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A Study of Grade Level and Gender Differences in Divergent Thinking among 8th and
11th Graders in a Mid-Western School District.

A DISSERTATION
SUBMITTED TO THE FACULTY OF THE GRADUATE SCHOOL
OF THE UNIVERSITY OF MINNESOTA
BY

Leah Christine Roue

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY

Dr. Theodore Lewis

September 2011

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Chapter I

Introduction

The current shortage of skilled workers in science and engineering makes it imperative that young students from all segments of our diverse society, particularly those who are currently least engaged, be attracted into these fields. Accelerating technological advancements and global competition creates a demand for a full workforce of creative scientists and engineers. During this time of significant shortage, women are underrepresented in science and engineering. Females constitute a large untapped resource that has the potential to ease the urgent need for skilled workers.

This study will examine whether the shortage of females in science and engineering is linked to possible gender-based differences in school-aged children's' divergent thinking, an important characteristic in science and engineering and a direct measure of creativity. Such an investigation has the potential to fill a research gap and serves as an aid in teaching and learning about gender-based differences in divergent thinking.

Creativity

Creativity is an essential skill for scientists, technologists, and engineers who are at the cutting edge of solving problems and developing new innovations vital to industry and society as a whole. Creative persons and organizations are admired. Martin (2006) describes creativity as discovering or inventing something new, valuable, and purposefully made. Runco (2003) defines creativity as problem solving or thinking that

involves the construction of new meaning. Creativity is the ability to exhibit creative behavior to a noteworthy degree (Guilford, 1950). Creative abilities establish whether an individual has the power to produce creative behavior to a mentionable degree.

The study of creativity spans multiple disciplines, making its definition more complex. The field of psychology focuses on the individual and the important components within creativity such as cognitive and personality traits that are native to creative people. Creativity within the realm of sociology has focused on creativity as an environmental task (Tornkvist, 1998). Social psychology has studied the creativity process and its interaction within a given context.

Past research on creativity has focused on enhancement, problem-solving, social influences, education, and personality. The sheer amount of research in creativity has in turn increased the rigor behind its evaluation (Runco, 2003). Years of research has brought more agreement and greater quality control, which helps to insure the reliability and validity behind the measurement of creativity leaving less room for bias and speculation.

Creativity is currently high in national priorities, generating summons for support from national science research boards (National Academy of Sciences, 2003; National Science Foundation, 2006). Companies are increasingly aware of the need for creative solutions in order to maintain their competitive edge and respond quickly to market challenges (Baillie, 2002). The products of creative science, engineering, scholarship, art, and design can bring immense benefits to society, as well as give satisfaction to their

discoverer. Society is willing to invest in projects and programs that promise creative outcomes (National Academy of Sciences, 2003).

History reflects a gender difference in significant creative accomplishments.

There have been far more accomplishments, particularly at the highest level, by males in science, literature, arts, music, and technical development than females (Eysenck, 1995).

Many researchers have determined factors that influence creativity but the inconclusive nature of the current collection of research emphasizes the fact that more research is needed to understand gender differences in creativity.

Creativity in Science and Engineering

Creativity is associated with the highest levels of achievement in many fields, and certainly this is true in science and engineering. Creativity has enormous importance in science and engineering (Martin, 2006). Creativity is a key attribute of talented scientists and engineers; people are the engines of creative practice. In the fields of science and engineering new systems, tools, processes, and equipment are the concrete result of creative acts (Tornkvist, 1998). Engineers develop numerous innovative and creative business solutions today (Fogal, 1998). In science and engineering, creativity can result in new predictive theories, new materials, more efficient energy sources, and safer products. The list is endless. Research has shown that creative ability is held in high regard in science and engineering, and various constraints may discourage creativity, such as the demand for productivity, competitiveness, and the various external pressures such as resources like time and money.

Mowry (2004), in his article *The Power of Creativity*, states that creativity is of vast importance to our economy. Creative individuals want to make breakthroughs in their discipline and strive to be inventive; therefore, creativity serves to advance the disciplines in which a person is creative. Creativity carries the added importance of enhancing one's sense of individual fulfillment. It provides engineers and scientists with a sense of meaning. Creativity in science and engineering is a revolving win-win cycle that benefits both industry and the individual. Mowry has praised our country's development of and future plans for promoting the creative sector, as an important step in the right direction.

Divergent Thinking

Divergent thinking is a direct measure of creativity and an important characteristic in successful advancements in science and engineering. Divergent thinking is defined as an idea-generating process wherein an individual is faced with problems or questions for which there is not just one answer (Guilford, 1950; Runco, Dow & Smith, 2006). It is the opposite of convergent thinking where ideas are eliminated to arrive at a single correct answer, as in multiple choice questions. Charles and Runco (2001) stated that divergent thinking is indicative of one's potential for creative performance. Integrating creative thinking into professional knowledge to create new ideas is of major importance (Hsiao & Liang, 2003).

The concept of divergent thinking was developed in the 1950s by J. P. Guilford (Gale Group, 2001). According to Guilford, divergent thinking is a key factor in

creativity, and he associates it with four main ingredients. The first is elaboration: the ability to think through the details and carry them out. The second is flexibility: the capacity to think about a variety of approaches simultaneously. Third is fluency: the capability to produce a large number of ideas rapidly. Last is originality: the expertise to develop ideas different from most people's ideas.

There are many possible factors that may influence divergent thinking. Runco et al. (2006) identified memory, information, and experience as factors. Thomas and Berk (1981) reviewed the possibility of environment influencing divergent thinking. Multiple researchers such as Reese, Lee, Cohen and Puckett (2001), McCrae, Arenberg, and Costa (1987), and Claxton, Pannells and Rhoads (2005) all published research on divergent thinking and age or grade level differences in test results. Anxiety has also been shown to influence divergent thinking (Feldhusen, Denny, & Condon, 1965; Wadia & Newell, 1963). Gluskinos (1971) found no significant relationship between creativity and grade point average. Russo (2004) revealed variability between performances of high-IQ and average students and creative thinking skills in his longitudinal study.

The 1960s and 1970s brought about an increased interest in non-cognitive (creativity) tests in an effort to identify gifted and talented students. With this effort came the need for a standardized testing method. Many researchers have created measures of creativity; the one that arguably is the most popular being Wallach and Kogan Creativity Test (WKCT) (Hsiao & Liang, 2003). This and other tests will be discussed in the literature review in the following chapter.

Tests of divergent thinking use open-ended means for the individual to come up with a variety of answers. Researchers use variations in testing instruments and in the scoring methods. One example of scoring measurements is the grouping of responses into three aspects (Runco et al., 2006; Guilford, 1950). *Ideational fluency* is the number of ideas. *Flexibility* is the number of categories or themes presented in the ideas. *Originality* is measured by the number of unique ideas presented.

Shortage of Scientists and Engineers

Success in a global economy is highly dependent on the education and employment of the best pool of workers in the areas of science and engineering. The number of engineers produced in the United States per capita is proportionally low compared to developing high-tech countries, such as India and China. The population of the United States is about 300 million people, and it produces 60,000 engineers each year (Wei, 2006). India has a population of 1 billion, or about three times that of the United States, and produces 350,000 engineers annually, or six times that of the United States. China with a population of 1.4 billion, or about four times that of the United States, graduates 600,000 engineers a year. That is 10 times the number of graduates in the United States (Wei, 2006). Japan trains twice as many engineers and scientists as does the United States (Beech, 2000). Failure to produce qualified workers means that the United States would be left in a position where it must compete abroad for qualified workers.

Isidore (2007) reports that economists and labor market experts say that job growth and the economy overall would be significantly stronger if employers could find

the skilled workers they desperately need. The deficiency of scientists, engineers, and technologists is likely the chief constraint on economic growth. The lack of workers skilled in these areas, in addition to the projected retirement of baby boomers, makes this an urgent problem that without immediate attention is certain to compound in the years to come.

The workforce shortage in science and engineering would be problematic if needs remained fixed, but the huge growth in these fields compounds the difficulty. Marcus (2000) said that the Bureau of Labor Statistics anticipated that during the years 2000-2006, the number of computer engineers needed would double. Marcus cited the National Science Foundation, which predicted jobs in engineering would grow at a rate triple that of other jobs.

Numerous studies provide statistics showing that women are underrepresented in science and engineering. Women comprise approximately 50% of the population, yet according to Science and Engineering Indicators (2008), women held only 26% of non-academic science and engineering occupations in 2005. DeBartolo and Bailey (2007) point out that women comprise fewer than 20% of engineering majors and stress that it is essential for our nation's high-tech industries to increase the diversity of engineering graduates. As business leaders and policy-makers seek to address talent shortages, it is becoming increasingly urgent to close this gap and leverage the talents of both men and women.

Reed-Jenkins (2003) states that females remain underrepresented in science, technology, engineering and math careers. Female enrollment in technology-related fields

is at the lowest level since 1985 (Treyvaud & Rounds, 2003). “Balancing the Equation” (1998), a press release by the National Council for Research on Women, stated that the United States workforce was comprised of 45% women in 1996 but only 12% of them held science and engineering jobs. The press release also stated that in 1996 women earned only 18% of engineering degrees and in 1999 they earned less than 20% of computer science degrees.

Today’s homogeneous male engineering teams may no longer be able to deal with the increasingly diverse needs of the customers (Ihsen, 2005). The lack of diversity and the issue of women in engineering holds more and more political and economic relevance worldwide. To survive and thrive, science and engineering must draw from the broadest and most diverse pool of candidates to attract and retain the best skilled workers. A diverse workforce blending genders, cultures, and ages has the advantage of representing a wider customer base in order to translate customer requirements into new and useful products.

Another factor in the scarcity of female scientists, engineers, and technologists is the dropout rate of women already employed in the field. Women tend to abandon full-time work at a higher rate than men, but this phenomenon is far greater in these fields (Hewlett, Luce & Servon, 2008). Many factors such as confidence, interests, social influences, perceptions, efficacy, desire to help others, physical abilities, and characteristics have been identified as potential negative influences on women and their lack of participation in these fields and the reasons they leave these fields after entering them (Jacklin 1989; Linn & Hyde, 1989). Identifying these factors has proved beneficial

but we are still struggling towards increased diversity in many fields, particularly science and engineering.

Current research points to perceptions and stereotypes as the greatest obstructions to young females becoming interested and thus entering the fields of science and engineering. Perceptions have obvious implications that have contributed to low levels of female participation in technology and engineering. Research shows that females view engineering and scientific fields as “geeky” (Muller, 2002).

Many girls are turned off by the thought of a career in technology. They are haunted by the image of nerdy male co-workers drinking Red Bull, eating Twinkies and having meaningful relationships with their computers. Sure, we know it’s a cliché, but to kids--and especially young girls--image is everything (Woodka, 2001, Introduction section, ¶ 1)

The current research has helped to identify shortages in science and technology; in response, many programs have been developed to reduce this insufficiency. President Bush’s American Competitiveness Initiative and the Democratic Innovation Agenda are two programs assembled to increase female participation through school funding, scholarships, and grants in science, technology, engineering, and math (STEM). Hundreds of programs both publicly and privately funded have been implemented in response to this national deficit.

Despite the wide recognition of the problem and the programs aimed at intervention, participation of females in STEM is still an issue. Further investigation is necessary to understand the fundamental reasons. Are there other factors beyond

stereotypes and societal norms that restrain women's involvement? Do innate differences between males and females play a larger role than is currently understood?

Statement of the Problem

There is a shortage of scientists and engineers at a crucial time when technological innovation depends on the involvement of our nation's best and brightest, representing all segments of our diverse society. Women comprise approximately 26% of the college educated workforce in science and engineering occupations (Science and Engineering Indicators, 2008). Sanders (2005) stated that women's lack of participation can only be measured in jobs not filled, problems not solved, and technology not created. Engineering must attract young people who are seeking stimulating and creative work (Wulf, 1998). "Diversity is the gene pool of creativity" (Wulf, 1998 p. 23).

Creativity is at the heart of science and engineering and is essential to scientists and engineers who are responsible for developing many of our most innovative and creative business solutions today (Fogal, 1998). Divergent thinking is a well accepted component of creativity (Charles & Runco, 2001) and is central to its measurement.

Understanding creativity and divergent thinking will potentially shed light on the underrepresentation of women in science and engineering. Few studies have been conducted which analyze creativity in underrepresented groups and most have revealed contradictory findings (Matud, Rodríguez, & Grande, 2007). Limited research has been conducted to determine whether there are fundamental differences between boys and girls

in the area of creativity and its key component, divergent thinking. Divergent thinking is a critical dimension of inventiveness in science and engineering related creativity.

The Study

This study compared gender and grade level differences in divergent thinking among middle school and high school students in the Midwest. The instrument used was an instrument based on the WKCT. There were 166 students in the study, including 45 8th graders and 121 11th graders. Both the middle school students and the high school students attend public schools.

Research Questions

Participants were given an instrument based on the WKCT creativity test, a measurement of divergent thinking. Results were analyzed in an attempt to determine whether gender or grade level-based differences exist in divergent thinking:

1. Are there gender differences in:
 - a. fluency of responses?
 - b. flexibility of responses?
 - c. originality of responses?
2. Are there grade level differences in:
 - a. fluency of responses?
 - b. flexibility of responses?
 - c. originality of responses?

Variables and their Measurements

Three main independent variables are present in this study of divergent thinking. Fluency is rated as the overall number of responses given to a question. Flexibility is defined as the plasticity with which mindset changes; the reverse, rigidity, is not a characteristic of creativity. Originality consists of novel or unique ideas that are measured by the frequency of uncommon yet appropriate responses.

It should be pointed out that the nature of creativity and the reliability of current measurements are still under debate by many, even after 50 years of work in the area (Russo, 2004). The lack of agreement in this area is often attributed to the multidimensional nature of creativity. It is thought however that divergent thinking and its measures, fluency, flexibility, and originality, are vital to the study of creativity (Torrance, 1981). Chapter III will provide more information on each of the factors and the measures used in scoring.

Significance of the Study

Research in the area of gender differences in divergent thinking has the potential to help us determine whether there are fundamentally embedded gender differences in inventive potential in children, or alternatively, whether gender differences with respect to career choices in science and engineering are not socially constructed.

Summary

The shortage of skilled workers in science and engineering, compounded by the additional stressor of impending “baby boomer” retirements, makes it of critical

importance to leverage the talents of both men and women. Women comprise less than 26% of non-academic science and engineering occupations (Science and Engineering Indicators, 2008). Fewer than 20% of engineering majors are women (DeBartolo & Bailey, 2007). The shortage of women is evident in these occupations as well as in the related educational institutions.

The successes of these fields depend on a diverse pool of creative individuals. Key to creativity is diversity (National Academy of Sciences, 2003). The current lack of diversity within science and engineering is compounding the shortage of skilled workers and impeding creativity within these fields. Not enough women are choosing the fields of engineering and science. Can this lack of female participation be linked to fundamental differences in divergent thinking?

Chapter II

Review of Literature

This study analyzes divergent thinking in males and females across grade levels in hopes of finding differences that could shed light on science and engineering participation among females. Topics covered in this chapter will include creativity, divergent thinking, science and engineering, gender differences, development, and women in science and engineering. This chapter will provide key theoretical concepts needed to inform this study on divergent thought.

Creativity

Creativity is widely recognized in society as valuable in scientific and technological advancements which can improve the quality of life and spur economic vitality. Chan (2005) argues that creativity is crucial in a world of swift change. What is creativity? Can it be measured? What factors influence creative acts, ideas, and dispositions? Can creativity be taught? Because creativity is essential to scientists, technologists, and engineers who are responsible for developing many of our most innovative and creative business solutions today (Fogal, 1998), an understanding of creativity and divergent thinking has the potential to shed light on the underrepresentation of women in science and engineering.

Creativity is defined by Guilford (1950) as one's ability to be creative and the ability to produce creative results. Guilford found that the traits characteristic of creative people are related to their personality and such dependent factors as motivation and

temperament. People exhibiting traits which mark them as creative may engage in such behaviors as composing, designing, planning, contriving, and inventing.

Most research in creativity pulls from Guilford's (1950) philosophy. Guilford spent most of his career studying creativity. He sought a deeper understanding of the ability to be creative and developed tests to measure it. In Guilford's significant body of work, he broke down specific aspects of creativity and various influencers of creativity in an effort to make creativity more measurable. Guilford has dedicated his research to discovering creative promise and learning how to promote it.

