 1962, Ribot 1900, Spearman 1931, Wallach & Kogan 1965). This research typically emphasizes the unusual cognitive recombination of stored associations. Spearman (1931) described the generation of new ideas through 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” (p. 18) and through 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" (p. 23). Many approaches to creativity including Spearman's are implicitly associationistic in that a creative idea results from the novel combination of two or more ideas that have been freed from their normal correlates. Mednick and his colleagues (1962; Mednick & Mednick, 1964) offered an explicitly associationistic theory of creativity based on introspective accounts. Mednick (1962) 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." (p.221). 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 and can consider the novel arrangement of temporarily contiguous, unusual associations with a given stimulus.

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. Wallach and Kogan (1965) adopted Mednick's basic theoretical view that creativity is an associative process. The idea that divergent thought largely focuses on ideational fluency led to the construction of a battery of verbal and visual tests that emphasized associative thinking. Wallach and Kogan asserted that the assessment 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). On the other hand, the Remote Associates Test (RAT) developed by Mednick (1962) deals with an individual's ability to identify a common connection in divergent topics. The test presents students with a set of words and requires them to identify a common word that unites them in a unique way. The widely used Torrance Test of Creative Thinking (1974) works in a similar fashion as it presents pictures and ask examinees to either draw pictures with titles or to provide questions, reasons, consequences, or different uses for specific images.

Current theories represent the development of creativity as a continuum. This continuum starts with novel and personally meaningful representations during knowledge acquisition that are filtered through background experience and are referred to as mini-c creativity (Beghetto & Kaufman, 2007). Next along the continuum are external representations of creativity from everyday experiences termed little-c creativity. Finally, at the pinnacle of the creativity continuum are eminent examples of creativity that are widely recognized and known as Big-C creativity. One distinction going from mini-c to Big-C is transitioning from personally relevant and unrecognized creative processes to externally recognized creative products and outcomes.

Metacognition and Instruction

Metacognition consists of both metacognitive knowledge and metacognitive strategies (Flavell, 1979). A taxonomy of metacognition includes both *knowledge of cognition* and *regulation of cognition* (Schraw & Moshman, 1995; Baker 1989). Knowledge of cognition consists of explicit knowledge of one's declarative and procedural memory, as well as conditional knowledge, or knowledge about why, when and where to use strategies. Regulation of cognition consists of knowledge about planning, monitoring, and evaluation. Importantly, learners must not only continue to gain a greater understanding of their knowledge and strategies as they learn but also be able to effectively regulate this knowledge as they cognitively manage tasks on-line in real time. The regulation aspect requires the learner to engage in the reciprocal processes of accurate monitoring and control processes that allow for adjustments to be made in response to monitoring feedback (Nelson & Narens, 1994). However, neither of these processes are a given in the absence of feedback or training (Nietfeld & Cao, 2005; West & Stanovich, 1997). Thus, the relationship between "knowing" and "doing" becomes essential for effective problem solving and ensuring that a cognitive goal has been met.

Jausovec (1994) conducted a series of studies designed to investigate the influence of metacognition on problem-solving performance. The results suggested that more proficient college age problem solvers used more sophisticated metacognitive strategies, monitored their performance more accurately than less-proficient problem-solvers, and also performed better on open-ended (creative) problems. Jausovec concluded that explicit metacognitive instruction is necessary in educational settings to improve problem solving performance. Evidence of successful explicit instruction is widely evident in the literature particularly with regard to improvement in monitoring and evaluation skills. King (1991) taught fifth-grade students to ask themselves questions designed to prompt the metacognitive processes of planning, monitoring, and evaluating as they worked in pairs to solve problems. The students in this guided question group performed better on a written test of problem solving and on a novel problem-solving task than did students in an unguided question group and a control group. Similarly, Berardi-Coletta, Buyer, Dominowski, and Rellinger (1995) found that college students given process-oriented (metacognitive) verbalization instructions that focused on monitoring and evaluation performed better on training and transfer problem-solving tasks than did students given problem-oriented verbalization instructions and those given simple think-aloud instructions.

In the classroom there are a number of approaches that teachers can use to facilitate metacognitive knowledge and regulation. One approach is for teachers to model their own metacognition for students as they solve a problem. When modeling, thinking aloud can assist students if teachers discuss their cognitive processes in real time (i.e., how to perform a task) and fix-up strategies can be provided to aid with monitoring and regulation processes (Huff & Nietfeld, 2009). Peer modeling of both strategies and metacognition is another approach that not only can improve metacognition and performance, but can also increase self-efficacy as well (Schraw, 1998). Sternberg and Williams (1996) present a number of suggestions for increasing students' regulation of cognition that include suggesting multiple approaches to solving problems, assessing creative strategies, defending strategy choices, developing plans to complete projects, keeping a daily thinking log of progress and roadblocks, discussing teacher feedback, and conduct peer evaluations. Teachers can promote metacognitive awareness by engaging their students in activities that require reflection to help make the sometimes invisible work of thinking visible and explicit. Hong, Jonassen & McGee (2003) concluded that solving ill-defined problems call on different skills than well-defined problems, including metacognition and argumentation, however less empirical evidence exists for metacognitive interventions related to ill-defined problems.

Ideally, instructional approaches as described above assist students in constructing an explicit mental model of metacognitive thinking processes (Schraw & Moshman, 1995). Mental models are necessary to monitor performance and in the development of self-regulatory skills. There are at least three basic levels of metacognitive mental models ranging from the basic tacit model, to the intermediate informal model, and eventually a sophisticated formal model (Schraw & Moshman, 1995). A *Tacit model* is an implicit understanding of one's cognitive processes without an explicit understanding model to work from. This basic model is acquired or constructed without any explicit awareness that one possesses a model (McCutcheon, 1992). Students at this level may be capable of solving complex problems but are unable to explain how they reached a solution. An *Informal model* is more advanced than the tacit model in that it is partially accessible to conscious introspection, scrutiny, and revision. This introspection allows for the revision of one's model over time. Informal models are fragmentary in that students are aware of some of their beliefs and assumptions but have not yet constructed an explicit theoretical structure that integrates and justifies these beliefs (Schraw & Moshman, 1995). A *Formal model* is an explicit, explanatory, representation of a complex phenomenon such as creative thinking. Students who have developed a formal model are explicitly aware of their purposeful efforts to construct and modify metacognitive theories. Schraw and Moshman (1995) suggested that learners develop metacognitive theories through cultural learning, individual construction, and peer interaction. Cornoldi (1998) echoed this perspective in his definition of 'metacognitive attitude' as the general tendency of a person to develop reflection about the nature of his or her own cognitive ability and to think about the possibility of extending and using this reflection.

The Intersection of Creativity and Metacognition

Perhaps the best analogy of the intersection of metacognition and creativity comes from the "glass box" perspective described by Jones (1980) as he contrasted this with the "black box" perspective when discussing the emergence of creative thought. The black box view can be expressed in cybernetic or physiological terms and suggests that humans are capable of creative output without being able to express how these outputs were obtained. The black box way view of thinking posits that skilled actions are unconscious and it is inappropriate to expect an individual to provide a full rational explanation of their creative activities. 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. The glass box view is concerned with externalized thinking rather than unconscious physiological processes. It implies that the individual can reflect on their thinking and "step outside" of the process to watch oneself solve a problem. This is a process-oriented perspective where reflection and regulation of thought assists individuals in learning from their failures and builds on their successes. This perspective is more in line with current theories of metacognition (Schraw & Moshman, 1995) and self-regulated learning (Pintrich, 2000, Winne & Hadwin, 2008, Zimmerman & Schunk, 2011) that emphasize the importance of activities such as strategy selection and shifting, evaluation, revision, goal-setting and monitoring, and a consideration of personal abilities and interests.

A growing literature is emphasizing the importance of metacognition in developing creativity (Armbruster, 1989; Barak, 2010; Jausovec, 1994; Nickerson, 1999; Sternberg & Williams, 1996; VanTassel-Baska & MacFarlane, 2009) yet the empirical support is scarce. Barak and colleagues (Barak & Goffer, 2002; Barak & Mesika, 2007) have shown the efficacy of teaching idea generation tactics to both adolescent school children and engineers and designers in the workplace and these efforts have shown increased problem-solving skills and have led to innovative business products. Barak (2010) has concluded that too little time is spent on metacognitive reflection, particularly with regard to evaluating one's strategy use and the consideration of contexts in which to employ such strategies.

Pesut (1984) has conceptualized creativity as being driven by metacognitive processes that promote the generation of novel, useful associations. In accordance with Pesut (1984) we believe that the fundamental skills of idea-based creativity are action-oriented metacognitive guides that function to sustain and enhance creative thinking. As a learner's metacognitive ability increases so does their potential for creative thinking. Assuming that learners have creative potential, the next question is how to evoke, access, stimulate, train, or develop that 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 evidence supporting this claim is weak, and the relevant instructional approaches are so diverse that clear, solid guidelines cannot be found (Feldhusen & Eng Goh, 1995). Moreover, good instructional strategies alone do not guarantee successful real-life creative production or little-c creativity. Considering these issues, one approach is to decide on a manageable set of strategies for inclusion into an educational program and to avoid trying to teach "creativity" and opt instead to 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 recommended a focus on brainstorming, attribute listing, morphological synthesis, idea checklist, and synectics. 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. Runco (1990) has stressed the importance of more general self-evaluative metacognitive skills that involve 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. In the current study this approach involves a narrowing process to consider pedagogical strategies that could impact idea-based creativity that function to increase the generation of creative problem solving solutions.

Current Study

The field of design emphasizes innovation and offers an appropriate context in which to measure creativity given that the problems in this domain are open-ended with multiple pathways for solutions. However, the influence of cognitive theories of learning is lacking in design education (Cross, 2006). In addition, design education currently suffers from not having a formalized component of reflection built into the studio-based learning environment (Ellmers & Foley, 2007). Instead, analysis of the product is featured at the expense of the process. However, it is clear that students' design abilities can be enhanced through educational programs with iteration and reflection as essential parts of the process (Eastman, 2001). If creative behavior is to be a central theme in the designer's education, new approaches to pedagogy and curriculum are needed.

Kvashny (1982) found increased benefits from design-based creativity training that consisted of active exercises designed to enhance creativity over those consisting only of reading books on the subject. More recently, Anderson (2002) took on such an approach when assessing the role of metacognition in the classroom as he included the following five components: 1) preparing and planning, 2) selecting and using strategies, 3) monitoring strategy use, 4) orchestrating various strategies, and 5) evaluating strategy use. Anderson's assessment was focused on teaching and learning a second language, however the components apply to creative problem-solving across disciplines. Anderson proposed that teachers 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? The process of responding to these four questions maps well onto prevalent models of problem solving that emphasize reflection (Polya, 1957) .

Similarly, Swartz (2001) presented a carefully sequenced curriculum of selected cognitive and metacognitive operations. Swartz assisted students by 1) teaching them explicit cognitive strategies and how the strategies related to creative thinking, 2) providing significant opportunities for students to practice planning, monitoring, and evaluating their thinking, 3) prompting active engagement and creative thinking within specific content, and 4) by providing practice sessions to creative thinking in new situations.

In the current study we sought to employ the practices described above as part of a semester-long intervention for first year design students. A supplemental one-hour per week course was created in which a representative sample of students from a larger introductory course practiced creative thinking strategies couched within a pedagogical approach that emphasized metacognitive knowledge and skills. The current study sought to address the following primary research question: *What impact does metacognitive instruction have on creativity, metacognitive awareness, and an authentic design-based task?* Within the broader purpose of the study we also sought to investigate the relationship between creativity scores and self-report metacognition and also the stability of metacognitive awareness scores over time. Recent evidence has shown the weakness of relying upon self-report measures (Winne, 2010) yet little work has examined how prevalent self-report measures such as the Metacognitive Awareness Inventory (Schraw & Dennison, 1994) relate to creativity or in the stability of such measures themselves over time.