While everybody has some ability to be creative, Guilford's (1950) works focused on creativity at the level where it is acknowledged or noteworthy. Guilford's hypothesis that everyone is capable of creative abilities and activities raises the question of why so few people are notably creative. Noteworthy levels of creativity are very infrequent and are genetically random. Very creative youngsters can be produced by average parents.

Guilford (1950) identified principal factors in measuring creativity. Fluency is a measure based on the number of ideas. Frequency is identified as a rate of occurrence of novel, uncommon or original ideas. An individual with many ideas per unit of time has a greater chance of having ideas of significance. Flexibility is the ease with which mindset changes; the reverse, rigidity, is not a characteristic of creativity. Novel or original ideas are measured by the frequency of uncommon yet acceptable responses.

As defined earlier, creativity is the ability to be creative and produce creative results. The subjective nature of creativity has led to multiple measures to determine

creative potential or creative behavior beyond the popular measures of creativity; that is fluency, flexibility, and originality as introduced by Guilford (1950).

Many abilities are required to produce creative results. These abilities include the capacity to synthesize ideas and organize them into inclusive patterns. Reorganization and redefinition can be effective tools in generating new ideas from existing models. Guilford (1950) noted that not all individuals have the ability to manipulate multiple interrelated ideas, which he refers to as complexity. Analyzing is the ability to break down symbolic structures to build new ones. Evaluative behaviors are needed to rank potential solutions in order of degree of excellence or fit. It is important for an individual to be able to evaluate ideas as realistic or acceptable. Personal evaluation plays a major role in the creative process. Too harsh a personal evaluation will rule out possibilities too quickly, while on the other hand one who lacks evaluative ability will be confused by the sheer number of ideas, making the work difficult to manage.

Evaluative thinking (Charles & Runco, 2001) determines how well-liked or preferred an idea is to the person who created it. Degree of complexity or intricacy within the concept structure is the number of interrelated ideas that can be manipulated. Design stance, dubbed by Dennett (1987), is an explanatory structure that underlies one's reasoning about artifacts, their existence, and proper function. The original intended function is the artifact's essence. This definition is directly linked to functional fixedness, a term identified by Duncker (1945). Another important factor in creativity is motivation, both intrinsic and extrinsic. Amabile (1983) has completed research in the area of

creativity and factors that motivate it and has emphasized intrinsic motivation and freedom as two important factors in fostering creativity.

The various abilities related to creativity and the factors that could be applied to measure creativity are subjective and nearly endless. The concepts listed above are by no means a comprehensive list, but they are important characteristics in the study and measurement of creativity and divergent thinking.

The groundwork has been laid in the theory of creativity but the question remains, can creativity be taught? Creativity training programs have only started to emerge. Schools emphasize testing in standard objective methods aimed towards meeting predetermined outcomes as they have been outlined by the government. Although the government has seen the importance of creativity within the competitive business sectors (National Academy of Sciences, 2003; National Science Foundation, 2006), it has done little to augment its teachings within our school systems.

Training in creativity is believed to help students in their academic experiments as well as in work and other facets (Hunsaker, 2005). Two programs have been highlighted for improving creative abilities. The first type focuses on the structure and materials. Creative Problem Solving and Talents Unlimited are two examples. The second focuses on learning and results in competitions such as Destination ImagiNation, Odyssey of the Mind, and Future Problem Solving.

Tornkvist (1998) emphasizes the importance of teachers in creative education. In their role they must promote creativity as a lifestyle. In doing so it is likely to have an effect on the students' future work. Teachers should keep an open and accepting position

in the classroom and utilize more open forms of learning such as problem-based learning. Also important is tolerance in regards to the students' various learning styles. Varying components of creativity such as affective, cognitive, attitudinal, and interpersonal components can be enhanced through the use of inspiring settings.

Karkockiene (2005) studied a program's effectiveness on enhancing each student's fluency, flexibility, and originality and whether the program altered the student's subjective assessments of their own creativity. Several positive effects were discovered immediately after program completion. Using an experimental group and a control group, subjects were given the Torrance Tests of Creative Thinking (TTCT) Verbal Form A and subjective evaluations of one's own creativity. Results showed that fluency, flexibility, and originality improved significantly after participation in the program, along with one's own ability to evaluate creative ideas.

With these findings and others, it can be said that there are real possibilities to develop each student's creativity during the learning process (Karkockiene, 2005). Using this information a new focus should be placed on promoting and developing creativity potential within all individuals.

There is a vital link between creativity and achievement in the areas of science and engineering. Scientists and engineers are inventors and thus do creative work; it can be easily argued that science and engineering are profoundly creative professions (Wulf, 1998). Industries that employ scientists and engineers aspire to find and improve the creative talent in their employees (Guilford, 1950).

New ideas, processes, and methods can have a huge impact on an industry's economic standing. It is essential that creative thinking be merged with professional engineering knowledge to keep pace in a swiftly changing technological economy (Hsiao & Liang, 2003).

Many personal benefits are an important motivator for creative persons and are documented within the realm of creativity. It can enhance one's sense of individual fulfillment and it can provide scientists and engineers with a sense of meaning and self-fulfillment; creativity in science and engineering is a revolving win-win cycle that benefits both industry and the individual.

Divergent Thinking

The divergent thinking theory of creativity focuses on the process of searching for ideas or problem solutions (Hsiao & Liang, 2003). Divergent thinking is defined as an idea-generating process wherein an individual is faced with problems or questions for which there is not just one answer (Guilford, 1950; Runco et al., 2006). Divergent thinking is a well-accepted element of creativity (Charles & Runco, 2001) that is essential to children's development and should be taught like other basic skills (Torrance, 1981). Hsiao and Liang (2003) feel that within education, creativity and thus divergent thinking should be combined with professional knowledge to create more new ideas and ideals.

Testing Methods and Techniques

Many methods and techniques have been created to assess divergent thinking. Open-ended problem solving tests are the most prevalent in measuring creativity and

divergent thinking. The majority of problem solving tests have two categories of open-ended questions: visual and verbal.

The nature of divergent thinking can be addressed in terms of its measures. Fluency, flexibility, and originality are the three main dimensions or outcome variables. These three components and others which are closely related will be discussed in this section to illustrate the most common measurements applied to divergent thinking. Research has shown that training in fluency or flexibility can enhance originality.

Factors that Influence Divergent Thinking

Many factors have been studied as influencers of divergent thinking. These factors, which include such aspects as gender, age, intelligence, anxiety, and environment, exhibit the variety of the interrelated elements affecting divergent thought.

Gender.

Essential to this study of divergent thinking is the issue of gender. Klausmeier and Wiersma (1964) believe that differences between males and females should be expected on divergent thinking tests simply because differences have already been found on tests of convergent thinking. Furthermore, tests have shown males and females vary on many items specific to the affective domain such as interests and values.

Studies of gender and divergent thinking have provided mixed results. Klausmeier and Wiersma (1964) found gender to be of major influence on divergent thinking tests. The results of their research on 320 fifth and sixth graders showed that the mean divergent thinking test scores for girls were higher than for boys. Reese et al. (2001)

found negligible results in establishing a connection between gender and divergent thinking after studying 400 adults ranging in age from 17 and older. Thomas and Berk (1981) suggest that gender differences were predictive in their study on the effects of school environment on the development of creativity. Creative learning aids for first and second grade girls were found to differ from those for boys; girls were found to benefit from intermediate and informal environments more than boys.

Age.

Age has been studied as it relates to creativity but little research has been done as it relates to divergent thinking. The presumed relation between creativity and divergent thinking would imply that research on the influence of age in creativity test scores should be similar to what we may find in divergent thinking. As individuals are expected to improve in scores on standard tests of knowledge as they progress through school, the same is thought of divergent thinking test scores.

Researchers have attempted to answer the question of whether divergent thinking peaks at a certain age. Reese et al. (2001) assessed divergent thinking with tests of associational fluency, production fluency, flexibility, and originality. Findings revealed a linear regression between associational fluency and age; associational fluency gradually decreased with age. A curvilinear trend was reported for production fluency, flexibility, and originality as it relates to age; the peak was reported in middle age, about age 45. These results are similar to those of a study involving 278 men ranging in age from 17-101 who received repeated administrations of a divergent thinking test involving six measures. This study conducted by McCrae et al. (1987) revealed the same curvilinear

trend. The scores increased for men under age 40 and declined thereafter. Klausmeier and Wiersma (1964) reported that seventh graders scored higher than fifth graders in all but three divergent thinking tests. This study also seems to confirm the results described earlier between childhood and college creativity increases.

Lehman (1953) was known for his research charting creativity across age groups and disciplines. He spent years tabulating by age group the frequency of the production of quality work. Lehman published a work depicting creative output as a function of age. His findings revealed an upward trend starting in the 20s and rising into the mid-30s, where creative output peaks. With this he concluded that maximum production of quality work occurred between the ages of 30-39. In rebuttal to Lehman's work, Dennis (1956) pointed out that Lehman used participants with varying life spans which could skew the results.

In a study conducted by Claxton, et al. (2005) two measures were used, one to measure divergent thinking and the other a measure of divergent feeling in fourth, sixth and ninth grades students. The Divergent Thinking Test was designed to measure the cognitive or intellectual behavior components using five factors: fluency, flexibility, originality, elaboration and title. The Test of Divergent Feeling was designed to measure the affective or feeling behavior components using curiosity, complexity, imagination, and risk taking as the four factors. The study revealed that there was only a slight increase in divergent thinking scores between fourth and ninth grade. A significant increase in mean scores at the alpha level of .01 was found when comparing the sixth and ninth graders on The Test of Divergent Feeling. This significant increase in all four

factors of divergent feeling scores took place between sixth grade and ninth grade, whereas little change was seen between fourth grade and six grade.

Charyton and Snelbecker (2007) conducted a study of creativity in university students to find differences in creativity between music and engineering students. The researchers measured general, artistic, and scientific creativity. A finding pertinent to this paper is that they found no significant differences in creativity based on gender or age within their subject group of university students.

Anxiety.

Anxiety has been shown to influence divergent thinking (Feldhusen et al., 1965; Wadia & Newell, 1963), though few studies have been conducted to determine anxiety's effect on divergent thinking. Of the studies conducted on anxiety in general, it has been determined that females are characterized by higher anxiety levels than males (Feldhusen et al., 1965). Wadia and Newell (1963) presented findings at the 71st annual convention of the American Psychological Association associating low-anxious males with superior performance on divergent performance tasks. This is in contrast to high-anxious males, who failed to perform at the same level. This same study found minimal differences between low- and high-anxious females using the same task.

Studies of the effect of anxiety on divergent thinking tests results show conflicting results. While the study cited in the previous paragraph found an adverse effect, others do not. Convergent and divergent tests were used by Feldhusen et al. (1965) in order to determine the correlations among general anxiety and School and College Achievement Test (SCAT), Sequential Test of Education Progress (STEP), a creativity self-rating

scale, and divergent thinking tests of originality, flexibility, and ideational fluency. They found little significant difference in divergent thinking scores between high-anxiety and low-anxiety students. The study also revealed a positive correlation between males' creativity self-rating scales and their SCAT, STEP, and originality.

Environment.

Environment can have an impact on the results of divergent thinking tests. Thomas and Berk (1981) studied six different schools; each of the schools was classified based on curricular methods and goals. Each of the six schools fell into one of the three categories: informal, intermediate, or formal. The results proved the relationship between school type and divergent thinking test results to be very complex, however the results did show the informal and intermediate environments led to more growth in several kinds of creativity. The findings also revealed gender differences between boys and girls and the environment that worked best in fostering their creativity.

The location of the school, or more specifically the size of the municipality, was taken into account in Klausmeier and Wiersma's (1964) study. Having studied 160 fifth graders and 160 seventh graders on seven tests of divergent thinking, they reported that students living in a large city scored significantly lower than those in a smaller city.

Divergent Thinking in Science and Engineering

When we think of scientists and engineers we tend to think of competent, talented individuals whose life's work is aimed at solving complex problems; the kind of problems that do not have single independent solutions. Each day scientists and engineers

deal with the kinds of problems that have abundant potential solutions. Solving these types of complex problems requires the production of a variety of new and original potential solutions, also known as divergent thinking. The combination of engineering knowledge and divergent thinking can accelerate the pursuit of new solutions and fresh ideas.

Seventy years ago Guilford began a career in the study of creativity which laid the foundations of the field. In his 1950 publication “Creativity,” Guilford developed hypotheses pertaining to the abilities present in specific types of creative people: scientists, technologists, and inventors. Sensitivity to problems describes an ability that makes a person become curious and feel challenged to solve a problem. This sense of engagement leads to more ideas and a greater chance of a breakthrough solution. A synthesizing ability is needed to organize ideas into larger patterns. An analyzing ability allows a person to break down ideas into components to rebuild them. The ability to reorganize or redefine can enable alterations in the design, or function of use, of an existing object. An ability of complexity can enable the manipulation of many thoughts at once. Finally, the ability of evaluation makes it possible to restrain the new ideas to a realistic solution. One can readily identify the importance of all these abilities in scientists and engineers.

McCumber and Sloan (2005) described the thought process of systems engineers, whose scope of responsibility is broad, as divergent thinking. In contrast, they described domain engineers, who are in-depth experts in a specific technology, as using a more convergent thought process, which reduces the options to one solution. They contend that

system engineers use divergent thinking to envision numerous solutions to a problem, exemplified in their consideration of all the things that could go wrong with a proposed system solution. This is an application of fluency and flexibility in divergent thinking.

Gender Differences

Key to finding any relationship between divergent thinking skills and the lack of females in science and engineering is an understanding of gender differences in education, work, and cognitive functioning. Substantial research has been done in the area of gender differences in these areas, and a basic understanding is important to this study. This section will give a brief summary of this research.

A report published by the National Center for Education Statistics, Trends in Educational Equity of Girls and Women (2004), gives the general picture of male and female educational performance. This study reports that regardless of gender, students start school on a relatively even playing field. In the early grades females may have a bit of an advantage in literacy participation experiences. At the 4th, 8th, and 12th grades, females exceed males in reading and writing assessments. Females are also less likely to repeat grades and seem to have fewer problems that put them at risk.

Coley (2001) has compiled a comprehensive set of data from multiple sources that compares the differences between males and females across racial and ethnic groups. The data Coley has assembled encompasses education and work from elementary through high school, college, graduate school, and in the workforce. Most of his findings show trends using a decade or more of data from varying sources. Among the major findings,

females scored higher than males in the National Assessment of Educational Progress (NAEP) in reading and writing across all ethnic and racial groups. NAEP science scores showed the highest levels of differences for whites and Hispanics, as well as the fact that males scored higher than females.

Most college-bound individuals take the Scholastic Aptitude Test (SAT) while in high school. Statistics on the SAT I Verbal Test showed that males score higher than females, with the exception that black college-bound senior females scored higher than their male counterparts (Coley, 2001). Males in all racial/ethnic groups scored higher than females on the SAT I Mathematics Test. A similar graduate school entrance exam, the Graduate Records Examination (GRE), showed comparable results. In all racial/ethnic groups, males scored higher than females on the GRE Quantitative, Verbal, and Analytic tests. These findings were also true in GMAT (Graduate Management Admission Test) scores.

More males than females took Advanced Placement Examinations (APE), but the number of female test takers has risen in the past decade across racial and ethnic groups (Coley, 2001). In the APEs there is little difference in scores between males and females in literature and composition. Males scored higher in biology and calculus.

Klausmeier and Wiersma (1964) tested divergent thinking in 320 fifth and seventh graders of high IQ. Girls had higher mean scores on tests of divergent thinking, whereas boys had higher mean scores on tests of convergent thinking.

Educational Attainment

Female high school seniors are reported to have higher educational aspirations and are more likely than males to register for college immediately after high school (National Center for Education Statistics, 2004). Hispanic and white females aged 25-29 surpassed males in the percentage completing high school or more, and this trend seems to be increasing (Coley, 2001). Black females of the same age show no changing trend in completing high school, nor is there a gender gap among blacks in high school completion. In all racial and ethnic groups, female college-bound seniors have made significant progress in taking four years of science in high school; they have almost caught up with their male counterparts (Coley, 2001).

Earnings and Employment

Male high school and college graduates earn more than female graduates regardless of ethnicity/race; white males have the largest income advantage (Coley, 2001). The male-female earning gap has been decreasing steadily for the last 30 years (National Center for Education Statistics, 2004). Females are more likely than males to be unemployed, though this gap is almost negligible for blacks. It is important to note that unemployment rates and differences in occupations may contribute to the respective difference in male and female unemployment rates and annual salaries.