Method

Participants

Participants were selected for the treatment condition from a required course entitled Design Thinking for freshman design students at a large university in the Southeastern United States. Participation in this study required students to enroll in an additional one-hour per week course for which they received two additional credit hours. A stratified random sampling process using creativity test scores from the previous semester, major, and gender as sorting variables was utilized from which to draw students (N = 30; 50% female) for the Design Thinking Explorations (DTE) course that functioned as the treatment condition. The purpose of this process was to draw out a sample of students that would be representative of the larger group of students taking the DTE course. Out of the participants who were invited to take part in the treatment condition only one refused. Majors of students in the treatment conditions included art and design = 17%, architecture = 30%, graphic design = 33%, industrial design = 10%, and landscape architecture = 10%. Students in the comparison condition (N = 92; 54% female) included majors from art and design = 22%, architecture = 32%, graphic design = 19%, industrial design = 17%, and landscape architecture = 10%. All participating students in both the treatment and comparison conditions were given informed consent forms regarding the nature of this study and then asked to participate.

Materials

Creativity Tests. Two tests of creativity were selected for this study: the Similarities Test (Wallach & Kogan 1965) and the Remote Association Task (Mednick 1962). For the Similarities Test (see appendix for example) the following directions taken from the administration manual were provided:

> In this test 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.

The Similarities Test is a measure of divergent thinking. It was scored for the total number of valid associations that a person was capable of and the relative uniqueness of his/her associations. A fluency score was determined by adding the number of valid responses provided across ten total items on the test. An originality score was also computed by totaling the number responses a participant generated that were given by no more than 5 percent of all respondents. These two scores were computed independently and the originality responses were subsumed within the fluency scores. We did consider the possibility that more common associations would occur earlier in the response period and more unique associations later in a sequence and that individuals who are able to produce a large number of associations might also produce a greater number of unique answers. Given that responses of greater stereotypy are likely to come early in a sequence, even in the case of creative persons, no time limit was imposed on the task in order to provide sufficient time for more unique responses to emerge. The range in response completion time for the Similarities test and the Remote Associate Test combined was approximately thirty minutes to an hour and a half. Previous validation of the creativity instruments included reliability and validity studies. Using the Spearman-Brown split-half reliability coefficient the Similarities Test was found to have a .87 reliability score for the originality score and a .93 reliability score for total correct item score (Wallach & Kogan, 1965). Additionally, the Similarities test has been shown to have high correlations with Wallach and Kogan's other subtest measures of creativity and no correlation with a variety of measures of intelligence.

Unlike the Similarities Test the Remote Associates Test (RAT) is a measure of convergent thinking as it applies to creativity. The objective is to provide a single term that fits as an associational bridge to unite three 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 following directions from the administration manual were read to the participants:

> 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.

The score for this test, then, was number of items correctly answered out of fifty total items. In two separate validation studies the Spearman-Brown reliability for the RAT was .92 and .91 (Mednick, 1962). The RAT also showed a high positive correlation ($r = .70$) with expert ratings of the creativity of a group of practicing architects.

Participants completed each of the creativity tests three times during the course of the study. Each administration was conducted with a unique parallel form of the test. All students were tested at the beginning and end of the semester preceding the DTE course and again at the end of the semester during which the DTE course occurred. Thus, the tests were given at three different times during the freshman year for all students.

Metacognitive Awareness Inventory. The Metacognitive Awareness Inventory (MAI) (Schraw & Dennison, 1994) was used to measure self-report knowledge and regulation of cognition. The inventory included 52-items that were answered in 5 point Likert format ranging from "Never True" to "Always True." Knowledge of cognition includes dimensions related to declarative, procedural, and conditional knowledge. A sample item is "I am a good judge of how well I understand something." Regulation of cognition measures control aspects of metacognition that include planning, information management strategies, comprehension monitoring, debugging strategies, and evaluation. A sample item under this facet would be "I think of several ways to solve a problem and choose the best one." An overall sum score across the two facets was used for analyses in the current study. The MAI has been shown to be internally reliable and have a test-retest reliability of .85 (Dennison, 1997). Furthermore, Hammann (2005) found the MAI to have strong predictive validity for test performance and self-monitoring in academic tasks.

Design Thought Model. Students' creative and metacognitive thinking was assessed through their final design project for the DTE course. This summative, performance-based project termed the Design Thought Model (DTM) required students to construct a three-dimensional personal philosophy of their design process. The project was selected due to its non-discipline specific nature and emphasis on creative thought processes. The project guidelines were provided at the beginning of the semester so as to allow students the duration of the semester to consider their design (see Appendix). The process required students to first provide a written summary of the design process during the semester. Next, they transformed their written explanation into a three-dimensional expression of their philosophy. Finally, at the end of the semester an exhibit was held in which students were required to present and orally communicate how their philosophy was represented through their model to neutral judges. Giving students the opportunity to create a physical artifact afforded students the opportunity to externalize the cognitive processes of design. All students in the Design Thinking course completed the DTM and were given the same directions for the project with no differential level of practice or preparation across groups.

During the DTM exhibit each student was given the opportunity to present their model to three different external reviewers (design professionals from across the United States representative of each of the disciplines in the College of Design) in addition to their course instructor. The evaluation process largely followed the consensual assessment technique recommended by Amabile (1982). The judges were experts within the domain of design, made initial assessments independently, assessed technical as well as creative and metacognitive dimensions of the DTM, and rated products from a relative perspective. The only deviance from the consensual assessment technique was that judges were not able to review the DTMs in a fully randomized order due to the nature of the event and procedural limitations. A student's grade was based on a sum of four categories (craft of the model, rigor of the concept, communication, metacognitive thinking) that was described in detail for the students in a comprehensive scoring rubric and also used by the external reviewers (see Figure 1). These categories represent a measure of students' metacognitive thinking ability including the clarity of ideas, depth of thought and reflection, and an awareness and understanding of one's own cognitive processes. At the culmination of the exhibit all external reviewers and instructors met to discuss any discrepancies in scoring across the four categories. After the discussion, student scores were determined with an average score across the ratings of the three external reviewers and instructor if discrepancies still existed.

Procedure

A summary of the procedural timeline is provided in Figure 2. The creativity tests and MAI were administered twice during the semester before the DTE course and once at the end of the course. A more detailed description of the curriculum and procedures within the DTE follows below.

Description of Design Thinking Explorations (DTE) intervention. The DTE course focused on improving students' creativity within a metacognitive framework. Specific creative skills were introduced, learned and practiced as action oriented metacognitive skills (see Appendix for course schedule). Instruction within the seminar focused upon developing conditional knowledge that would enhance students' creative thinking abilities, particularly the creative skill of association. The framework was situated within a self-regulated metacognitive approach to design thinking. A topical approach was taken each week.

At the initial stages of the course students were provided with information about the meaning and importance of metacognition as well some background on the knowledge and regulation of cognition facets subsumed within metacognition. This grounding was followed by a discussion of the importance of metacognition within design education in order to establish a level of personal relevance for the students at the beginning of the seminar. In addition, students learned about the relationship between cognition and metacognition. A standard format was maintained for each weekly session. Instruction began each session by introducing a single creative strategy. After new strategies were introduced a discussion related to all three knowledge components (conditional, procedural, declarative) followed. While a metacognitive approach to creative thinking remained constant, various creative strategies were introduced, learned individually, and then later practiced as a skill set. The focus of the class time was on exercises and examples that encouraged student involvement and offered perspective.

The assumption of this study was that improving metacognitive thinking would enhance creative thought. A number of instructional strategies were utilized in the DTE course including direct instruction, modeling, and paired problem solving with a common emphasis on the *active* construction of knowledge. For instance, paired problem solving activities 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. Thus, the core of the educational intervention was interactive and involved activities and exercises allowing students to experience using the creative strategies for themselves. This open learning environment increased motivation as students became active and willing participants in activities. The instructor also used a taxonomy of subcomponents from the regulation of cognition dimension of metacognition throughout activities in order to guide students and encourage self regulation. Students practiced these subcomponents (e.g., identifying potential obstacles, knowing when a subgoal has been achieved, evaluating the appropriateness of procedures used) when solving problems and were encouraged to extend their use to projects in their design studios. Finally, students were provided with opportunities to analyze how numerous expert designers engage in various kinds of thinking operations. To accomplish this students viewed, listened to, or read examples or case studies of thinking in action, and with instructor assistance identified the kinds of cognitive and metacognitive strategies and skills employed by the various experts. In addition, students in the DTE were challenged to find and bring to class new examples of metacognitive thinking by experts in various domains (design and otherwise). To summarize, the major tenants of the instruction included:

1. *Assist students' development and learning of explicit cognitive strategies that inform and organize the way that they engage in specific types of creative thinking (Knowledge of Cognition),*
2. *Include significant opportunities for students to plan, monitor and evaluate their thinking during instruction (Regulation of Cognition).*
3. *Conduct instruction in an open learning environment where advanced creative thinking is modeled and where students are given opportunities to reflect on their thinking.*
4. *Prompt creative thinking processes within the context of actual domain-specific content that students are learning (Active Construction of Knowledge).*
5. *Ensure high quality practice of specific strategies and concepts after instruction to encourage the internalization and self-regulated use of creative strategies in new contexts.*

A number of tools such as the Strategy Evaluation Matrix (SEM), the Regulatory Checklist (RC), a personal reflection journal, and a metacognitive mental model matrix served to assist students in monitoring their metacognitive thought processes. Students were asked to complete a SEM over the duration of the semester (Schraw, 1998). The SEM was introduced during the first week of the semester and the students were asked to incorporate each new strategy into their matrix. Students were given time to reflect individually and in small groups about strategy use. The matrix required students to record “how to use,” “when to use,” and “why to use” portions for each strategy. 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, and 3) encouraged students to actively construct knowledge.

The use of a RC (Schraw, 1998) provided an overarching heuristic that facilitated regulation of cognition. It provided prompts for students to implement in a systematic sequence to help them control their performance. Students were encouraged to use their RC in all classroom problem-solving examples. Included within the RC were four prompts under each of three facets: 1) planning (e.g., What is my goal?), 2) monitoring (e.g., Am I reaching my goals?), and 3) evaluation (e.g., What strategies worked?).

Journal keeping was a form of independent reflection used to document an increasing understanding of one's metacognitive knowledge. In the presentation of design projects students may have a polished representation of their final product, but often lack the documentation on the process that aided them in arriving at a solution. Therefore, journals provided the opportunity for students reflect on their problem-solving process through writing and illustrations. 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 with cognitive strategies.

Assessment was an important part of tracking students pursuit of a conceptual level of understanding about their metacognitive process and in their construction of a mental model for a creative approach to design-based problems. Therefore during the first session students self-assessed where they currently stood in terms of the use of cognitive strategies using a matrix that was adapted from Wiggins and McTighe (2005) that we refer to as the metacognitive mental model matrix. This activity was used as a baseline for periodic re-evaluation during the course.

It was important to formulate a plan to help students move from implicit to informal to formal mental models, or at least make them aware that these different stages existed and why one should strive toward a formal model. Making one's mental model explicit and accessible to conscious introspection was a significant challenge for many students. However, this introspection that allowed for scrutiny and revision of one's model over time provided the potential for advancement to a higher, more formal model. The goal was for students to develop an explicit, explanatory, representation of creative thinking over time. During the latter part of the semester a greater emphasis was placed upon reflection of their mental models. Each week a different facet of the matrix was discussed in class and what it would take to move through the different levels. Students were encouraged to have an accurate self-assessment and then identify strategies for advancement to higher levels. Students also met individually with the instructor to discuss strategies for advancement.

Results

Descriptive statistics for the current study variables are presented in Table 1 and bivariate correlations are provided in Table 2. The remainder of this section is organized by the primary research questions.

What impact does metacognitive instruction have on creativity, metacognitive awareness, and an authentic design-based task?

This question was addressed by examining group differences between three measures of creativity that included similarities fluency, similarities originality, and on the RAT. Group differences in metacognitive awareness were assessed using the MAI. Finally, differences on the design-based task were determined using the overall and metacognition-specific ratings on the DTM.