Science and Engineering

The research discussed in this section has provided a general depiction of the range of gender differences in education, work, and cognitive functioning. These statistics demonstrate the nature of gender differences in educational testing results,

likelihood of higher education, and employment disparities. In some areas males outperform females and in others these roles are reversed. With this foundation, this paper will examine gender differences within the areas of science, technology, engineering, and math. What can this information tell us about the gender gap in science and engineering?

The National Center for Education Statistics published a report, *Entry and Persistence of Women and Minorities in College Science and Engineering Education* (2000), which examined gaps related to race/ethnicity and gender in entrance, persistence, and achievement in postsecondary science and engineering education. Regardless of race, ethnicity, or gender, this report describes the student who had a greater likelihood of majoring in science and engineering in postsecondary education as one who has taken advanced science courses, a student who has self-motivation to study science, a student whose parents had high expectations for their child's college education, and a student who has relatively higher levels of educational attainment. The report also states that once these characteristics have been met, or held constant within the population, the racial/ethnic and gender differences tend to get smaller.

Society has a general idea of gender differences in educational trends, work, and cognitive functioning and an awareness of variations in performance, annual salary, and general aptitudes. However, little is known about gender differences in creativity, original thinking, spatial abilities, fluency, divergent thinking, flexibility, generation, elaboration, and analogizing. Are there differences? Research in these areas has developed over the years but is still fairly limited with respect to gender.

Spatial abilities are important to our everyday lives and are even more important in our technologically-advanced society where we are often required to use maps, graphs, architectural drawings, and x-rays. These activities and many more require spatial abilities. Levine, Huttenlocher, Taylor, and Langrock (1999) studied early sex differences in spatial skills. When given a spatial transformation task boys scored substantially higher than girls by age 4½. Cronin (1976) found similar results in a study of kindergarten and first-grade students. The boys were better than the girls in discriminating mirror reversals of triangles from identical triangles. It is more typical for these spatial sex differences to become recognizable at 8 years of age (Kerns & Berenbaum, 1991; Guay, & McDaniel, 1997; Johnson & Meade, 1987).

Gender Differences in Creativity and Divergent Thinking

In general, creativity studies have found no gender differences, and the few that have reported differences are inconsistent (Kaufman, 2006; Baer, 1994). A reoccurring finding is that females score higher than males on verbal tests, and males score higher on figural tests of divergent thinking (DeMoss, Milich, & DeMers, 1993). Opposing results appeared in the findings of a study conducted by Dudek, Strobel, and Runco (1993).

Some reports describe gender differences within creativity and divergent thinking. A study by Kogan and Pankove (1972) reported numerous differences between male and female 5th and 10th graders. When administered tests of divergent thinking, females test scores were more consistent when the test was given by a female non-evaluative examiner, whereas males' scores were more consistent during impersonal mass testing. In

the same study, Kogan and Pankove suggest that open-ended tasks of divergent thinking are more likely to engage motivation and personality in girls, whereas boys seem to perform better under stricter cognitive control.

Women in Science and Engineering

Women comprise approximately 50% of the population yet fewer than 20% are choosing engineering majors (DeBartolo & Bailey, 2007). It is essential to increase the diversity in engineering and science to develop the strongest workforce possible.

Although females and minorities are less likely than males to enter science and engineering, once in the “pipeline,” female students in these programs actually did better than their male counterparts in completing their degree (National Center for Education Statistics, 2000). Additionally, women enrolled in four-year degrees in science and engineering reported solid academic preparation, high expectations, healthy self-confidence, and a strong family support system.

Huang, Taddese and Walter published a study through the National Center for Education Statistics (2000) which examined the relationship of gender and race to the likelihood of majoring in science and engineering in postsecondary education. Gender was found to create a larger gulf in enrollment into science and engineering majors than racial and ethnic factors. It also reported that while females were less likely to enter science and engineering programs, they did better than male students in completing their degree. Women enrolling in science and engineering programs in their first year of

college tend to have strong family support, high expectations, self-confidence, and firm educational preparation.

A factor in the scarcity of female scientists, engineers, and technologists is the dropout rate of women already employed in the field. Women tend to abandon full-time work at a higher rate than men, but this phenomenon is far greater in these fields (Hewlett et al., 2008). Half of the women in science, engineering and technology opt out, with a surprisingly high incidence occurring for women in their mid to late thirties. Hewlett et al. cited five reasons for this mass departure. The major reason given is the sense of hostility in the workplace culture, followed by the sense of isolation at being the only woman on a team or at her rank. Another factor is the divide between women's favored work rhythms and the risky behavior that is rewarded in these male-dominated fields. Also, the long hours and travel common in these fields clash with the demands of household management, for which women still bear the primary responsibility, even in two-income households.

The majority of research on the reasons for underrepresentation of women in science and engineering examines influences such as self-efficacy, social support, self-esteem, and perceptions. There is a scarcity of research on the impact of gender differences in creativity and divergent thinking, which are key attributes in science and engineering.

Zeldin and Pajares (2000) studied the influence of self-efficacy beliefs in women's selection of math, science, and technology careers. Through case studies of women who excelled in these careers, they concluded that self-efficacy is fostered by

families, educators, and peers. The encouragement and modeling received gave them the persistence and resilience to surmount personal, societal, and academic impediments.

Stereotypes and Societal Deterrents

Societal factors may deter women from careers that are stereotyped as male-dominated. Women who join science- and engineering-related activities and programs may be elbowed off the equipment or dismissed to a task of filling out the paperwork while the men do the active work. This may be a factor in explaining the disproportionate number of girls from single-sex and independent schools who make it through to be women engineers (Pullin, 2005).

Programs to Promote Women in Science and Engineering

Fox (1998) states that women lag behind men in participation in science and engineering professions and that the disparity is a concern because of the under use of women as human resources and because of the unmet democratic ideal of social equity. These concerns have resulted in programs to enhance the participation and performance of women in science and engineering. Fox studied the programs that have been developed to promote graduate-level women's participation in science and engineering in order to learn the problems addressed and solutions posed. The identified problems were depicted as reflecting either the individual characteristics of the women or reflecting their educational and work environments. Some programs attributed gender disparity in science and engineering to power and hierarchy, but most have shifted to a view of gender neutrality. Solutions most commonly involved fitting women into the existing

structures of education and workplaces, which meets fewer barriers than efforts to change organizations and hierarchies.

Hewlett et al. (2008) purported that if this exodus were abated by 25%, 220,000 highly skilled workers would be retained in the science and engineering market nationwide. Credibility is given to this assertion when many of the nation's top corporations have recognized the problem and have put money towards initiating programs to stop the attrition. Cisco has begun an Executive Talent Insertion Program to offset the difficulty of isolation felt by women executives. Johnson and Johnson's program, Crossing the Finish Line, offers leadership development as well as connections to senior managers for high-potential young multicultural women. Microsoft created "mentoring rings" to give female talent more access to senior managers, particularly during the key career stages when support is most needed. Alcoa's Women in Line Roles program aims to attract talented women into advancement opportunities by offering temporary assignments and career development plans. Pfizer started a mentorship program with Yale University to retain female graduate students by showing them the opportunities in private companies for scientists.

Measurement

One of the biggest debates within the study of creativity has been its assessment. Assessment of non-cognitive traits became of significant interest to researchers in the 1960s and 1970s as a way to further understand and identify gifted and talented students. With this interest came the creation of many instruments for measuring non-cognitive

abilities. It has taken many researchers and many approaches to develop valid and reliable creativity assessments.

Guilford (1956) defined divergent thinking and differentiated it from convergent thinking. While convergent thinking is readily measured by multiple-choice questions, a standardized measurement was needed for divergent thinking.

The majority of creativity tests evaluate divergent thinking, a key component of creativity (Clapham, 2004). Tests of divergent thinking evaluate the test taker's quality and quantity of creative ideas. In the late 1950s to the mid 1960s Elis Paul Torrance developed the TTCT creativity and its four dimensions (flexibility, fluency, originality, and elaboration) as defined by Guilford (1956).

The TTCT are the most widely used divergent thinking tests, thus the most popular (Lissitz & Willhoft, 1985). The creator of these tests, Dr. Torrance, has been referred to as the "father of creativity" (Kim, 2006). Since the initial test development, several revisions have been made in order to enhance the validity of these tests.

The TTCT includes two testing methods: verbal and figural (Gifted Education, n.d.). Both methods assess five mental characteristics: fluency; originality; elaboration; abstractness of titles; and resistance to closure, or openness. The tests were created for participants age 5 and over. The participants are given open-ended tasks, and the responses are used to assess the five mental characteristics.

The first of the Torrance tests employs figural exercises or more specifically, abstract pictures. The participants are given an abstract picture and asked what the picture might be. The figural test can be administered to participants aged five and over. The

second test is verbal and requires the test participants to give verbal responses to various “just suppose” questions. This test is beneficial to the examinee and the examiner because it allows each to ask questions in order to improve the overall responses.

Both tests are available in pre-test and post-test versions and are scored or assessed using the manual created by Torrance. The manual provides a scoring method and includes national norms, standard scores, and national percentages for each age level.

Wallach and Kogan (1965) developed a creativity test in 1965 that is similar to the TTCT. The main difference is that Wallach and Kogan’s test focuses on specific components. Some examples of these components are: wheels, round things, and things that make noise. The participant would be asked to ‘name as many things you can with wheels’.

The scoring of the Wallach and Kogan test is comprised of four components. The first is originality and is rated based on the responses of all the test participants. If a response has been given by only 5% of the participants, it is given one point. If the response has been given by less than 1% of all respondents the answer gets two points. The points are then totaled and the higher the score, the more creative the individual. The second component of the Wallach and Kogan test is fluency. Fluency is rated as the number of overall responses. The third component is flexibility. In order to rate flexibility, the answers are categorized. The number of categories is equal to one’s flexibility. To clarify, if a participant was asked to name things with wheels, and their responses were a car, a truck, a bike, and your mind, they would get a flexibility score of two. One point is for responses in the category of transportation and the other point is for

the response in a non-transportation category for the answer “your mind.” The fourth component is elaboration. Responses are rated for amount of detail. Using the same example question about things with wheels, the answer “a car,” would get a detail rating of one, whereas a response like “a car speeding down the street” would get a rating of two.

In 1967 Guilford created a test for creativity referred to as Guilford’s Alternative Uses Task. In this assessment the participants are given a common household item such as a brick, cup, paperclip, or newspaper and asked to name as many uses as they could for the item (Creativity Test, 2003).

Guilford’s test has three scoring components. The first is originality. This is typically rated based on the responses of all the test participants. If it is a response that been given by only 5% of the participants, it is given one point. If the response has been given by less than 1% of all respondents, then the answer gets two points. The points are then totaled and the higher the scores, the more creative the individual. The second component is fluency which is scored by adding the total number of responses. Flexibility is measured by the number of categories present in the responses. Elaboration is scored based on the amount of detail, usually scoring zero for a response with no elaboration, one for one elaboration, and so forth.

Validity of Creativity Tests

It is important to note that the accuracy of measurements of creativity and the divergent thinking process, even after years of research, is still open to differing opinions. The tests reviewed above are still scrutinized. Many critics propose that these tests have

nothing in place to account for the many factors that cause variation within a person's creative production, nor for the variation within and between tests of creativity. They also question whether domain-specific questions impact the measurement of creativity (Brown, 1990).

Many factors have been shown to influence creativity test results. Researchers should specifically ask for creativity when conducting these types of tests according to Runco and Mraz (1992). The test administrator should also be considered. Kogan and Pankove (1972) reported test administrator and atmosphere affected consistency of test results over a 5-year period.

Runco et al. (2006) performed a study on divergent thinking in creative problem solving. They sought to learn whether divergent thinking test scores were biased based on experience. Were the tests scoring the subject's raw ability, or did the subject's experience, knowledge, and memory affect the score? The subjects consisted of 115 undergraduate students from a university in California who were given 10 minutes to respond to each open-ended task. The tests were scored for fluency (number of ideas) and originality (number of unique ideas). The number of original ideas was divided by the number of ideas to calculate a percentage score. The purpose of the percentage was to even the playing field by eliminating the likelihood of more original ideas from the highly fluent participants. A low percentage score means a large number of unique responses compared to the number of responses. The results showed no significant correlations between test score and GPA. This means the scoring method was successful in measuring divergent thinking independently of general intelligence.

The findings for the Runco et al. (2006) study showed that divergent thinking is related to knowledge for some tasks, especially when the tasks cover just one domain. For example, a horticulturist would likely score well on a divergent thinking test if all the tasks related to plants. But this study also showed that experiential bias can be avoided by crafting divergent thinking tests where the tasks represent unfamiliar domains.

Lissitz and Willhoft (1985) were concerned by the amount of evidence indicating that creativity tests can be influenced by context of the testing conditions. In response to their concerns they set out to test possible influences that could affect a subject's creativity test performance. They hypothesized that by adding to the standard instructions given at the onset of the TTCT that they would be able to affect creative responses, in turn affecting the TTCT scores.

Lissitz and Willhoft's (1985) TTCT test conducted in the College of Education at the University of Maryland had 198 subjects. Each of the participants was randomly assigned into one of four treatment groups. There were roughly 50 participants in each group; each participated in Activity Five of the verbal form of the TTCT. Each participant was given 10 minutes to list as many new and unusual uses for cardboard boxes as they could think of. Performance was scored on three scales: fluency, flexibility, and originality.

Treatment Group I was given the standard set of instructions typically given to TTCT participants during this activity. Treatment Group II was designed to be restrictive. Participants were urged to consider practicality and reasonableness of their ideas. Treatment Group III was given instructions that emphasized the number of ideas. Lastly,

Treatment Group IV received an extended version of the original directions that was designed to place emphasis on unique ideas.

The results showed that Treatment Group I, the control group which used the original instructions, performed the lowest on all three scales. Treatment Group II was the lowest of the three altered instruction treatments. Treatment Group III had the least restrictive instructions with the effect that this was the highest scoring of all groups on fluency and flexibility. Treatment Group IV, which emphasized unique ideas, was the highest in originality. With these results came more questions than answers. Why was it that Treatment Group I scored lower on fluency than did the more restricted Treatment Group II? These findings led to further tests.

In conclusion, Treatment Group II, which was designed to be restrictive, had minimal differences in results from that of Treatment Group I, which used TTCT standard instructions. Because of this similarity in results, Lissitz and Willhoft (1985) concluded that this was a possible indicator that the standard TTCT instructions may be constraining responses. The authors concluded by pointing out an additional conjecture that there do not appear to be three distinct creativity traits measured by Activity 5 of TTCT. They warned researchers who used the TTCT to be very cautious when interpreting the results and that the recommended univariate approach to data analysis can be misleading.

There is evidence that suggests that high scores in divergent thinking may be domain specific (Baer, 1994). In Kaufman, Baer, Agars & Loomis' 2010 article on divergent thinking, they suggest that whatever it is that leads to creativity in writing

poetry, does not augment creativity in teaching. Therefore, they contend that it is of no surprise that tests of general creative ability lack validity and consistency.

Clapham (2004) compared the scores of four creativity tests in order to answer four research questions. The first question the study addressed was whether there is evidence of convergent validity between scores on creativity interest inventories and divergent thinking tests. The second research question asked if there is evidence of convergent validity between scores on the creative interest inventories. In the third research question, Clapham asked whether a correlation exists between academic aptitude/achievement and creativity test scores. The last question was whether relations between scores support the contention that divergent thinking is multidimensional.

In order to answer her questions, Clapham (2004) studied 285 introductory psychology students. The study used two divergent thinking tests, the Figural and the Verbal TTCT. The study also used two creativity interest inventories: Davis's (1975) How Do You Think? (HDYT; as cited in Clapham, 2004).

The results to Clapham's first research question, whether convergent validity existed between scores on creativity interest inventories (HDYT and the Raudsepp) and divergent thinking tests (TTCT), led her to conclude that different tests of creativity should not be assumed to measure the same construct, thus they should not be used interchangeably. The results of her testing of research question two, whether there is evidence of convergent validity between scores on the creative interest inventories (HDYT and the Raudsepp), concluded that there is a convergent validity between the HDYT and the Raudsepp inventories. Clapham also emphasized the need for further

research in this area because there may be a difference in the value of predicting creative performance. The third research question addressed whether there is a relationship between different types of creativity tests and an individual's academic aptitude/achievement. In response to this research question, Clapham concluded that the minor correlations between creativity test scores were not attributable to academic aptitude/achievement as earlier hypothesized. The final question addressed by this study was whether test scores suggest that divergent thinking is multidimensional. The results concluded this hypothesis to be true. Not only did scores from the different types of creativity tests not show convergent validity, but neither did the two TTCT tests, both of which aimed at assessing divergent thinking. This result further validates Baer's (1994) test described earlier, which suggests that divergent thinking tests are not interchangeable.

Our educational system often neglects creativity in curriculum not because its worth is unacknowledged, but rather because of the difficulties in measurement and alignment with national standards. In doing so, schools miss out on opportunities to motivate participation by allowing students to draw upon their natural creative abilities (Lewis, 2008). Standard intelligence tests do not measure creativity even though it is a trait valued in many facets of life, and is essential in science and engineering.

Chapter III

Method and Procedure

The purpose of this study was to examine whether there are gender and grade level differences in divergent thinking. An instrument, based on the WKCT, was used to examine divergent thinking characteristics in the study's participants. The participants were selected from schools within the Bloomington School District in Minnesota. This chapter describes the methodology employed, including the research questions, population, sample description, the survey instruments, validity and reliability, data collection, and data analysis.

Research Questions

Divergent thinking is a measure of creativity and an important characteristic in science and engineering achievement. The research questions selected for this study examined possible gender-based differences in school-aged children's divergent thinking. The data gathered may help to identify reasons behind the shortage of females in science and engineering, and may serve as an aid in teaching and learning about gender-based differences in divergent thinking. This study has the potential to fill the gap in research in this area. Chan et al. (2000-2001) were puzzled by results of their study which found a lack of gender and grade differences in figural tasks, and recommended that the issue should be addressed in future studies.

The research questions were:

1. Are there gender differences in the solution of creativity tasks with respect to:
 - a. fluency of responses?

- b. flexibility of responses?
 - c. originality of responses?
2. Are there grade level differences in the solution of creativity tasks with respect to:
- a. fluency of responses?
 - b. flexibility of responses?
 - c. originality of responses?

Methodology

This research applied quantitative analysis to determine whether there are gender differences in divergent thinking among 8th and 11th grade students. A version of the Wallach and Kogan Creativity Test (WKCT) was chosen as an effective survey tool for this study. It is one of the most widely used divergent thinking tests (Cheung, Lau, Chan, & Wu, 2004) and is useful in gathering data quickly and effectively. Additionally, this study investigated whether grade level differences in divergent thinking exist among 8th and 11th grade students. In order to further contextualize the research data, qualitative methods were also applied to report findings.

Instrumentation and Measures

The researcher used a framework developed by Wallach and Kogan (1965) to measure divergent thinking within the sample. The instrument was comprised of three sections: uses, similarities, and instances. Each of the three sections contained three questions; the participants wrote responses in the blanks provided on the survey sheets. A 12 minute time limit was set for each of the three WKCT test sections because of the time restraints within the schools' classroom schedule.

Wallach and Kogan Creativity Test

The WKCT are available in both verbal and figural components (Wallach & Kogan, 1965); this research implemented the verbal questions. The WKCT is approved for written administration in participants in the fourth grade and older. The instrument used in this study contained three verbal test sections: instances, similarities and uses.

Instances.

The first category of questions in the WKCT verbal test addressed instances. Participants were asked to generate responses for three instances questions of an everyday concept or item. For example, one of the questions was “name all of the things that can rotate.”

Similarities.

The second category of three questions addressed similarities. The participants were asked to list possible similarities between two everyday objects. For example, the participant was asked a question like “tell me all the ways in which a train and an elevator are alike.”

Uses.

The third category asked three alternate uses questions. The participant was asked to generate all possible uses for a given object. For example, the participant was asked “tell me all the different ways you could use a brick.”

Responses for each of the three sections were measured for originality (an atypical or novel response), fluency (total number of responses), and flexibility (the ease with which mindset changes).

Wallach and Kogan creativity test measures.

Measures of fluency, flexibility, and originality were applied in scoring the WKCT questions. The general instructions for administering these tests were based upon instructions provided by Wallach and Kogan (1965). Fluency is defined as the total number of responses given by a participant to a particular item. The participant's responses were totaled, which became the participant's fluency score for a particular question.

Flexibility is the number of categories into which the responses could be grouped. As a flexibility scoring example, if a participant is asked to name things with wheels and the responses are a car, a truck, a bike, and your mind, the participant would get a flexibility score of two points. One point is awarded for the response in the category of transportation and the other point for the non-transportation response of "your mind." Originality or uniqueness can be defined as one's capacity to think independently or be inventive. Based on this definition, an answer is dubbed original as determined by the three judges. As an example, a participant may be asked to indicate all the ways in which an orange can be used. A rare response like "as ammo for a slingshot or catapult" would receive a higher originality score than a common response like "to eat." Again, an average of the judges' scores was calculated to obtain the participant's originality score.

Multiple judges were selected from various backgrounds, and their individual scores were averaged to reduce subjectivity and increase validity. Each of the three judges went through the same scoring process: the three scores were averaged to become the participant's flexibility score for that question.

Cronbach’s alpha is the most common form of reliability rating. Table 3.1 reports Cronbach’s alpha across the three judges. The results in this table are all above the standard alpha rating of 0.80, therefore the judge’s scores are reliable.

Table 3.1 *Interrater Reliability Statistics*

Cronbach’s Alpha			
	Cases	Flexibility	Originality
Instances	169	0.880	0.872
Similarities	169	0.905	0.833
Uses	169	0.895	0.875
Overall	169	0.928	0.899

N = 3 judges

Judge 1 has a bachelor’s degree in civil engineering with years of experience varying from communication infrastructure design and technical assistance, to bridge, road, and highway design.

Judge 2 has spent over nine years in K-12 Engineering and Technology education classrooms and has Ph.D. in Technology and Engineering Education.

Judge 3 has a technical background as a web content management prototype, experience in testing software, database creation, and project management.

Population.

The population for this study was the Bloomington School District #271 in Minnesota. The research was proposed to the school district (Appendix A); the district was quick to respond with a letter allowing access to the students (Appendix B). The

students were chosen because their classrooms teachers volunteered them. The district consists of 10,207 students: 4,493 elementary (K-5) students; 2,338 middle school (6-8) students; and 3,376 high school (9-12) students (Annual Report on Curriculum, Instruction and Student Achievement 2008-2009: Bloomington Public Schools 271, 2009). In 2008, Bloomington’s diversity increased 2% from the previous year. The school currently has 38% diversity: 62% of the school districts population is white, 16% black, 11% Hispanic, 10% Asian/Pacific Islander, and 1% American Indian/Alaska Native. The school has more males (52%) than females (48%). Within the district, 32% of students qualify for free or reduced-price lunches.

Sample.

Participants came from middle and high school classrooms within the Bloomington school district. A total of two 8th grade and three 11th grade classes participated in the survey. There were a majority of males at the 8th grade level and a majority of females at the 11th grade level (See Table 3.2). The average age of the 8th grade students who participated was 14.17 years and the average age of the 11th grade students was 16.92 years. The data collected contained a total of three non-responses to gender: two in the 8th grade and one in the 11th grade.

Table 3.2 *Gender and Grade Level of Participants.*

	Male	Female
Grade 8	34	11
Grade 11	42	79
Total	77	90

Pilot instrument.

A pilot study was conducted after the survey instrument was developed. The students were selected by their classroom teacher. The participants consisted of one male and one female in the 8th grade and two males and two females in the 11th grade. The students that participated in the pilot did not participate again during final data collection.

The pilot had 20 open-ended questions broken down into three sections. The survey instrument's first section asked seven "uses" questions, such as "indicate all of the ways in which you can use a shoe." The second section asked six questions about the "similarities" between two items, such as "list all of the similarities between an elevator and a train." The last section of the instrument asked seven questions about "instances." One of the questions was, "list all the things you can think of the provide energy." Demographic information was collected on gender, grade level, and date of birth. The pilot survey instrument is included in Appendix C.

The pilot was implemented by the researcher; instructions were given orally and in writing, directing the participants to provide as many creative answers as possible. The participants were also asked to provide feedback on the survey's format, wording, and questions. Based on the pilot, adjustments were made to the format to aid the participant by providing more room for responses and to include spaces for the researcher's use in coding the data. The number of survey questions was reduced from the original 20 questions down to nine because of participants' classroom time constraints. The final survey questions (Appendix D) were chosen based on student feedback and the number of responses the questions provoked.

Validity and reliability.

Wallach and Kogan is one of the most widely used divergent thinking test series (Cheung et al., 2004). The WKCT has been in use over many decades, and researchers within the field of creativity have recognized and accept this test as generally reliable and valid. The WKCT is thought to effectively test abilities attributed to creative persons.

The WKCT has been noted as cross-culturally fair in the measurement of divergent thinking because of its use of common daily objects familiar to most people. Psychometric properties of the WKCT are generally good (Runco & Albert, 1986; Runco, Okuda, & Thurston, 1987).

Institutional review board and participant assent.

Institutional Review Board (IRB) approval was granted with stipulations from the University of Minnesota's IRB (see Appendix E for a copy of the IRB notice as it was received from the University of Minnesota). The researcher sent a letter in response to IRBs approval (Appendix F) requesting 180 participants, double that of the original request; the request was accepted (Appendix G). Because the study participants were under the age of 18, they received an assent form to take home to their parents (Appendix H) one week prior to the survey. The parents and/or guardians had up to one week to contact the researcher to remove their child from the research. Prior to data collection, the students were again told that their participation was voluntary, even if their parents consented (see Appendix I for a copy of the student assent form). All of the students in the surveyed classrooms were given a five dollar gift card regardless of participation. They were given the gift cards on the day of data collection.

Data Collection

Data collection began in the spring of 2009. A letter was sent to the three classroom teachers and district officials detailing the study and what was needed from them. From there, additional correspondence was needed with the school district's research coordinator and the classroom teachers to work out the details of the data collection. Survey packets were assembled by the researcher for use on the day of the data collection to ensure consistent and accurate testing preparation. The test was administered by the researcher in a group setting, according to the administration methods suggested by Wallach and Kogan. The researcher collected data from a total of two 8th grade and three 11th grade classrooms.

Data Analysis

The Statistical Package for the Social Sciences (SPSS) was used to analyze the data. For the WKCT, the dependent variables are the tests' subscales: fluency, flexibility and originality. The independent variables are grade level and gender. Analysis of the data collected from the survey instruments started with the analysis of fluency. Considering the number of surveys, it was important to reduce the time constraints on the judges; therefore, the researcher hand counted the fluency data. The fluency scores were recorded in a specified area at the bottom of each survey, these numbers were then entered in SPSS.

The three judges and the researcher met for a day to discuss scoring flexibility and originality. The definitions for both flexibility and originality were discussed as well as the methods for scoring. After this introduction, the judges were each given copies of the pilot surveys and asked to score the responses for the first section (instances). The judges

compared the scores they awarded for both flexibility and originality. Where there were discrepancies, the judges talked through why they scored the question the way they did. This allowed the judges to hone their scoring processes. This was done for each consecutive survey section. As the surveys were returned to the researcher, the scores were entered into Microsoft Excel. It was at this time that missing values were identified and judges were prompted in responding to the absent values. The judges' scores were averaged, and individual scores were awarded for each question and for each participant. It was at this time that Cronbach's alpha was computed using the SPSS Reliability program to determine the consistency between the judges (see Table 3.1).

Chapter IV

Data Analysis

As described in the previous chapter, the data being reported upon in this chapter was gathered from two 8th grade and three 11th grade class rooms. The data collected were rated by three judges; individual scores were created as an average of the three judge's scores. This chapter will start with descriptive statistics, and continue on to presents the research findings using both quantitative and qualitative analysis. The quantitative section is broken down by research question, whereas the qualitative section is structured according to the three divergent thinking measures.

Descriptive Statistics

In this section descriptive statistics are presented and general trends are discussed. Mean scores were calculated for each of the surveys' sections (uses, similarities, and instances) for each of the measures (fluency, flexibility, and originality). Overall survey scores, when broken down by grade level and gender, showed that fluency and flexibility increased from 8th grade to 11th grade for both males and females, while the mean originality score in 11th grade students was less than that of 8th grade students. Fluency is higher among 8th grade females than 8th grade males; this is reversed in the 11th grade, where males are more fluent than females. This information is in Table 4.1.

Table 4.1 *Total Fluency, Flexibility and Originality Scores*

	Grade 8				Grade 11			
	<u>Male</u>		<u>Female</u>		<u>Male</u>		<u>Female</u>	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Fluency	7.63	4.00	8.19	3.96	8.32	2.75	8.27	2.77
Flexibility	2.59	0.76	2.63	0.73	2.78	0.52	2.75	0.55
Originality	2.17	0.69	2.19	0.75	2.02	0.48	1.95	0.51

To further describe the data, fluency has been broken down by the three survey sections (uses, similarities, and instances). Table 4.2 provides the mean fluency scores. In the uses category, both males and females increased their fluency from 8th to 11th grade. Males showed a larger increase, (7.20 to 8.46) than females (8.00 to 8.33). Males in 11th grade scored higher than females, whereas for 8th grade the opposite is true, so females scored higher than males. Overall in the similarities category, females (5.97 to 6.00) scored higher than males (5.18 to 5.70). Eighth grade females (5.97) had a higher mean score than 11th grade males (5.7). In the instances category for fluency there is little difference in the mean score between 8th grade females (10.61) and males (10.67). The same is true for the 11th grade females (10.54) and males (10.70).

Table 4.2 *Fluency Scores by Survey Section*

		Uses		Similarities		Instances	
		<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Grade	Female	8.00	4.46	5.97	3.09	10.61	5.15
8	Male	7.20	3.33	5.18	2.89	10.67	6.53
Grade	Female	8.33	2.98	6.00	2.37	10.54	3.93
11	Male	8.46	3.01	5.70	2.30	10.70	4.44

Flexibility has also been broken down by the three survey sections (uses, similarities, and instances). Table 4.3 provides the average flexibility scores according to survey section. Flexibility scores in the uses section reported that 8th grade females (2.85) had a higher mean score than did 8th grade males (2.63); the opposite was true for 11th graders. In the similarities section, the flexibility scores were slightly higher among females at the 11th grade level than females at the 8th grade level. The instances section showed very little difference between 11th grade females (2.85) and 11th grade males (2.86); whereas in the 8th grade, females (2.96) scored higher than 8th grade males (2.72).

Table 4.3 *Flexibility Scores by Survey Section*

		Uses		Similarities		Instances	
		<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Grade	Female	2.85	0.79	2.50	0.79	2.96	0.77
8	Male	2.63	0.80	2.30	0.79	2.72	0.78
Grade	Female	2.90	0.65	2.51	0.61	2.85	0.64
11	Male	2.96	0.59	2.51	0.65	2.86	0.55

Originality has also been broken down according to the three survey categories (uses, similarities, and instances). Table 4.4 provides the average originality scores.

Originality scores in the uses section recorded 8th grade females (2.53) had a higher mean score than 8th grade males (2.16), where the opposite was true in 11th grade when males (2.19) had a higher mean score than females (2.01). In the similarities section, 8th grade females (2.25) scored higher than did 8th grade males (1.93). The 11th grade originality scores in the similarities section reflected only a small difference between male (1.90) and female (1.86) mean scores. In the instances section, 8th grade females (2.40) scored higher than 8th grade males (2.27); there was little difference between males (2.04) and females (2.03) in the 11th grade.

Table 4.4 *Originality Scores by Survey Section*

		Uses		Similarities		Instances	
		<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Grade	Female	2.53	0.87	2.25	0.72	2.40	0.86
8	Male	2.16	0.82	1.93	0.64	2.27	0.76
Grade	Female	2.01	0.69	1.86	0.55	2.03	0.73
11	Male	2.19	0.69	1.90	0.59	2.04	0.70

Quantitative

Correlations

Correlation analyses were conducted among the dependent variables (fluency, flexibility and originality). All of the dependent variables were significantly correlated with one another. The highest significant correlation (.838) was between flexibility and originality. Similarly, fluency and flexibility were also correlated (.580). Originality and fluency were also significantly correlated (.439). The results from the analyses are presented in Table 4.5

Table 4.5 *Inter-Correlation of Dependent Variables Table*

Items	<i>N</i>	<i>1</i>	<i>2</i>	<i>3</i>
1. Fluency	169			
2. Flexibility	169	.580	**	
3. Originality	169	.439	**	.838

** Correlation is significant at the 0.01 level (2-tailed)

In some studies, researchers have combined all three variables, yielding a result that would be an average standard score, which is an indicator of overall creative strength (Torrance, 1990). In other studies, example Dudek et. al (1993), the high redundancy between production scores resulted in a simplified analysis where scores were averaged and replaced with *z* scores and renamed.