Similarities Fluency. A 2 (groups) X 3 (sessions) repeated measures ANOVA revealed a significant main effect of time across the three testing sessions $F_{(2, 230)} = 33.98$, $p < .001$, partial $\eta^2 = .228$ (see Figure 3). More importantly a significant interaction was also found $F_{(2, 230)} = 52.48$, $p < .001$, partial $\eta^2 = .313$. Simple effects follow up tests revealed that the treatment group ($M = 102.97$) scored significantly higher ($F_{(115)} = 78.65$, $p < .001$, partial $\eta^2 = .406$) on the posttest than the comparison group ($M = 53.39$). No significant differences were found for either of the two pretest scores.

Similarities Originality. A 2 (groups) X 3 (sessions) repeated measures ANOVA revealed a significant main effect of time across the three testing sessions $F_{(2, 230)} = 88.12$, $p < .001$, partial $\eta^2 = .434$ (see Figure 4). In addition, a significant interaction was also found $F_{(2, 230)} = 71.01$, $p < .001$, partial $\eta^2 = .382$. Simple effects follow up tests revealed that the treatment group ($M = 48.40$) scored significantly higher ($F_{(115)} = 127.26$, $p < .001$, partial $\eta^2 = .525$) on the posttest than the comparison group ($M = 15.62$). No significant differences were found for either of the two pretest scores.

Remote Associate Test. A 2 (groups) X 3 (sessions) repeated measures ANOVA revealed a significant main effect of time across the three testing sessions $F_{(2, 224)} = 4.01$, $p = .02$, partial $\eta^2 = .035$ (see Figure 5). A significant interaction was also found here $F_{(2, 224)} = 14.35$, $p < .001$, partial $\eta^2 = .114$. Simple effects follow up tests revealed that the treatment group ($M = 22.77$) scored significantly higher ($F_{(112)} = 14.09$, $p < .001$, partial $\eta^2 = .112$) on the posttest than the comparison group ($M = 17.55$). No significant differences were found for either of the two pretest scores.

Metacognitive Awareness Inventory. A 2 (groups) X 3 (sessions) repeated measures ANOVA revealed a significant main effect of time across the three testing sessions $F_{(2, 228)} =$

13.54, $p > .001$, partial $\eta^2 = .106$. No significant interaction was found. Pairwise Bonferroni comparisons revealed that scores from the posttest ($M = 199.69$) were significantly higher ($p < .001$ for both) than those from pretest 1 ($M = 191.81$) and pretest 2 ($M = 192.52$).

Design Thought Model. Independent measures *t* tests were utilized to examine group differences in overall scores and metacognition specific ratings from the Design Thought Model activity. Results revealed that the treatment group ($M = 36.95$ overall; $M = 8.32$ metacognitive rating) scored significantly higher than the comparison group ($M = 34.32$; $M = 7.86$ metacognitive rating) on both the overall DTM score ($t_{(114)} = 4.73$, $p < .001$, Cohen's $d = 1.11$) and on the metacognitive specific rating ($t_{(114)} = 2.07$, $p = .04$, Cohen's $d = .45$).

What is the relationship between creativity scores and self-report metacognition?

The correlational statistics provided in Table 2 revealed no significant correlations between the MAI and any of the three creativity measures (fluency, originality, RAT) for either the treatment or comparison group. Moreover, this lack of relationships held across all three administrations of the tests including the posttest for the treatment group. Thus, it appears that even in the context of extended metacognitive training that self-report metacognitive awareness and these particular aspects of creativity were not related for this sample.

How stable are metacognitive awareness scores over time?

An examination of correlations of the MAI across administrations reveals an interesting finding. Scores on the MAI for the comparison group showed stability over time as indicated by consistent significant correlations between pretest 1 and pretest 2 ($r = .73$, $p < .01$), pretest 1 and pretest 3 ($r = .66$, $p < .01$), and pretest 2 and the posttest ($r = .81$, $p < .01$). However, for students in the treatment group stability occurred only between the two pretest sessions ($r = .73$, $p < .01$).

The lack of significant relationships between the pretest measures of the MAI and the posttest measure of the MAI suggests that the DTE course had an impact on the posttest responses.

Discussion

This study examined the impact of an educational intervention focusing on enhancing creative thought and problem solving within a metacognitive framework. Findings revealed the intervention to be successful in facilitating creativity as measured by standardized tests and a domain-specific measure of creativity. This supports prior research that claims that creative thinking can be learned and developed over time (Adams, 2001; Davis, 1997; De Bono 1973, 1992; Kvashny, 1982; Nickerson, 1999; Parnes, 1967, 1981; Sternberg & Lubart, 1996; Sternberg & Williams, 1996; Torrance, 1962, 1974) rather than as an innate ability that students either do or do not possess. Furthermore, the current findings extend the growing body of literature supporting the efficacy for metacognitive training to positively impact important academic outcomes (Delclos & Harrington, 1991; Desoete et al., 2003; Hacker et al., 2000; Harris et al., 2009; Nietfeld et al., 2006; Pressley et al., 2006). Implications that arise from this study center on the importance of such pedagogical approaches and secondarily on the measurement and conceptualization of metacognitive skills.

Our findings lend support for the inclusion of formalized training in metacognitive approaches to encourage creative problem solving. The intervention in the current study resulted in large effect size differences on measures of creative fluency and originality and moderate effect size differences on a measure of remote associates test of creativity. In addition, there were large effect size differences between students who participated in the DTE course and their comparison peers on on the DTM. Students who participated in the educational intervention were also found to have significantly higher metacognitive thinking skills represented in their

DTMs. This is an important result due to the fact that the DTM is a physical manifestation of one's thinking process and evidence of movement from mini-c to little-c on the creativity developmental continuum (Beghetto & Kaufman, 2007). We would suggest that the intervention was successful for a number of reasons related to the structure of the curriculum itself. A goal of the educational intervention was to increase students' awareness and appreciation of metacognitive and creative thinking skills. Subseqently, most activities in the DTE 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 more prepared to implement various strategies.