Research Questions

Research Question 1

- Are there gender differences in fluency of responses, flexibility of responses, or originality of responses?

To answer this question, 3 one-way ANOVAs were computed. The first analyzed the between-subjects effects of fluency and gender. There are no gender differences when fluency is considered, as shown in table 4.6.

Table 4.6 *Analysis of Variance: Fluency and Gender*

Source	<i>Type III Sum</i>				
	<i>of Squares</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>Sig.</i>
Gender	2.901	1.000	2.901	.298	.586

a. $R^2 = .002$ (Adjusted $R^2 = -.004$) R^2

The second ANOVA computation analyzed the between subjects effects of gender and flexibility. No gender differences were found as reported in Table 4.7.

Table 4.7 *Analysis of Variance: Flexibility and Gender*

Source	<i>Type III Sum</i>				
	<i>of Squares</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>Sig.</i>
Gender	.093	1.000	.093	.255	.614

a. $R^2 = .002$ (Adjusted $R^2 = -.005$)

Another ANOVA analyzed the between-subjects effects of gender and originality (table 4.8). There was no significant interaction between originality and gender.

Table 4.8 *Analysis of Variance: Originality and Gender*

Source	<i>Type III Sum</i>				
	<i>of Squares</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>Sig.</i>
Gender	.486	1.000	.486	1.539	.217

a. $R^2 = .009$ (Adjusted $R^2 = .003$)

To further analyze research question 1, separate ANOVAs were run based on the fluency, flexibility and originality scores in each of the three sections of the survey (uses, similarities and instances).

The first of these ANOVAs was computed based on the average fluency score for the uses section of the survey. There was no significant relationship between fluency in the uses section of the survey and gender, as shown in Table 4.9.

Table 4.9 *Analysis of Variance: Fluency in Uses Section and Gender*

Source	<i>Type III Sum</i>				
	<i>of Squares</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>Sig.</i>
Gender	6.390	1.000	6.390	.632	.428

a. $R^2 = .004$ (Adjusted $R^2 = -.002$)

The second ANOVA was computed based on the average fluency score for the similarities section of the survey. Table 4.10 reports no significant relationship between fluency in the similarities section of the survey and gender.

Table 4.10 *Analysis of Variance: Fluency in Similarities Section and Gender*

Source	<i>Type III Sum</i>				
	<i>of Squares</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>Sig.</i>
Gender	11.414	1.000	11.414	1.816	.180

a. $R^2 = .011$ (Adjusted $R^2 = .005$)

Another ANOVA was computed based on the average fluency score for the instances section of the survey. There was no significant relationship between fluency in the instances section of the survey and gender (Table 4.11).

Table 4.11 *Analysis of Variance: Fluency in Instances Section and Gender*

Source	<i>Type III Sum</i>				
	<i>of Squares</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>Sig.</i>
Gender	.804	1.000	.804	.036	.850

a. $R^2 = .000$ (Adjusted $R^2 = -.006$)

The same procedure was used for flexibility scores. Three separate ANOVAs were computed for flexibility in each of the three survey sections (uses, similarities and instances).

The first of these ANOVAs was computed based on the average flexibility scores for the uses section of the survey (Table 4.12). There was no significant relationship between flexibility in the uses section of the survey and gender.

Table 4.12 *Analysis of Variance: Flexibility in Uses Section and Gender*

Source	<i>Type III Sum</i>				
	<i>of Squares</i>	<i>Df</i>	<i>MS</i>	<i>F</i>	<i>Sig.</i>
Gender	.230	1.000	.230	.492	.484

a. $R^2 = .003$ (Adjusted $R^2 = -.003$)

The second of these ANOVAs was computed based on the average flexibility scores for the similarities section of the survey. Table 4.13 shows no significant relationship was found between flexibility in the similarities section of the survey and gender.

Table 4.13 *Analysis of Variance: Flexibilities in Similarities Section and Gender*

Source	<i>Type III Sum</i>				
	<i>of Squares</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>Sig.</i>
Gender	.378	1.000	.378	.842	.360

a. $R^2 = .005$ (Adjusted $R^2 = -.001$)

The third ANOVA was calculated based on the average flexibility scores in the instances section of the survey. Table 4.14 shows that there was not a significant relationship between flexibility scores in the instances section of the survey and gender.

Table 4.14 *Analysis of Variance: Flexibilities in Instances Section and Gender*

Source	<i>Type III Sum</i>				
	<i>of Squares</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>Sig.</i>
Gender	.168	1.000	.168	.392	.532

a. $R^2 = .002$ (Adjusted $R^2 = -.004$)

Originality scores were also broken down into the three survey sections (uses, similarities, and instances) and ANOVAs computed.

Average originality in the uses section of the survey was computed (Table 4.15). There was no significant relationship between originality in the uses section of the survey and gender.

Table 4.15 *Analysis of Variance: Originality in Uses Section and Gender*

Source	<i>Type III Sum</i>				
	<i>of Squares</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>Sig.</i>
Gender	.421	1.000	.421	.776	.380

a. $R^2 = .005$ (Adjusted $R^2 = -.001$)

An ANOVA was calculated based on the average originality scores in the similarities section of the survey (Table 4.16). According to the results, there is not a significant relationship between originality scores in the similarities section of the survey and gender.

Table 4.16 *Analysis of Variance: Originality in Similarities Section and Gender*

Source	<i>Type III Sum</i>				
	<i>of Squares</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>Sig.</i>
Gender	.000	1.000	.000	.000	1.000

a. $R^2 = .000$ (Adjusted $R^2 = -.006$)

An ANOVA was computed for originality in the instances section of the survey and gender. The results revealed that there is not a significant relationship between gender and originality in the instances section (Table 4.17).

Table 4.17 *Analysis of Variance: Originality in Instances Section and Gender*

Source	<i>Type III Sum</i>				
	<i>of Squares</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>Sig.</i>
Gender	.135	1.000	.135	.244	.622

a. $R^2 = .001$ (Adjusted $R^2 = -.005$)

Further analyses were conducted to determine if individual survey questions revealed a relationship between gender and fluency, flexibility, and originality scores. Separate ANOVAs were computed based on the fluency, flexibility, and originality of individual questions to test the effect of gender.

ANOVAs were conducted for fluency for each survey question to determine if a relationship exists between fluency on a particular question and gender. After running the nine separate ANOVAs for fluency of each question, results showed there is a relationship between fluency score on the question “name all the uses you can think of

for an orange” and gender, $F(1,165) = 5.226$, $MSE = 8.081$, $p\text{-value} = .024$. The females had a higher mean score (7.2556) than did the males (6.2468). Females provided more responses when asked to “name all the uses you can think of for an orange.”

ANOVAs were conducted for flexibility scores for each survey question to determine if a relationship exists between flexibility on an individual question and gender. The analyses determined that there were no effects between flexibility of a particular question and gender.

ANOVAs were conducted for originality scores for each survey question to determine if a relationship exists between originality on an individual question and gender. The analyses revealed a relationship between the question “uses of a brick” and gender, $F(1,165) = 5.174$, $MSE = .823$, $p\text{-value} = .024$.

Research Question 2

- Are there grade level differences in fluency of responses, flexibility of responses, or originality of responses?

In order to answer this question, 3 one-way ANOVAs were computed with each of the three dependent variables (fluency, flexibility, and originality). The first ANOVA analyzed the variance of fluency scores by comparing them against grade level. There were no significant grade level differences between fluency scores (Table 4.18).

Table 4.18 *Analysis of Variance: Fluency and Grade Level*

<i>Type III Sum</i>					
<i>Source</i>	<i>of Squares</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>Sig.</i>
Grade Level	7.198	1.000	7.198	.747	.389

a. $R^2 = .004$ (Adjusted $R^2 = -.002$)

To further analyze this question, the fluency scores of a particular survey section (uses, similarities, and instances) were compared to grade level. No significant grade level differences were found (Tables 4.19, 4.20, 4.21).

Table 4.19 *Analysis of Variance: Fluency in Uses Section and Grade Level*

<i>Type III Sum</i>					
<i>Source</i>	<i>of Squares</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>Sig.</i>
Grade Level	29.874	1.000	29.874	3.020	.084

a. $R^2 = .018$ (Adjusted $R^2 = .012$)

Table 4.20 *Analysis of Variance: Fluency in Similarities Section and Grade Level*

<i>Type III Sum</i>					
<i>Source</i>	<i>of Squares</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>Sig.</i>
Grade Level	8.271	1.000	8.271	1.325	.251

a. $R^2 = .008$ (Adjusted $R^2 = .002$)

Table 4.21 *Analysis of Variance: Fluency in Instances Section and Grade Level*

<i>Type III Sum</i>					
<i>Source</i>	<i>of Squares</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>Sig.</i>
Grade Level	.481	1.000	.481	.022	.883

a. $R^2 = .000$ (Adjusted $R^2 = -.006$)

To analyze the question of whether a relationship exists between flexibility and grade level, an ANOVA was conducted. No significant grade-level differences were found for flexibility (see Table 4.22).

Table 4.22 Analysis of Variance: Flexibility and Grade Level

<i>Type III Sum</i>					
Source	<i>of Squares</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>Sig.</i>
Grade Level	.797	1.000	.797	2.230	.137

a. $R^2 = .013$ (Adjusted $R^2 = .007$)

To further analyze the question of whether a relationship exists between flexibility and grade level, ANOVAs were conducted based on flexibility scores as an average for each survey section. The uses section (questions 1-3) were averaged to create a uses flexibility score and compared to grade level. The same was done for the other two sections of the survey: similarities (questions 4-6) and instances (questions 7-9).

The flexibility scores for the uses section do not have a significant relationship with grade level, as seen in Table 4.22.

Table 4.23 Analysis of Variance: Flexibility in Uses Section and Grade Level

<i>Type III Sum</i>					
Source	<i>of Squares</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>Sig.</i>
Grade Level	1.629	1.000	1.629	3.564	.061

a. $R^2 = .021$ (Adjusted $R^2 = .015$)

The flexibility scores in the similarities section and grade level are not significant at the alpha 0.5 level with grade level. However with a 0.061 significance, this finding is noteworthy, as seen in Table 4.23. The 11th grade participants had a higher mean

flexibility score in the similarities section of the survey (2.9074) than did the 8th grade participants (2.6853).

Table 4.24 *Analysis of Variance: Flexibility in Similarities Section and Grade Level*

Source	<i>Type III Sum</i>				
	<i>of Squares</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>Sig.</i>
Grade Level	.855	1.000	.855	1.939	.166

a. $R^2 = .011$ (Adjusted $R^2 = .006$)

Grade level did not have a significant relationship with the flexibility scores in the instances section, as seen in table 4.24.

Table 4.25 *Analysis of Variance: Flexibility in Instances Section and Grade Level*

Source	<i>Type III Sum</i>				
	<i>of Squares</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>Sig.</i>
Grade Level	.109	1.000	.109	.254	.615

a. $R^2 = .002$ (Adjusted $R^2 = -.005$)

An ANOVA was run to analyze whether a relationship between originality and grade level exists. The results showed that there is a relationship between grade level and originality, $F(1,167) = 4.45$, $MSE = .308$, $p\text{-value} = .036$. Participants in the 8th grade had a mean score of 2.1756; 11th grade participants had a mean score of 1.9719.

Table 4.26 *Analysis of Variance: Originality and Grade Level*

Source	<i>Type III Sum</i>				
	<i>of Squares</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>Sig.</i>
Grade Level	1.369	1.000	1.369	4.450	.036

a. $R^2 = .026$ (Adjusted $R^2 = .020$)

To further analyze the significance found between originality score and grade level, separate ANOVAs were conducted to determine if this was true for all survey sections. There was no significance found between originality scores in the uses section and grade level, as seen in Table 4.26.

Table 4.27 *Analysis of Variance: Originality in Uses Section and Grade Level*

Source	<i>Type III Sum</i>				
	<i>of Squares</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>Sig.</i>
Grade Level	1.045	1.000	1.045	1.957	.164

a. $R^2 = .012$ (Adjusted $R^2 = .006$)

An ANOVA was computed to determine if there is a significant relationship between originality scores in the similarities section and grade level; a significant relationship was not found. See table 4.27.

Table 4.28 Analysis of Variance: Originality in Similarities Section and Grade Level

Source	<i>Type III Sum</i>				
	<i>of Squares</i>	<i>Df</i>	<i>MS</i>	<i>F</i>	<i>Sig.</i>
Grade Level	.638	1.000	.638	1.812	.180

a. $R^2 = .011$ (Adjusted $R^2 = .005$)

An ANOVA computed for originality score in the instances section and grade level was significant, $F(1,165) = 4.398$, $MSE = .533$, $p\text{-value} = .038$. The mean score for the 8th grade participants originality score in the ‘instances’ section was 2.301, which is higher than the 11th grade participants (2.032).

Table 4.29 Analysis of Variance: Originality in Instances Section and Grade Level

Source	<i>Type III Sum</i>				
	<i>of Squares</i>	<i>df</i>	<i>Mean Square</i>	<i>F</i>	<i>Sig.</i>
Grade Level	2.344	1.000	2.344	4.398	.038

a. $R^2 = .026$ (Adjusted $R^2 = .020$)

To further analyze the significant relationship between originality scores and grade level, ANOVAs were computed on a per question basis. Two individual questions had significant findings. There is a significant relationship between grade level and the question about similarities between “an apple and a bar of chocolate,” $F(1,167) = 8.956$, $MSE = .424$, $p\text{-value} = .003$. The younger participants had higher mean originality scores (2.1264) than did the older participants (1.7873). There was also a significant relationship between grade level and the survey question asking participants to list things that rotate,

$F(1,165) = 4.137$, $MSE = .704$, $p\text{-value} = .044$. The mean score for 8th grade participants (2.3189) was higher than for 11th graders (2.0191). The finding that younger students had higher originality scores is consistent with functional fixedness theory which claims that older children are less prone to deviate from the standard function of artifacts (German & Johnson, 2002; German & Defeyter, 2000).

Qualitative

The following qualitative report is structured according to the three dimensions across which divergent thinking can be measured as set forth by Wallach and Kogan, and as was reflected in the questionnaire for this study, namely *uses*, *similarities*, and *instances*. As indicated earlier, three measures of divergent thinking—fluency, flexibility, and originality, were considered across these dimensions.

The creative responses reported in this section have been chosen because they received the highest marks for originality. While the judges' scores determined which participants' responses were the most original, it is important to note that not all of the participants' responses have been listed. The more common responses were omitted.

Uses

The uses category was comprised of three questions; the uses for *a brick*, the uses for *an orange*, and the uses for *a lake*. The following paragraphs will break down each of these three questions, summarizing types of common responses and the responses that were rated as original by the judges.

Brick.

Common responses for “indicate all of the ways in which you can use a brick” dealt with building various items such as a wall, a house, or buildings. Violence was another common theme that used words such as hitting, throwing, and breaking. A third common response was to use the brick as a weight: a door stop, a paper weight, or to weigh something down.

In reading through the responses given for uses for a brick, it could be said that the 11th grade students were more likely to give a longer list of specific things which they would build, whereas the 8th grade students seemed to simply state that they would build something. Most listed a few items and moved on.

The original responses for “indicate all of the ways in which you can use a brick” are highlighted in the tables below. The first table, 4.30, highlights a few of the original responses given by 8th grade students. Examples include “use it as a bomb to attack an ancient city of monkeys” and “use it to find how many feathers weigh the same as the brick.” The originality score is shown in the first column of the table below.

Table 4.30 *Brick Original Responses 8th Grade*

Score	Survey #	Gender	Response
4.33	9	Female	use it as a bomb to attack an ancient city of monkeys tie it to someone's leg as a joke throw it down the toilet to see if it will go down use it to find how many feathers weigh the same as the brick carve it as something pretty to put in your room sharpen it, and use it as a hunting weapon
3.67	26	Male	a support for a broken couch, chair, etc a replacement foot a firework launch pad a toy soldier barricade
4.00	23	Male	to stand up higher games that you can improvise to wall away someone you don't like make holes in the ground
3.67	20	Male	part of a well use as a toy: a wall, a tower, a truck, a submarine, a building a way to disguise a gifts weight a book end an instrument (bang against stuff)
3.67	22	Male	just having it around causing a Macintosh system to fail throwing it at evil teachers compressing old papers sharpening a knife

The 11th graders' top five original responses for the question about a brick are listed in order of highest originality scores in Table 4.30. Males received the top score at 4.67 with answers such as "wrecking ball" and "you could put a brick on the gas pedal of a car to scare everyone around you to think that a ghost is driving your car."

Table 4.31 *Brick Original Responses 11th Grade*

Score	Survey #	Gender	Response
4.67	53	Male	play catch/ medicine ball wrecking ball Volvo styling inspiration throw through the window of a burning building if yellow a memento for Dorothy
4.67	96	Male	you could put a brick on the gas pedal of a car to scare everyone around you to think that a ghost is driving your car you could solder a big dowel into one of the holes in the brick and turn it into a hammer you could pretend to use a brick as a pair of binoculars
4.33	103	Male	to sing "Brick House" as a demonstration tool for those of Asian descent to tie to someone's leg if your trying to drown them to use in analogies when referencing dumb people
4.33	122	Female	brick museum really heavy sweater a friend character on Sesame Street Mr. Brickly is really tricky dentist (will break your teeth)
4.00	12	Female	for extra weight as in shipping to test balance as a type of sand paper measure things (water) to identify a color (brown)

Orange.

The second question in the uses category was “indicate all of the ways in which you can use an orange.” The most common answers fell in the category of food, such as

eat it, use it for food, and make juice. A second type of common answer involved using it as a projectile, as seen in responses like throw it or use it as a ball.

Original responses for the uses of an orange for the 8th grade students are in Table 4.31. The top scorer was a female, with a score of 4.0 out of 5.0. It is important to note that while she received the highest originality score, the list of her original responses is in no particular order, which is true of all responses in the Original Responses tables. A sample of original answers included “pretend it’s a planet in a diagram” and “chuck it at the Germans and start WWII.”

Table 4.32 *Orange Original Responses 8th Grade*

Score	Survey #	Gender	Response
4.00	5	Female	make a Cub ad with it color it ruin someone's shirt color something orange pretend it's a planet in a diagram stuff your bra for fake boobs
3.33	8	Female	Poison prop in a show throw at bad actors ruin camera equipment make paintings make cleaner
3.33	9	Male	pour the orange juice all over your sister's homework so it gets sticky chuck it at the Germans and start WWII drop it from a really tall building in a plot to assassinate someone
3.33	13	Male	see how high it bounces use it to teach how to find the volume of irregular objects (water displacement) use it to study plant genetics
3.33	16	Female	blind someone maybe to power ears with the juice as a fragrance (burning peels)

The original responses for the 11th grade students are in Table 4.32. A male received the highest originality scores with 5.0 out of 5.0, while the rest of the top five scorers were female. Some examples include using the orange as “ammo (slingshot/catapult)” and “buy it a plane ticket and send it to Florida to see its family.”

Table 4.33 *Orange Original Responses 11th Grade*

Score	Survey #	Gender	Response
5.00	10	Male	torture device (eyes, open wound) seeds to plant a tree bait for an animal (hunting?) cleaning device (citric acid) color reference ammo (slingshot/catapult) testing knife sharpness (advertising!)
4.67	122	Female	fruit basket Compost check if a table is level a really bad television show check acidic energy
4.33	102	Female	use the peel as a boat for a bug feed it to a monkey keep it as a pet buy it a plane ticket and send it to Florida to see its family
4.00	2	Female	to blind someone to help get rid of/prevent a cold floatation device for very small objects writing secret messages roll otherwise heavy object atop many many oranges
4.00	19	Female	solar system model use it to learn colors or numbers wear it as a clown nose use it for a magic trick use it to make a "homemade" facial, shampoo, etc.

Lake.

The final survey question in the Uses category was “indicate all the ways in which a lake can be used.” The great majority of answers involved recreation with the most common uses of a lake including examples such as swimming, boating, and fishing.

The original responses for the lake question for the 8th grade participants are listed in Table 4.33. The three with a score of 4.00 are displayed in no particular order, since all of them had the same score. Sample responses include “pull the plug out and see what happens” and “marine warfare simulations.”

Table 4.34 *Lake Original Responses 8th Grade*

Score	Survey #	Gender	Response
4.33	9	Female	create a secret hideout under it test a submarine pull the plug out and see what happens get a hose and see how long it takes to flood put a lot of fruit into it, and make a giant fruit smoothie see how many people can stand in it see how much homework can be ruined in it
4.00	8	Female	fill with alligators for a set holding injured animals testing bullet trajectory busting myths use as a reserve for planned explosions bird watching marine warfare simulations rehabilitation of endangered species proving people can walk on water
4.00	2	Male	location to put a top secret government base that experiments with U.S.O's (unidentified submerged objects) a safe haven for Aquaman suicidal attempts
4.00	20	Male	farming algae military base place for a resort source of revenue tours tourist attraction
3.67	16	Male	power houses to use the algae for food water fields to heat houses (power heaters) quick way to travel to cool objects to grow rice

The 11th grade students top 5 original response are listed in Table 4.34. The top five all had the same score, so the surveys are listed in no particular order. Original responses for uses of a lake among 11th graders included “disposing of corpses” and “a point on a map or something to give one's location.”

Table 4.35 *Lake Original Responses 11th Grade*

Score	Survey #	Gender	Response
4.00	2	Female	disposing of corpses releasing snapping turtles dying because you drove your car/walked out onto thin ice emergency landing in a glider/airplane breeding ground for mosquitoes
4.00	48	Male	make a jump and see if your car can fly triathlon (the swim part) murder romance snow shoeing pick up some bitties
4.00	61	Female	show wealth become part of a state park and protect land around it a point on a map or something to give one's location habitat for animals
4.00	67	Male	irrigate farmland study marine life stabilize nearby temperature rent it skate on it
4.00	103	Male	for a submarine testing facility lame scuba diving synchronized swimming Aquaman headquarters

Similarities

The similarities category is comprised of three questions: the similarities between an apple and a bar of chocolate, an elevator and a train, and a pizza and the sun. In the following paragraphs and tables, the responses, both original and common, will be summarized.

Apple and a Bar of Chocolate.

When asked to list all of the ways in which an apple and a bar of chocolate are similar, participants most commonly came up with qualities relating to food and taste. Food responses included both are edible, can eat both, and can use both as food. Taste responses were generally phrased as both taste good or both are sweet.

The original responses for the similarities question between an apple and a bar of chocolate for the 8th grade students are laid out in Table 4.35. The highest scorers were females at 3.67, with only one male making the top five. High-scoring responses included “both can be changed in their making (genetic modifications, different chocolate recipes)” and “can’t fly unless wings strapped on.”

Table 4.36 *Apple and Chocolate Original Responses 8th Grade*

Score	Survey #	Gender	Response
3.67	6	Female	both have been eaten for centuries both cannot be collected both can be changed in their making (genetic modifications, different chocolate recipes) both can be associated with evil (Adam and Eve, 'dark' chocolate)
3.67	9	Female	crunchy are not living can't fly unless wings strapped on can make music with both get rotten make clothing out of both
3.33	1	Female	can taste it can be brown Death Gods like apples and chocolate inside an apple is white - white chocolate both words have "a's", "I's", and "e's". are mentioned in this survey
3.33	23	Male	not imported have a wrapping small enough to hold both can be red both will be brown
3.00	8	Female	both dessert both include pesticides mentioned in Twilight have a long shelf life can be poisoned

The original responses from the 11th grade students for the question about the similarities between an apple and a bar of chocolate are listed in Table 4.36. Of the top scorers, four were female and no one received a score higher than 3.33. Original

responses included “can choke on both” and “used to tempt (Adam - Eve = apple, fat person = chocolate).”

Table 4.37 *Apple and Chocolate Original Responses 11th Grade*

Score	Survey #	Gender	Response
3.33	61	Female	good part of a healthy diet different kinds of each can choke on both comes in clear-ish plastic bags
3.33	122	Female	sometimes bitter can be used for injury can be used for joy used to tempt (Adam - Eve = apple, fat person = chocolate) can be hard on teeth
3.00	19	Female	both get old (not edible anymore) liked by many people have a center both could be red, green, yellow, etc inexpensive
3.00	53	Male	helps you buy less at the grocery store if eaten before bribes for little children come from nature transported across the world
3.00	81	Female	fondue (both used in) fill you up make you happy Halloween activities (bobbing for apples and trick-or-treating) kids love them may be in your lunch box may get in the fall (apple picking & Halloween)

Elevator and Train.

Another question in the similarities category asked participants to list all of the ways in which an elevator and train are similar. The most common answers involved transportation and movement, such as both transport people, both are forms of transportation, and both move.

The top five 8th grade originality scores for the similarities question about an elevator and a train are listed in Table 4.37. A female received the highest score of 4.0. Her answers included “both require a fuel source” and “both can be fears.”

Table 4.38 *Elevator and a Train Original Responses 8th Grade*

Score	Survey #	Gender	Response
4.00	6	Female	both go either vertical or horizontal both require a fuel source both can be fears both can have different meanings (train of ducklings, drugs as elevators)
3.67	9	Female	taken apart and put back together smell good or bad beg mom for food in both can get something stolen from you in both
3.00	17	Male	have amusement park rides that are modeled after these devices have multiple stops
2.67	34	Female	lots of people use it can be crowded can carry hundreds of pounds
2.67	13	Male	move in two directions a mechanic can fix both of them they both can have bumpy rides some carry advertising pictures/posters on them

If the top five original responses for the 11th grade participants, four were male, and they gave answers like “both are full of people,” “both rely heavily on computers,” and “both can be good places to meet hot girls.” The full list of the top five original responses for the 11th graders is in Table 4.38.

Table 4.39 *Elevator and a Train Original Responses 11th Grade*

Score	Survey #	Gender	Response
3.67	18	Male	you use elevators in subway stations both were invented in England both were invented after 1700 there are elevators made by Otis and there is a train station in Otis, Colorado
3.67	43	Male	both bad places to fart both are full of people both can be good places to meet hot girls both invented by white people
3.67	103	Male	both are usually crowded in scary movies, the lights are turned out in both of these places both have interesting homicide and suicide capabilities
3.67	122	Female	take you somewhere have "crossing paths" (-door let people in/out, - train tracks) Songs... Get on my Elevator, Start a Love Train invented in the last three centuries
3.33	6	Male	both can kill you if they malfunction neither are safe to be on during a catastrophe both rely heavily on computers I've been on both both have annoying music playing

Pizza and the Sun.

When asked to list all of the ways you can think of in which a pizza and the sun are similar, the majority of respondents came up with answers involving shape and temperature. The common answers given were, both are round, both have circles, and both are hot.

The 8th grade participants with the highest originality scores for the question about the similarities between a pizza and the sun are listed in Table 4.39. The highest score of 4.00 was awarded to a male who had responses such as “can be seen in many countries across the world” and “takes about the same amount of time to cook a pizza as it does for sunlight to reach earth.”

Table 4.40 *Pizza and the Sun Original Responses 8th Grade*

Score	Survey #	Gender	Response
4.00	17	Male	are heated are circular shaped in drawings are in many movies at the same time takes about the same amount of time to cook a pizza as it does for sunlight to reach Earth are more than one of each can be seen in many countries across the world
3.67	4	Male	tempting to look at God to ancient civilizations (Egyptians) God to tongues of little kids makes you feel warm inside
3.67	20	Male	cheese on pizza can give you gas, sun made of gas have bubbles on surface sometimes
3.33	8	Female	possibly edible divisible signify happiness has spots can hurt you songs about both prominent in Cusco, Peru
3.33	18	Male	both appear round to us both can help us stay alive both are physical objects both burn

The top five original responses for the similarities question about a pizza and the sun are listed in Table 4.40. The top three of the top five were males with such responses as “glistening”, “both are symbols of life,” and “absorbed in one way or another.”

Table 4.41 *Pizza and the Sun Original Responses 11th Grade*

Score	Survey #	Gender	Response
4.00	10	Male	yellow in color with spots (pepperoni - sun spots) both are symbols of life allow for work (sun-farmers; pizza - delivery boys) sometimes unnecessarily large
4.00	67	Male	glistening distant to some rises best when hot surface not uniform can have ruptures on surface
3.67	21	Male	multiple people look at them daily absorbed in one way or another taken for granted on a daily basis
3.67	122	Female	hot colorful burn circle out of this world (pun) bring happiness too much is bad will eventually be gone
3.33	12	Female	picnic fun events comes and goes different types is everywhere

Instances

The instances category is also made up of three questions: participants listed all of the instances in which things are fast, things that provide energy, and things that rotate. In the following paragraphs and tables, the responses, both original and common, for these three questions will be summarized.

Things that are Fast.

In the instances category of the survey, the first question asked participants to write as many examples as they could think of for things that are fast. The most common answers involved motorized vehicles and animals. Common vehicles were cars, race cars, and airplanes, and the commonly cited animal was the cheetah.

The original responses for the 8th grade students for this question about things that are fast are listed in Table 4.42. The highest score was received by a male who gave answers such as “time in hindsight” and “ninjas.”

Table 4.42 *Fast Original Responses 8th Grade*

Score	Survey #	Gender	Response
4.67	20	Male	time in hindsight air currents ninjas how fast I am writing this thoughts
4.33	6	Female	volcanic eruptions auctioneers multiple people working on something versus just one hungry kids towards pizza little kids getting over fights adults getting into fights
4.00	4	Male	email blinking eye muscles when watching a movie ice cube melting in hand atoms
4.00	7	Female	implosion of a star -supernova time (especially when excited) skidding on ice reactions, especially chemical spaceships -Bender from Futurama dark matter passing death?
3.67	23	Male	a cheater history a guy with speed hacks how fast we got killed by an elite

The original responses for the instances in which things are fast for the 11th grade participants are listed in Table 4.42. Some of the original responses include “modern teenage girl,” “saying I love you on the first date,” and “the mouths of people that like to hear themselves talk.”

Table 4.43 *Fast Original Responses 11th Grade*

Score	Survey #	Gender	Response
4.67	122	Female	modern teenage girl the economy going down my pencil (powered by me) Jimmy Hendrix Shred AP courses
4.33	6	Male	the mind sneezes my handwriting bugs' lifespans my attention span late people surgery car crashes pain flash floods
4.00	98	Female	pizza delivery guy check out people at Target saying I love you on the first date the time it takes me to forget something kissing on the first date every orchestra piece from our last concert
4.00	99	Female	thing that is chasing you in a nightmare Energizer bunny my dog when she has something she shouldn't pizza delivery guy (he'd better be)
4.00	103	Male	those tiny little twitchy fish Sonic the Hedgehog the mouths of people that like to hear themselves talk Life

Things that Provide Energy.

The second question in the instances category was to give examples of things that provide energy. Common answers included food, the sun, batteries, and various types of electricity.

The original responses given by 8th graders to the question about things that provide energy are listed in Table 4.44. The top two scorers were female; they gave responses such as “spiritual pressure,” “disagreement,” and “adrenaline.”

Table 4.44 *Energy Original Responses 8th Grade*

Score	Survey #	Gender	Response
3.67	7	Female	release of kinetic energy orbit - gravity spiritual pressure splitting of an atom disagreement pepfest
3.67	14	Female	adrenaline fission/fusion money enthusiasm
3.67	23	Male	lightning magnets little kids organic material Static
3.33	17	Male	Lasers holding a ball (potential energy) explosions
3.33	19	Male	everything has energy and can provide it using formula $E = mc^2$ we can find out how much energy an object has

The 11th grade responses for things that provide energy included “compliments,” “being on stage,” “energetic teacher,” and “outlets.” The top five responses for this question are listed in Table 4.45.

Table 4.45 *Energy Original Responses 11th Grade*

Score	Survey #	Gender	Response
4.33	43	Male	compliments hot girls good food not going to school going to bed early Running Tobacco
4.33	86	Female	fats/lipids Starch being on stage little children mother to baby in womb energetic teacher Barack Obama
4.33	107	Female	hyper people rock music weekends parties compliments good night’s sleep
4.00	54	Female	hamsters (hamster’s wheel) war (energy to kill) discovery (energy to find more) outlets human curiosity friends (to keep going) brains (brain power)
3.67	52	Female	naps during English class energy boosts at Jamba Juice things that make you happy

Things That Rotate.

In the final instances question, respondents were asked to give examples of things that rotate. Planetary bodies were the most common answers, including the Earth, planets, sun, and moon. Other common answers were wheels and clocks.