Another interesting finding was the positive correlation between the fluency and originality scores on the Similarities Test. 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. An examination of responses coded as original revealed that they tended to occur later in students' lists of alternatives. 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 this likely frees the mind to consider how these common responses may lead to new responses; that is, they required a new way of looking at the available information occupying the problem state. This process illustrates the associationistic approach to creativity adopted in this study, and representative of other scholars and prior research (Ribot 1900, Spearman 1931, Mednick 1962, Wallach & Kogan 1965, Koestler 1964, Maltzman 1960).

Ideally having multiple classes or extended opportunities for practice devoted to each of the creative strategies presented in this study would allow for advancement in complexity and automaticity on the part of the learner. This would also lend itself to reflection and discussion of each strategy in the context of the specific domain. We would advocate emphasizing the explicit teaching of metacognitive and creative thought with domain-specific problems with an emphasis on subsequent practice of such strategies across contexts. Moreover, we would argue that the effects found in the current study would be magnified if the intervention were to be maintained throughout the duration of undergraduate studies. One approach might be to offer a general class covering metacognitive processes for all first year students followed by an explicit integration of such processes within advanced discipline specific courses as students' progress in their education.

Findings in the current investigation also lend support for using caution when relying solely on self-report measures of metacognition. Both the metacognitive training and the metacognitive ratings from the neutral judges on the DTM revealed relationships with outcomes measures however self-report findings from the MAI did not. This finding aligns with the weaknesses inherent with self-report measures (Winne, 2010) in that subjects are either not able or willing to report accurate judgments. Given this finding future investigations that employ explicit metacognitive training should consider using multiple measures of metacognition rather than relying solely on self-report measures as a form of triangulation in measurement. One positive finding related to self-report measurement within the current study was the lack of stability scores found for students in the treatment condition. Thus, it is possible that students in this condition gained a more accurate understanding of their own thinking and metacognitive abilities. If this was, in fact, the case one might reasonably expect to see some scores increase and some decrease over the course of the semester to correct for initial over- or underconfidence rather than an overall gain across students (as was the case here).

Of particular concern is the fact that the students in the comparison group demonstrated a significant decrease in creativity scores across the testing period. This begs for a broader investigation of higher education courses and their influence on creativity over time. Student in the treatment group were likely 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 comparison group may have reflected a design approach that valued products at the expense of process. The decline in creative thinking abilities of students in the comparison group represents an area that needs further exploration and continued testing.

Future Directions

Future studies might consider collaboration-based designs given that students in the current study appeared to become more active and expressive after participating in such activities. 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.

The DTE course in the current study 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 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. Bruning, Schraw, and Norby (2011) point out the need for instructors to embed strategy instruction within their domains and curricula. An examination of design education reveals the lack of instructors' formal training in education / learning theory. Thus, while many design instructors are accomplished professionals, this competency does not automatically translate into the skills needed to help others reach their creative potential.

Finally, future research could expand on the study to examine other aspects of creativity as it applies to design and also with similar metacognitive interventions in other disciplines. An important question for higher education going forward will be how to restructure courses and programs to ensure that advanced knowledge acquisition is taking place (Spiro, et al., 1988).

Limitations

In this study freshman design students served as the study population. Therefore, the results and conclusions are limited to some degree to this level of education. Future research should assess if findings generalize across educational levels. Moreover, this study relied on the students' motivation and willingness to explore these strategies on their own. Students who are less motivated or possibly less self-regulated may be more challenged in a similar educational environment.

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Figure 1 Design Thought Model Scoring Rubric for External Reviewers

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.

Figure 2 Data collection timeline.