The original responses for things that rotate from the 8th grade responders are listed in Table 4.46. Males held the top two places with answers such as “tectonic plates,” “job shifts,” and “karma.”

Table 4.46 *Rotate Original Responses 8th Grade*

Score	Survey #	Gender	Response
4.00	13	Male	Rubik's cube radar globe whirlpool karma dogs when chasing their tail
4.00	22	Male	planets "heavenly bodies" motors job shifts lava (convection) tectonic plates
3.67	5	Female	shapes in geometry Merry-go-rounds days of the week clothes I wear mood cycles music on an iPod
3.67	7	Female	protons/neutrons train of thought probability child in Duck, Duck, Goose
3.67	14	Male	Milky Way circular objects shifts at a certain plant money interests lighthouses light beacon

The top responses for 11th graders to the question about things that rotate are listed in Table 4.47. Only one male made the top five, and he gave answers such as “the pupils of pretentious people” and “the cycle of life in Buddhism.”

Table 4.47 Rotate Original Responses 11th Grade

Survey			
Score	#	Gender	Response
4.33	103	Male	pupils of pretentious people the buttocks or hips at a dance party the cycle of life in Buddhism Gatling gun
4.33	122	Female	your finger when you call someone crazy the Earth, moon, planets, etc drunkard patterns your heart when your in love (maybe not)
4.00	76	Female	rotisserie chicken cooker old fashioned slide projector square dance partners currents wind streams blood circulation
3.67	54	Female	galaxies rooms lives Earth spinning tops information the truth (changes with times, is spun and rotated to what people want to see or want to be seen) owl's heads tides, currents
3.67	99	Female	head of the girl in <i>The Exorcist</i> sunglasses display case revolving glass door pole dancer

When compiling the qualitative data, several observations were made. It could be said that participant responses started out slow, with fewer answers on the first

question(s) but subsequently seemed to warm up and were able to produce more ideas. It was also found that some participants who came up with an original response for a particular question began to repeat it for subsequent questions. For example, in the uses section a respondent may say that one thing you can do with a brick is look at it, then go on to say that you can look at an orange and you can look at a lake. Other examples of this appeared in the similarities category with responses like both are mentioned in this survey or they both contain certain letters. While these were original the first time, repetition quickly reduced the originality.

Furthermore there seemed to be fewer responses to the similarities questions. Maybe there was an inherent limitation due to the fact that the responses had to fall in line with two qualifications instead of just one. For example, participants may have found it easier to list many things that are fast than to find ways in which a pizza and the sun are similar.

Some respondent's answers had a recurring theme, like sex, drugs, killing or hitting. Some seemed to channel their responses more along an artistic vein, frequently listing decorative or artistic uses, similarities and instances. Others gravitated around movies or music.

Chapter V

Discussion

The purpose of this study was to examine whether the shortage of females in science and engineering is linked to possible gender-based differences in school-aged children's divergent thinking. Students in both 8th and 11th grade from Bloomington School district were surveyed. The WKCT, which has three test sections (uses, similarities, and instances) each containing three questions, was implemented. The results gathered from the 167 students were analyzed in an effort to answer two research questions set forth by this study. This chapter reviews the quantitative and qualitative findings, discusses the findings, reviews study limitations, and conclusions.

Quantitative

Research question one: Are there gender differences in fluency, flexibility, or originality of a response? As a whole, the findings revealed no significant relationship between gender and fluency, flexibility, or originality. However, more detailed analysis determined that gender and fluency score for the question "name all the uses you can think of for an orange" was correlated (0.024). When asked about the uses for an orange, females were more fluent; females gave an average of 7.2556 responses whereas males gave 6.2468 responses.

Research question two: Are there grade level (age) differences in fluency, flexibility, or originality of a response? The results of an ANOVA showed grade level and originality scores were highly correlated (0.036). The older, 11th grade students had a mean originality score of 1.9719 where the 8th grade students received a mean score of

2.1756. Further analyses determined that originality scores in the instances section of the survey were highly correlated (.038); the younger participants (8th grade) had a mean originality score in the instances section of 2.301 whereas the 11th grade participants had a mean score of 2.032. ANOVAs were computed on a per question basis. There is a significant relationship between grade level and the question about similarities between an apple and a bar of chocolate: $F(1,167) = 8.956$, $MSE = .424$, $p\text{-value} = .003$. The younger participants had higher mean originality scores (2.1264) than did the older participants (1.7873). There was also a significant relationship between grade level and the survey question asking participants to list things that rotate: $F(1,165) = 4.137$, $MSE = .704$, $p\text{-value} = .044$. The mean score for 8th grade participants (2.3189) was higher than for 11th graders (2.0191).

Flexibility and grade level were not found to be significantly correlated. However further analysis determined that depending on the survey section (instances, uses, and similarities), a noteworthy correlation was found. Flexibility in the uses section and grade level had a noteworthy correlation (0.061). The mean scores show that the 11th grade participants (2.9074) had higher flexibility scores than did the 8th grade participants (2.6853).

Qualitative

Qualitative reporting was used in this research to draw a verbal picture in order to describe the participants' responses. It is important to reiterate that this report focuses on the creative responses as determined by the judges quantitatively; the more common responses were omitted from the tables.

When recapping the qualitative data, several observations were made. Participants started out slowly, with fewer answers on the first question(s) but subsequently seemed to warm up and become more fluent.

When analyzing the qualitative data according to the test sections, there seemed to be fewer responses to the questions that fell within the similarities category. It is plausible that there was a limitation due to the fact that the responses had to fall in line with two qualifications instead of just one. For example, participants may have found it easier to list many things that are fast than to find ways in which a pizza and the sun are similar.

Several respondents' answers had recurring themes like sex, drugs, killing or hitting. Some seemed to channel their responses more along an artistic vein, frequently listing decorative or artistic uses, similarities and instances. Others gravitated around TV, movies, or music.

Discussion of the Findings

Based on the results of this research, the most important finding of this specific research study is that there is no difference between girls and boys on the three measures of divergent thinking (fluency, flexibility, and originality). In view of the fact that women are less likely than men to enroll in engineering related courses, this finding supports the notion that additional exposure to science and engineering through divergent-thinking activities will provide girls with the self-knowledge that they are capable of solving open-ended problems and engineering tasks. In addition to providing more opportunities in order to attract a more diverse population, it would be beneficial for science and

engineering curriculum to stress non-technical competencies, such as creativity skills and communication skills (Linn & Hyde, 1989).

This study's findings show there is no gender difference on the three measures of divergent thinking. This contradicts Klausmeier and Wiersma's (1964) study of 320 fifth and seventh graders of high IQ that revealed girls generally scored higher on tests of divergent thinking. Dudek et al. (1993) tested 1,445 children from grades 5 and 6, using the TTCT in agreement with Klausmeier and Wiersma's findings; girls in general scored higher than males on tests of divergent thinking. A more recent study in Hong Kong that used the WKCT found that boys had higher fluency scores (Chan et al., 2000-2001). Overall, Linn and Hyde (1989) may have been correct in stating that gender differences are not general but specific to situational and cultural frameworks.

It is interesting to note that there is a relationship between grade level and originality (.036). Younger participants (2.1756) were more likely than older participants (1.9719) to develop ideas different from most people's ideas. This ties into functional fixedness research performed by Defeyter, Avons, and German (2007) who found younger children's responses more flexible. In the research performed in this paper and that performed by Defeyter et al., all participants seemed to highlight an objects designed intent when brainstorming about possible uses; in both cases younger participants were more likely to produce novel ideas. Further research in this area (German & Barret, 2005) confirms that participants become functionally fixed based on an object's use, therefore making it difficult to produce uses for an object outside of that intended. Younger participants were less likely to become functionally fixed.

Chan et al. (2000-2001) researched ideational fluency using the WKCT and found that overall children of higher grades gave more responses than those of lesser grades. The study conducted in this research found no significant relationship between flexibility and grade level. However, separate univariate analyses revealed a noteworthy correlation between flexibility scores in the uses section and grade level. Older students were found to have a slightly higher flexibility score than their younger counterparts.

The only significant changes found in a longitudinal study by Claxton, et al. (2005) were a decrease in originality scores between the 4th grade and the sixth grade and an increase in elaboration scores between the sixth and ninth grades. Contrary to Claxton, Charles and Runco (2000-2001) the findings did not reveal a drop in divergent thinking among 4th graders. In fact in their raw fluency scores they saw an increase the 4th grade. While my research did not study the same age groups, it did reveal a significant loss of originality between 8th graders and 11th graders, the opposite was true in Charles and Runco's study. They discovered children's accuracy of their originality judgments increased significantly across the 3rd, 4th, and 5th grades. One could speculate that functional fixedness played a role or that students near the end of their K-12 education ruled out original responses for fear of deviating from the norm. The need for further research is without question.

Study Limitations

A shortcoming of this study concerns the sample. It would be desirable to collect larger samples of both males and females, of various ages, from more than one school district. It should be noted that the participants were given a time limit in which to

complete the survey; this could also be viewed as a limitation. Leniency was used in scoring participants responses. During the scoring process, nonsensical responses were found and counted.

Conclusions

This study contributed to the research community by reviewing decades of literature and pinpointing the importance of creativity and how it got its start as a field of research to current research methods, instruments, and consequently the relevant findings. Two major findings came forth from this body of research: 1) there are no gender differences in divergent thinking, but there are grade level differences in one's ability to be original, and 2) younger students had higher originality scores than did the older students.

Recommendations and implications

It is important to inquire as to why these two main results exist. Is it as Defeyter, Avons, and German (2007) say: do we teach the creativity out of our students? Do they become fixated on an object's function and have a hard time coming up with other novel solutions?

This study used the verbal portion of the WKCT. Past research has shown that grade level and gender effects apply differently to verbal and figural fluencies (Chan et al., 2000-2001). If research by German et al (2007) is correct in saying that subjects become fixed on an object's purpose which hinders their functional fluency, it seems that testing creativity using objects with known uses would result in questions of dependability.

These results indicate little reason as to why participation in science and engineering is male dominated. It should be of key concern for science and engineering educators to continue to focus professional development and curriculum on attracting all potential prospects. As educators become more informed as to the diverse jobs of today's scientists and engineers they will be better equipped to develop engaging curriculum. More needs to be done to ensure engineering design teams reflect the diversity of today's customers (Ihsen, 2005).

During a visit with my high school guidance counselor I was informed about a trip to the local cosmetology school for all the girls. I went with a handful of my girlfriends and a few of them joined without hearing other options. The good thing is they got an education; the bad thing is that the stereotypes of the day set their course for life. While these stereotypes have definitely improved, guidance counselors and principals must know that creativity (divergent thinking) is not gender specific but is an essential trait for scientists and engineers.

Creativity is emphasized globally as one of the most important goals of education (Rabari, Indoshi, & Okwach, 2011). Martin (2006) describes creativity as discovering or inventing something new, valuable, and purposefully made. Every day scientists and engineers deal with problems that have abundant potential solutions. People must improve their creative and problem solving abilities in order to develop technological improvements and utilize them in today's continuously changing world. Solving these types of complex problems requires the creation of a variety of new and original potential solutions, using divergent thinking and problem solving (Baillie, 2002, Mowry, 2004,

Hsiao & Liang, 2003). Today's classrooms are in desperate need of activities geared towards teaching these traits across all curriculums, regardless of gender.

According to DeHaan (2009) students need to be shown how to be creative by promoting cognitive flexibility, he encourages imagination, and supports questioning of one's own assumptions using inquiry based teaching. DeHaan is not alone; many other researchers also believe fostering creativity is important and has the potential to improve divergent thinking and problem solving skills (Lau, Ng, & Lee, 2009; Fawcett & Hay, 2004, Karkockiene, 2005).

Professional development will play a crucial role in preparing teachers to include divergent thinking activities into today's curriculum. Fawcett and Hay (2004) encourage collaboration, stating that professional development is the foundation and should be attended by all educators in order to establish effective teaching models and activities. The heart of these professional development models lies in teaching educators to be enablers, who attend to students' creations, their creative development, and the communication of their creative ideas.

Exactly what these divergent thinking and problem solving activities will look like remains to be determined; what researchers like DeHann (2009) and Fawcett and Hay (2004) have given us is the foundation for encouraging creativity. Across the curriculum, classrooms of today should focus on teachers who model creativity, where constantly questioning assumptions is awesome because students are focusing on what questions to ask rather than learning the answers by rote. No one should be criticized for a response because the class as a whole understands the importance of broadening ideas

and concepts based on new points of view. Putting all of these things into a classroom curriculum that avoids teaching from subject area boxes will promote creativity and integration of subjects across the curriculum.

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Research Journal, *37*(1), 215-246.

Appendix A

Research Request Form: Bloomington Public Schools

Research Request Form

Bloomington Public Schools

Department of Research & Evaluation

Name: Leah Roue _____ **Date:** Sept 22, 2008

Address: College of Education and Human Development

1954 Buford Ave Room 425

St Paul MN, 55108

Phone: 651 341-6500

Organization: University of Minnesota

If the study is part of your work for a degree, indicate type of degree:

Undergraduate ___ M.A. Or M.S. ___ **Ph.D.** Ed.D. ___

Advisor's Name: Dr. Theodore Lewis **Phone:** _____

Address: Dr Lewis is over sea's and is best reached via email. lewis007@umn.edu

Purpose of Study: This research will examine possible gender-based differences in school-aged children's divergent thinking. Divergent thinking is a measure of creativity and an important characteristic in science and engineering achievement. The Wallach and Kogan Creativity Test (WKCT) will be used to examine divergent thinking characteristics in the study's participants. The data gathered may help to identify reasons behind the shortage of females in science and engineering, and has the potential to serve as an aid in teaching and learning about gender-based differences in divergent thinking. Chan and Cheung (2000) were puzzled by results of their study which found a lack of gender and grade differences in figural tasks, and recommended that the issue should be addressed in future studies.

- 1. What request are you making of the Bloomington Public Schools? Give specific information on sampling, measuring instruments, time schedule, amount of time required by students or staff, number and names of schools to be involved (if known). If non standardized instruments are to be used, attach copies please.**

I am requesting approximately 30 students (males and females) from three different grade levels (Middle and High School), for example 7th grade, 9th grade and 11th grade. The exact grade levels are flexible. Data collection would only require one visit of approximately 1 hour and I would administer the surveys, give

instructions to the students, and collect the instruments when the students are finished. I would appreciate starting data collection by October 6th, 2008. The instrument, Wallach and Kogan Creativity Test (WKCT) will be used. It is a well known creativity assessment instrument.

- 2. If you have discussed this proposal with Bloomington Public School personnel, indicate with whom you have talked and the nature of your discussion.**

I contacted Jim Angermeyr, Director of Research and Evaluation via email. We have exchanged emails about the research request and the appropriate method of request. His helpful and timely advice was to submit this form to him for review as soon as possible.

- 3. What practical implications does your study have for the Bloomington Public School System? (If none, say none, but describe what value the study may have for children, in general.)**

This research could lead to possible increases in female participation in STEM (science, technology, engineering and math) within our educational systems and within the Bloomington Public School system. Divergent thinking is an important dimension of creativity and inventiveness, but it is a neglected aspect of the conversation on student choice of careers. Because divergent thinking is an important characteristic in science and engineering achievement, more attention should be placed upon divergent thinking activities in the curriculum. The intended outcome would be heightened interest and capacity for success in technical or engineering related careers for all students, and particularly for girls who are underrepresented in these fields.

- 4. Have you conducted previous studies in the Bloomington Public Schools?**

Yes___ **No X** If yes, give sufficient information about the most recent or pertinent study so that it can be located, i.e, date, who your contact was, and title or nature of the study.

- 5. List the names of all personnel who will be involved in carrying out field operations.**

Jim Angermeyr has suggested waiting on contacting teachers until this form has been reviewed by him.

- 6. Do you have any objection to publicity of your study at this time? Yes___ **No X****

7. Do you have the support of your supervisor? (For staff members only)? NA

8. If you have a formal research proposal, please include it with this request.

See attached

RETURN TO
Department of Research and Evaluation
Bloomington Public Schools
1350 West 106th Street
Bloomington, MN 55431
PH: (952) 681-6486
Fax:(952) 681-6497

For Bloomington Public Schools Use

Bloomington Public Schools					
Required Approval	Department	Signature	Date	Approval	
				Yes	No
x	Research & Evaluation				
x	Assist. Superintendent				
	Bldg Principal				
	Other Administration				

Appendix B

Research Request Approved: Bloomington Public Schools

Bloomington Public Schools

Office of Research, Evaluation, and Assessment



October 7, 2008

Leah Roue
University of Minnesota
College of Work & Human Resource Development
1954 Buford Avenue Room 425
St. Paul, MN 55108

Dear Ms Roue:

We have reviewed your research request (examine gender-based differences in children's divergent thinking - dated September 15, 2008) within the Bloomington Public Schools.