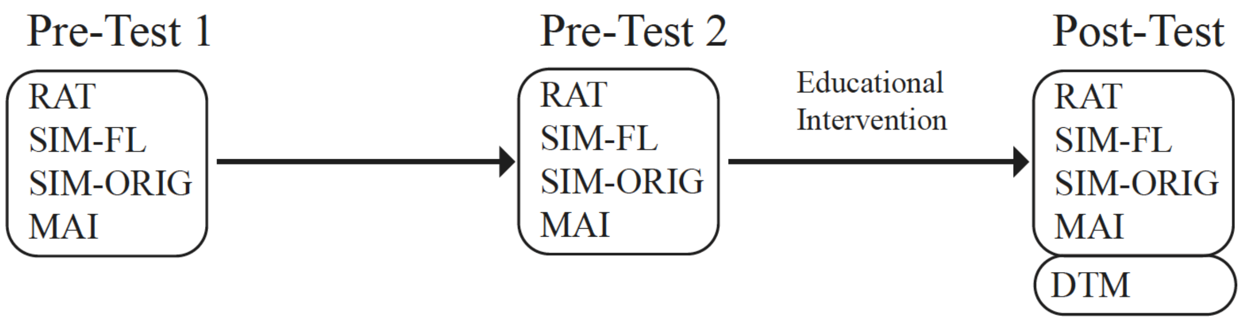


Figure 3 Similarities Test

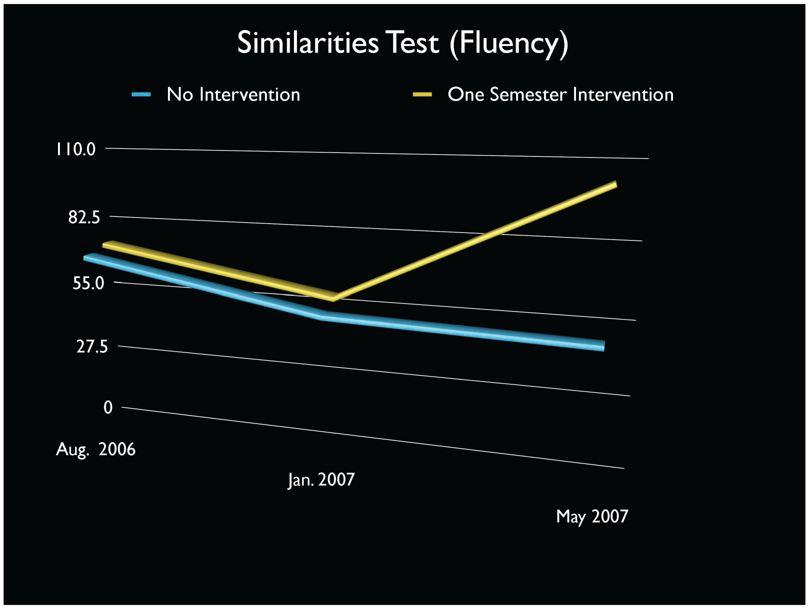


Figure 4 Similarities Test – Originality

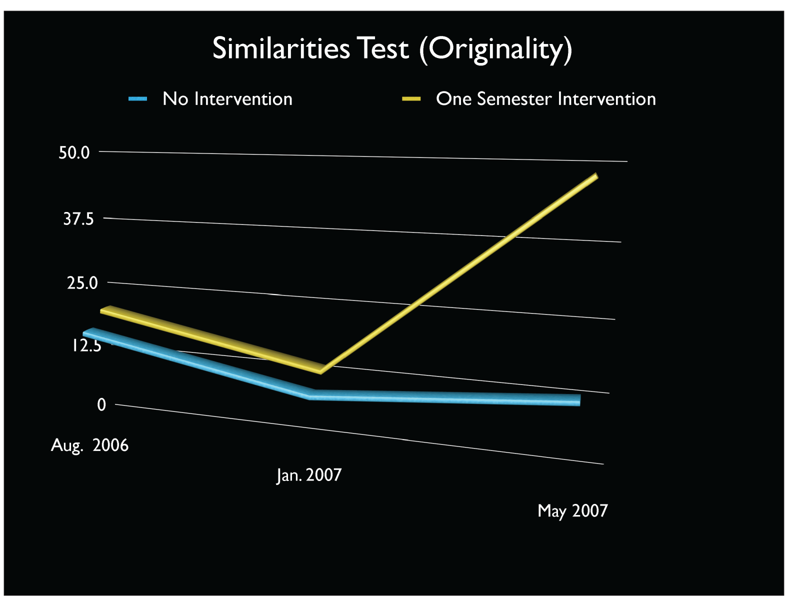


Figure 5 Remote Associates Test

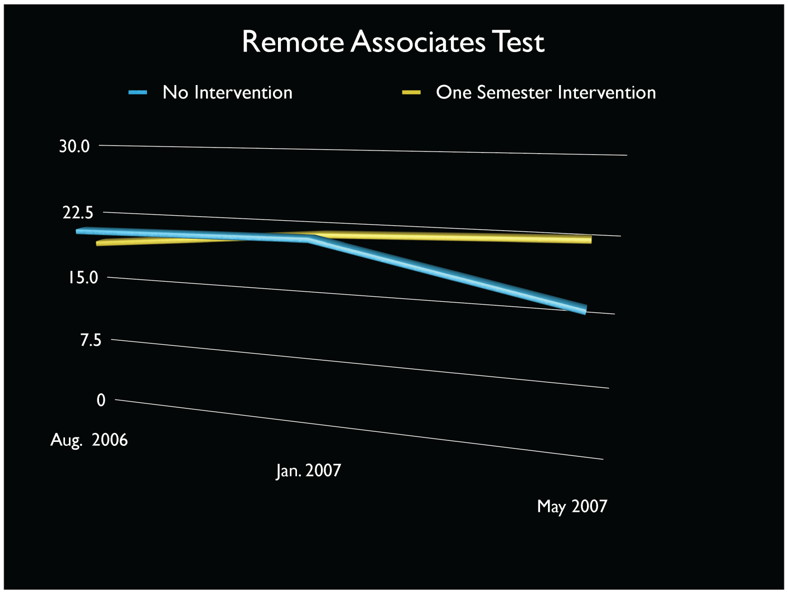


Table 1. Means and standard deviations for study variables

Group	Pre 1 MAI	Pre 1 RAT	Pre 1 Sim-FI	Pre 1 Sim-Orig	Pre 2 MAI	Pre 2 RAT	Pre 2 Sim-FI	Pre 2 Sim-Orig	Post MAI	Post RAT	Post Sim-FI	Post Sim-Orig	DTM
Treatment	191.87 (18.41)	19.87 (7.29)	74.13 (28.15)	21.73 (14.85)	192.73 (16.94)	22.0 (5.62)	59.37 (24.68)	14.17 (7.80)	202.27 (16.08)	22.77 (5.95)	102.97 (40.16)	48.40 (22.29)	4.16 (0.496)
Comparison	193.21 (19.51)	21.68 (7.95)	71.26 (29.23)	18.87 (13.96	193.34 (21.59)	22.30 (5.86)	55.57 (22.52)	11.63 (7.90)	197.81 (22.15)	17.12 (7.13)	52.99 (19.85)	15.42 (9.18)	3.932 (0.524)
Total	193.37 (19.86)	21.23 (7.80)	71.97 (28.88)	19.57 (14.20)	192.88 (19.17)	22.22 (5.78)	56.53 (23.03)	12.27 (7.92)	198.93 (20.83)	18.55 (7.26)	65.48 (34.06)	23.67 (19.74)	3.99 (0.525)