We have determined that the proposal falls within the guidelines approved by the Board of Education, and you are hereby **approved** to complete your research.

Please contact Richard Cash (952-681-6438) to obtain the necessary teachers' names that will allow you to move forward in your research.

Let me wish you the best of luck as you continue in your work.

Sincerely,

A handwritten signature in cursive script that reads "James Angermeyr".

James Angermeyr, Ph.D.
Director of Research, Evaluation, and Assessment

Attachment (Approved Research Request)

Appendix C

Pilot Survey Instrument

Creativity Activity

General Instructions: Think of this as a **fun game**. There are three sections to it, USES, SIMILARITIES, and INSTANCES. For each section will be three challenges which you must address in the time given. There are **no wrong answers**, and you are not competing with each other.

Try to be as creative as you can when you answer. For each question, try to provide as many responses as you can.

Please circle the one that applies to you:

Male or Female

8th grade 10th grade 11th grade

Section A-USES

Instructions: In this section there are **three** items. For each one, think of as many **uses** as you can to which the given item can be put, no matter how far out your answer might be. For each question, provide as many answers as you can on the sheet provided.

1. Indicate all of the ways you can think of for using **a shoe**?
2. Indicate all of the ways in which the **sheet of paper** shown can be used
3. Indicate all of the ways in which you can use the **empty jar** shown
4. Indicate all of the ways in which you can use **a brick**
5. Indicate all of the ways in which you can use an **orange**
6. Indicate all of the uses you can think of for a **motor car**
7. Indicate all of the ways in which a **lake** can be used

Section B—SIMILARITIES

Instructions: In this section there are **six** items, each of which has two items that may be similar. For each item, list all of the ways you can think of in which the two items indicated are similar.

1. An apple and bar of chocolate

2. An elevator and a train

3. Pipeline and a river

4. A motor-car battery and a lake

5. A song and a painting

6. A pizza and the sun

Section C- INSTANCES

Instructions: In this section there are **seven** items. For each thing listed, you must indicate as many examples of it that you can think of.

1. Things that are fast

2. Things that provide energy

3. Things that rotate

4. Things that are scarce

5. Things that flow

6. Things that are liquid

7. Things that need water

Appendix D

Final Survey Instrument

Creativity Activity

General Instructions: Think of this as a **fun game**. There are three sections to it, USES, SIMILARITIES, and INSTANCES. For each section will be three challenges which you must address in the time given. There are **no wrong answers**, and you are not competing with each other.

Try to be as creative as you can when you answer. For each question, try to provide as many responses as you can.

Please circle the one that applies to you:

Male or Female

8th grade 10th grade

Section A-USES

Instructions: In this section there are **three** items. For each one, think of as many **uses** as you can to which the given item can be put, no matter how far out your answer might be. For each question, provide as many answers as you can on the sheet provided.

8. Indicate all of the ways in which you can use a **brick**

9. Indicate all of the ways in which you can use an **orange**

10. Indicate all of the ways in which a **lake** can be used

Section B—SIMILARITIES

Instructions: In this section there are **three** items, each of which has two items that may be similar. For each item, list all of the ways you can think of in which the two items indicated are similar.

7. An apple and bar of chocolate

8. An elevator and a train

9. A pizza and the sun

Section C- INSTANCES

Instructions: In this section there are **three** items. For each thing listed, you must indicate as many examples of it that you can think of.

8. Things that are fast

9. Things that provide energy

10. Things that rotate

Appendix E

IRB Approved with Stipulations

From: <irb@umn.edu>
Date: Monday, November 17, 2008 9:58 AM
To: <rouex006@umn.edu>
Subject: IRB 11/06/2008 Response to HSC #0810P49461

November 10, 2008

Leah C Roue
College of Education and Human Development
1954 Buford Ave
St. Paul, MN 55108

RE: "Divergent thinking skills in science and engineering influence of gender and grade level"

IRB Code Number: 0810P49461

Dear Ms. Roue

Notification of IRB Committee Action

IRB Meeting: November 6, 2008

Item Under Review: New Application

IRB Action: Stipulations must be met before final approval can be granted.

Additional Requirements Pending Approval:

1. Provide the committee with a copy of what the teachers will say to students when introducing the proposed research.
2. Provide more information for section 6.4 of the application.
3. Provide more information regarding the inclusion/exclusion criteria i.e., will students with disabilities be included, will second language learners be included?
4. Provide answers for section 9.1 through 9.3 of the application.
5. Provide the committee with a copy of the and Kogan Creativity Test (WKCT) for review.
6. In the invitation letter to parents clearly state that you are a student investigator; that the creativity test is not an intelligence test; and that parents will not receive the results.
7. Confirm that there are no individual identifiers that could link subjects to the study.
8. Provide more detail in Appendix J including your experience working with this population.

Provide a written response to these points of concern and respond to the following

changes to the consent form that have been stipulated:

9. The IRB waives the requirement for written documentation of parental consent because it is in accord with 45 CFR 46.117(c); the research involves minimal risk and includes no procedures for which written consent is normally required outside the research context. Obtaining subjects' signatures on the consent form would increase the risk for breach of confidentiality, as it would be the only record linking a subject to this study. Please note that the waiver of the requirement for written documentation of consent does not waive the informed consent process, rather the requirement to obtain subjects' signatures on the consent form. The researcher will send each parent an invitation letter. Please submit an Appendix W.
10. In the parent invitation letter state that ¶ There are no direct benefits to participation in the study.¶
11. Provide an assent form for students.
12. In the assent form inform students of what tasks they will be asked to do and the time anticipated to complete those tasks.
13. In the assent form state clearly that the child can refuse to participate even if a parent agrees.

We cannot record final approval for this study, and the study may not be initiated, until the stipulations have been satisfied. If your response is not received within 90 days, the study will be filed as inactive and a new application required for further consideration.

Please send your response to RSPP (Mayo Mail Code 820; D-528 Mayo Memorial Building; 420 Delaware St. SE; Minneapolis, MN 55455) The entire application does not need to be resubmitted; your response should address the sections requiring change. The signature of the Principal Investigator is the only signature required with the response. Only one copy of the response is necessary.

If you have questions concerning this specific correspondence, contact Bri Warner at 612-624-5142.

Sincerely,

Jeffery Perkey, MLS, CIP
Research Compliance Supervisor
JP/bw

CC: Theodore Lewis

Appendix F

Response to IRB's Approved with Stipulations

Leah Roue
PhD Candidate/Instructor
Department of Work and Human Resource Education
1954 Buford Avenue
Rm 425B
St. Paul MN, 55108
December 2nd, 2008

Bri Warner
IRB

Dear Bri:

This letter is in response to your approved with stipulations letter (study # 0810P49461). I am the principle investigator of this study and I would like to add participants. I would like to study a total of 180 students, rather than the original number of 90. I will pilot my instrument to 5 students in each grade level for a total of 15 students; those 15 students will be pulled from same classes where the rest of the students will be pulled from. The school is choosing randomly the classes and the students. The pilot students will not be involved in the final data collection. There is more information about the pilot and the instrument below.

I would also like to add compensation to my study. Each student, in the classrooms studied will be given \$5, regardless of whether they participate. The lead teacher will be given \$200, this teacher will be responsible for scheduling classrooms and teachers for the pilot and the final survey. Each classroom teacher will receive \$100 for administering and collecting surveys.

Also, I will no longer be using both Cambridge-Isanti high school and Bloomington. I will only be using students from Bloomington school district. They have offered me all the students I need without the extra travel time.

You have requested the following changes:

1. Provide the committee with a copy of what the teachers will say to students when introducing the proposed research.

Script for Administration of Survey

2. Provide more information for section 6.4 of the application.

The survey is a version of the Wallach and Kogan. The data will be collected in one visit, taking up approximately one, one hour class.

The survey instrument will be piloted to the students prior to final data collection. Five students from each of the three proposed grades will be recruited by the school district to partake in the pilot. These students will be part of the classes that will be asked to complete the final instrument. The pilot students will not be asked to participate in the final data collection, so as to not skew the results. All recruitment is being handled by the school district at their request.

3. Provide more information regarding the inclusion/exclusion criteria i.e., will students with disabilities be included, will second language learners be included?

All students will be picked by the Bloomington school district. To my knowledge the school district will be picking classes based on grade level and schedule. Once a class is chosen, no one in that class will be excluded.

4. Provide answers for section 9.1 through 9.3 of the application.

- 9.1 The research does not involve any of the possible risks or harms listed in this section.
- 9.2 NA
- 9.3 NA

5. Provide the committee with a copy of the Wallach and Kogan Creativity Test (WKCT) for review.

See attached

6. In the invitation letter to parents clearly state that you are a student investigator; that the creativity test is not an intelligence test; and that parents will not receive the results.

See attached letter to the parents.

7. Confirm that there are no individual identifiers that could link subjects to the study.

There are no individual identifiers that could be used to link participants to the study.

8. Provide more detail in Appendix J including your experience working with this population.

I have no experience working with the students at Bloomington School District. I do have experience with this age group. Data collection for my master's thesis required me to spend a summer with middle and high school students. I also have 4 years of teaching experience at the college level. I have completed all coursework for my PhD and the protection of human subjects training as required by the U of M. I feel confident that I am qualified to be the principal investigator behind this research.

Provide a written response to these points of concern and respond to the following changes to the consent form that have been stipulated:

9. The IRB waives the requirement for written documentation of parental consent because it is in accord with 45 CFR 46.117(c); the research involves minimal risk and includes no procedures for which written consent is normally required outside the research context. Obtaining subjects' signatures on the consent form would increase the risk for breach of confidentiality, as it would be the only record linking a subject to this study. Please note that the waiver of the requirement for written documentation of consent does not waive the informed consent process, rather the requirement to obtain subjects' signatures on the consent form. The researcher will send each parent an invitation letter. Please submit an Appendix W.
See attached "appendix W"

10. In the parent invitation letter state that "There are no direct benefits to participation in the study."
See parent invitation/letter to the parents.

11. Provide an assent form for students.
Please see attached student assent form.

12. In the assent form inform students of what tasks they will be asked to do and the time anticipated to complete those tasks.
Please see attached Script for Administration, which is the student assent form.

13. In the assent form state clearly that the child can refuse to participate even if a parent agrees.
Please see attached student assent form.

Sincerely,

Leah Roue

Appendix G
IRB Final Approval

UNIVERSITY OF MINNESOTA

Twin Cities Campus

December 15, 2008

Leah C Roue
College of Education and Human Development
1954 Buford Ave
St. Paul, MN 55108

*Research Subjects' Protection Programs
(RSPP)*

Office of the Vice President for Research

*D-528 Mayo Memorial Building
420 Delaware Street S.E.
Minneapolis, MN 55455*

Office: 612-626-5634

Fax: 612-626-0061

www.research.umn.edu/subjects

Email: lrb@umn.edu or

incac@umn.edu or lrb@umn.edu

RE: "Divergent thinking skills in science and engineering influence of gender and grade level"
IRB Code Number: **0810P49461**

Dear Ms. Roue

The Institutional Review Board (IRB) received your response to its stipulations. Since this information satisfies the federal criteria for approval at 45CFR46.111 and the requirements set by the IRB, final approval for the project is noted in our files. Upon receipt of this letter, you may begin your research.

IRB approval of this study includes the invitation letter to parents and student assent form (script) received December 5, 2008.

The IRB would like to stress that subjects who go through the consent process are considered enrolled participants and are counted toward the total number of subjects, even if they have no further participation in the study. Please keep this in mind when calculating the number of subjects you request. This study is currently approved for 90 subjects. If you desire an increase in the number of approved subjects, you will need to make a formal request to the IRB.

For your records and for grant certification purposes, the approval date for the referenced project is November 6, 2008 and the Assurance of Compliance number is FWA00000312 (Fairview Health Systems Research FWA00000325, Gillette Children's Specialty Healthcare FWA00004003). Research projects are subject to continuing review and renewal; approval will expire one year from that date. You will receive a report form two months before the expiration date. If you would like us to send certification of approval to a funding agency, please tell us the name and address of your contact person at the agency.

As Principal Investigator of this project, you are required by federal regulations to:

- *Inform the IRB of any proposed changes in your research that will affect human subjects, changes should not be initiated until written IRB approval is received.
- *Report to the IRB subject complaints and unanticipated problems involving risks to subjects or others as they occur.
- *Respond to notices for continuing review prior to the study's expiration date.
- *Cooperate with post-approval monitoring activities.

Driven to Discover™

Information on the IRB process is available in the form of a guide for researchers entitled, What Every Researcher Needs to Know, found at <http://www.research.umn.edu/irb/WERNK/index.cfm>

The IRB wishes you success with this research. If you have questions, please call the IRB office at 612-626-5654.

Sincerely,



Jeffery Perkey, M.L.S., CIP
Research Compliance Supervisor
JP/bw

CC: Theodore Lewis

Appendix H

Parents Assent Form

Dear Parents,

My name is Leah Roue. I am a graduate student in the Work and Human Resource Education Department at the University of Minnesota. I would like your child to take part in my research. In the following months I will be surveying high school students to learn about creativity, engineering, and science. If you and your child agree that your child may participate in the study I will ask your child to complete a creativity assessment involving open ended questions and abstract pictures. Completion of this survey is estimated to take no more than one class period. Your child's teachers have already graciously agreed to help in this research.

All of the information I obtain from your child will be kept confidential. Your child's name will not be used on any of the forms they complete, and no information about your child will ever leave school premises with a name attached.

The information collected from this study is the basis of my dissertation. My dissertation will not contain any INDIVIDUAL information about children. It will describe results and draw conclusions based on my findings. I will also use the information from this study to publish articles in professional publications, so that teachers can learn more about youth creativity and its relationship with engineering and science. Once again, I will never report individual information.

The school principal has approved this study and the survey. However, your child does not have to participate. Participation or non-participation will not affect your child's grades. If your child does not want to do the survey, or wants to quit after starting, other work will be given to do in the classroom. I and the classroom teacher will be present during the survey. Following the completion of the survey, all students, regardless of participation, will be given a treat.

The information from the survey should help us learn more about creativity and its role in education. There are no known risks associated with participation in this study, and most students enjoy the opportunity to express their opinions.

The University of Minnesota greatly appreciates the participation of people who help it carry out its function of developing knowledge through research. If you have any questions about the research, you may call me, Leah at (651) 341-6500.

If you and your child agree that your child may take part in the research please return a signed copy of this form to me in the enclosed envelope. You may keep the other copy for future reference.

You have read this permission form and agree to have your child take part in the research.

Name of Student _____

Printed Name of Parent _____ Signature of Parent _____ Date _____

Appendix H

Student Assent Form

University of Minnesota

Department of Work and Human Resource
Education
College of Education and Human
Development
1954 Buford Avenue, Room 425
St Paul, MN 55108

Dear Participant:

Hello, my name is Leah Roue and I am a graduate student at the U of M. I am currently working on my PhD in Business and Industry Education and I am requesting the opportunity to survey your students.

The purpose of this study is to increase research in the area of creativity and its key component, divergent thinking. Very little research has been conducted to determine whether there are fundamental differences among boys and girls in the area of creativity and its key components: divergent thinking, fluency, elaboration, originality, resistance to premature closure and abstractness of titles. These attributes are all critical dimensions of inventiveness and science and engineering related creativity.

My intent is to survey the students in order to determine if there are differences in their creativity scores in regards to age and gender.

The Wallach and Kogan Creativity Test (WKCT) will be distributed by me to each of you. The assessment will take approximately 50 minutes. This survey invites you to draw and give a title to their drawings or to write questions, reasons, consequences and different uses for objects. When you have completed the WKCT you will be given three open-ended questions, such as 'name as many round things as you can'. There are no right or wrong responses to any of the activities; this should be fun!

The results of this study will give us information on gender and age differences in the 5 areas addressed above. Many researchers have named creativity as a key component in engineering and science. Thus the results have the potential to help us enhance curriculum, teacher education, creative growth, and further address the issue of diversity within these areas.

I will use the data collected for my dissertation which addresses creativity and its link to engineering and science. Again, the results that I will share will not indicate the student from whom the data was gathered.

Signature of participant _____

Signature of person explaining study _____

Date _____