Table 2. Correlations between study variables

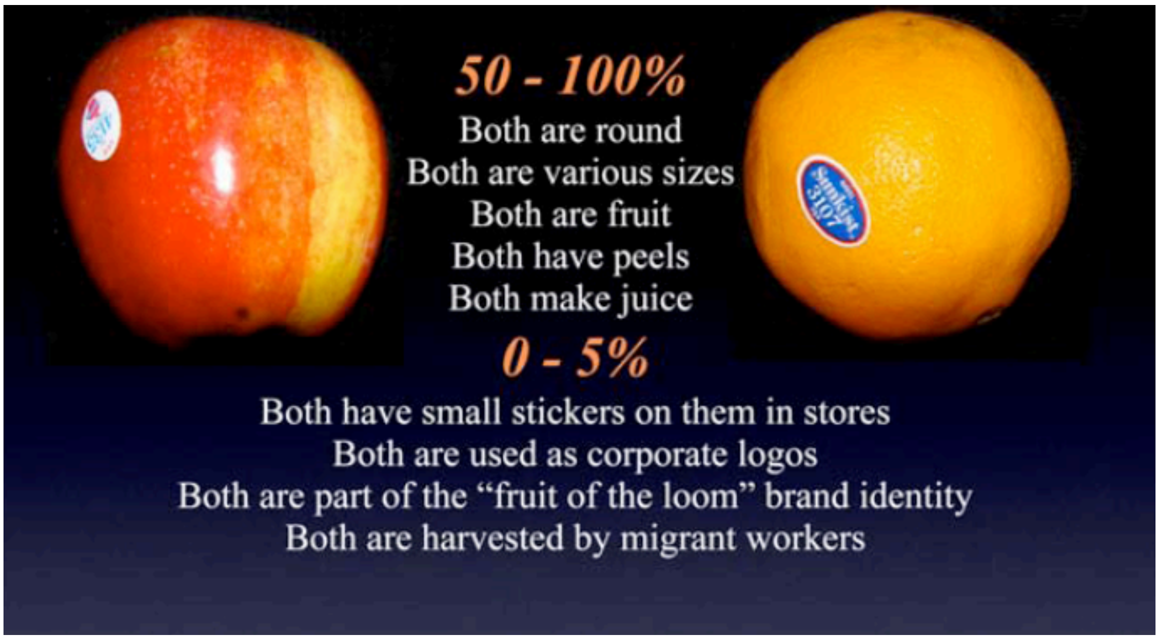
Variable	1	2	3	4	5	6	7	8	9	10	11	12	13
1. Pre 1 MAI	1	-0.09	0.30	0.15	.73**	-0.22	-0.03	0.04	0.29	-0.25	0.00	-0.09	0.22
2. Pre 1 RAT	-0.07	1	-0.16	-0.15	0.08	0.19	0.06	0.10	-0.29	.50**	-0.31	-0.26	0.03
3. Pre 1 Sim-Fl	-0.15	0.14	1	.91**	0.27	-0.10	0.43*	.45*	-0.14	0.08	0.64**	0.43	0.18
4. Pre 1 Sim-Orig	-0.20	0.11	.78**	1	0.16	-0.11	0.36	.38*	-0.19	0.04	0.57**	0.44*	0.23
5. Pre 2 MAI	0.73**	-0.07	0.01	-0.08	1	-0.11	-0.12	-0.08	0.35	-0.01	-0.09	-0.22	0.13
6. Pre 2 RAT	0.11	.48**	-0.01	-0.07	0.10	1	-0.03	0.07	-0.18	.48**	-0.16	-0.08	0.08
7. Pre 2 Sim-Fl	-0.08	0.12	.62**	.52**	-0.01	0.04	1	0.88**	-.55**	0.31	0.57**	0.50**	0.06
8. Pre 2 Sim-Orig	-0.16	0.11	.44**	.56**	-0.13	-0.11	0.81**	1	-.56**	0.32	0.49**	0.46*	0.19
9. Post MAI	.66**	-.24*	-0.05	-0.19	0.81**	0.00	-0.03	-0.14	1	-0.21	-0.17	-0.18	0.15
10. Post RAT	-0.10	.58**	0.19	0.06	-0.04	.61**	0.20	0.06	-0.10	1	0.11	0.20	-0.04
11. Post Sim-Fl	-0.09	0.18	.61**	.41**	0.04	0.08	.56**	.42**	-0.03	.22*	1	.91**	0.28
12. Post Sim-Orig	-0.05	0.16	0.35**	0.33**	0.04	0.02	.33**	0.36**	-0.04	0.06	.81**	1	0.31
13. DTM	0.10	0.06	.31**	.28**	.27*	0.01	0.22*	0.20	0.18	0.08	.38**	.42**	1

Note: Values for treatment group above the diagonal and values below the diagonal for comparison group. *p<.05; **p<.01.

APPENDICES

Sample Similarities Problem

List all the ways in which a apple and an orange are alike:



A Three-Part Presentation

Physical – Design Thought Model

You are asked to create a physical representation of your creative 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 – Critical Manifesto

You will supplement the physical artifact representing your design thought process with a written narrative. This is the final expression of the Critical Manifesto assignment. In this assignment you are asked to practice the act of "thinking about thinking". In order to clearly articulate the cognitive processes (strategies and skills) that make up your creative process, this exercise will serve to strengthen your physical representation by clarifying your intention. The written documentation should include within it at least two (2) photographs of the model.

Verbal – Final Presentation

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. 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 creative thinking process.

Schedule for the Semester

Class 1: Activity
Introduction to creative strategies
Discussion of class purpose and objectives
Class 2: Creative Strategy 1 – Brainstorming / Reverse Brainstorming
Framework for effective metacognitive practices
Class 3: Creative Strategy 2 – Lateral Thinking
Knowledge of cognition
Class 4: Creative Strategy 3 – Random Input
Regulation of cognition
Class 5: Creative Strategy 4 – Analogy Technique / Forced Analogy / Mind Mapping
Cycle of knowledge and regulation of cognition
Class 6: Creative Strategy 5 – Metaphorical Thinking
Key operations of metacognition
Class 7: Creative Strategy 6 – Synectics
Importance of practice
Class 8: Creative Strategy 7 – The Discontinuity Principle
Reaching the conceptual level
Class 9: Creative Strategy 8 – Storyboarding
Rubric for self-assessment
------------------------SELF-ASSESSMENT --------------------------------
Class 10: Creative Strategy 9 – Lotus Blossom Technique
Metacognitive Facet 1 - Explanation
Class 11: Creative Strategy 10 – Assumption Smashing
Metacognitive Facet 2 - Interpretation
Class 12: Creative Strategy 11 – Escapism Technique
Metacognitive Facet 3 - Application
Class 13: Creative Strategy 12 – Search and Reapply Technique
Metacognitive Facet 4 - Perspective
Class 14: Creative Strategy 13 – Idea Checklist / SCAMPER
Metacognitive Facet 5 - Empathy
Class 15: Creative Strategy 14 – Attribute Listing / Morphological Charts / Morphological Forced Connections
Class 16: Metacognitive Facet 6 – Self-Knowledge
Conclusion and Wrap-up