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THE EFFECT OF GENDER AND IMPLICIT THEORIES OF MATH ABILITY ON MATH INTEREST AND ACHIEVEMENT

A Specialist Project
Presented to
The Faculty of the Department of Psychology
Western Kentucky University
Bowling Green, Kentucky

In Partial Fulfillment
Of the Requirements for the Degree
Specialist in Education

By
Jillian Hendricks

May 2012

THE EFFECT OF GENDER AND IMPLICIT THEORIES OF MATH ABILITY ON MATH INTEREST AND ACHIEVEMENT

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Directed by: Dr. Steven R. Wininger, Dr. Carl Myers, Dr. Janet Tassell

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The current study examined whether males and females differed in math achievement and held different beliefs regarding the malleability of math ability at the elementary level. The study also explored the relationships between students' implicit theories of math ability, math interest, and math achievement. Potential grade level differences in math trait beliefs were also investigated. Study participants consisted of a total of 1802 students from six elementary schools that participate in the Gifted Education in Math and Science (GEMS) Project. Project GEMS is a federal grant project seeking to encourage science and math interest and achievement in children from low-income and diverse populations. Data were analyzed by means of Pearson correlations and one-way analysis of variance. Male and female math achievement was equivalent. No gender or grade level differences were observed in implicit theories of math ability. As predicted, students who believed their math abilities were malleable earned higher math achievement scores. Several limitations of this study are discussed and recommendations for further investigation are presented. Findings from this study suggest it is important to consider the impact of domain specific beliefs on math achievement, which may have implications for early identification and supports for those students who may be vulnerable to poor achievement outcomes.

Introduction

Women are still underrepresented in science, technology, math, and engineering (STEM) careers despite focused efforts to increase the number of women in such fields (Hill, Corbett, & St. Rose, 2010). In 2007, only 26% of mathematical and computer scientists and 11% of engineers were women (National Science Foundation, Division of Science Resources Statistics, 2009). The number of science and engineering bachelor's and graduate degrees earned by women has increased, however certain degrees are still disproportionately male. In 2006, women accounted for only 23% of graduate students in engineering, 25% in computer sciences, and fewer than 25% of postdoctoral fellows in computer sciences, engineering, mathematics, and physical sciences (National Science Foundation, Division of Science Resources Statistics, 2009).

Early interest and achievement in math are seen as important factors in future math and science course selection as well as future career choice (Singh, Granville, & Dika, 2002). In elementary school, boys and girls typically show similar levels of interest in math (Eccles, Wigfield, Harold, & Blumenfeld, 1993; Wigfield et al., 1997); however, by middle school girls are less interested in math than boys (Linver & Davis-Kean, 2004; Watt, 2004). Researchers have also found gender differences in math achievement, with boys showing higher achievement in math beginning as early as first grade (Penner & Paret, 2008). However, recent research indicates the difference in mean math achievement scores between girls and boys has been drastically reduced (Hyde, 2005; Hyde, Lindberg, Linn, Ellis, & Williams, 2008; Hyde & Linn, 2006) and achievement scores at the low end of the distribution are now essentially equal between the two genders (Hyde & Mertz, 2009).

The gender gap in math achievement mainly persists among those with the highest ability levels, with boys tending to outperform girls at the 95th and 99th percentiles; however, the gender gap among those at the highest ability level has decreased in the United States and is not seen in some countries, such as Denmark and the Netherlands (Hyde & Mertz, 2009; Wai, Cacchio, Putallaz, & Makel, 2010). Hyde and Mertz (2009) attribute the differences in variability in math performance between males and females among countries to sociocultural factors. Wai et al. (2010) found that over a span of thirty years the ratio of boys to girls at the highest levels (i.e., 95th percentile) of math ability as measured by the SAT math exam has declined from about 13:1 to 4:1. Such a change in the proportion of girls among the highest math achievers suggests that other factors aside from differences in ability are contributing to the gap in math performance and STEM career choice.

What factors might contribute to the gender differences in math interest, achievement, and subsequently STEM career choice? Researchers are currently exploring the idea that women's implicitly held beliefs about their intelligence play a role in the gender gap in math achievement and the underrepresentation of women in STEM careers (Burkley, Parker, Stermer, & Burkley, 2010; Dweck, 2006). The idea is that regardless of their actual ability levels, if women believe their intelligence is something that cannot be improved, their math achievement will suffer. However, few studies have addressed the role of gender and implicit theories of specific domain ability (e.g., math ability) and how they might affect both domain interest (e.g., math interest) and achievement, particularly at the elementary grade level. The following review of the literature will examine gender and developmental differences of (a) implicit theories of ability and their motivational outcomes, (b) individual interest in mathematics, and (c) mathematics achievement.

Literature Review

Implicit Theories

Implicit theories are the views or beliefs that people hold about their various personal traits, such as intelligence or math ability (Burkley et al., 2010; Dweck & Leggett, 1988). According to Dweck and Leggett (1988), there are two types of implicit theories: an entity theory and an incremental theory. Individuals with an entity view of their intelligence believe it is “fixed” or that they have a set amount of intelligence that cannot be changed. Individuals with an incremental view of their intelligence believe it is malleable and can be further developed through hard work and effort.

Research suggests that younger children typically hold an incremental theory of intelligence and beginning at 10 to 12 years of age may begin to adopt an entity theory of intelligence (Dweck, 2000; Elliott & Dweck, 1988). Gender differences in implicit theories of intelligence have been found in some studies. In one study, high-achieving (defined by grades) eighth-grade boys were more likely to have an incremental theory of intelligence while high-achieving eighth-grade girls were more likely to have an entity view of intelligence (Henderson & Dweck, 1990).

Findings of gender differences in implicit theories of intelligence are important because research indicates that entity and incremental theories of intelligence lead to different achievement outcomes (Dweck, 2000). Holding a fixed entity belief has been shown to be negatively related with high performance in academics (Siegle, Rubenstein, Pollard, & Romey, 2010). Among junior high school students, having an incremental theory of intelligence was shown to predict higher math grades and having an entity theory of intelligence predicted stagnation in math grades (Blackwell, Trzesniewski, & Dweck, 2007).

Through her research, Dweck (2000) has found that specific motivational patterns are associated with the two types of implicit theories. Dweck and Leggett (1988) put forth a model, shown in Table 1, which describes how these motivational patterns lead to different responses in achievement situations. The heart of the model is the individual's implicit theory of intelligence, which orient them to particular goals that subsequently produce different behavioral outcomes depending on how the individual perceives their current ability level.

Table 1

Implicit Theories, Goal Orientations, Perceived Ability, and Behavior Patterns in Achievement Situations

Theory of intelligence	Goal orientation	Perceived present ability	Behavior pattern
Entity (Intelligence is fixed)	Performance (Goal is to gain positive judgments/avoid negative judgments of competence)	High	Mastery oriented (Seek challenge; high persistence)
		Low	Helpless (Avoid challenge; low persistence)
Incremental (Intelligence is malleable)	Learning (Goal is to increase competence)	High or low	Mastery oriented (Seek challenge that fosters learning; high persistence)

Note. Adapted from "A Social-Cognitive Approach to Motivation and Personality," by C. S. Dweck and E. L. Leggett, 1988, *Psychological Review*, *95*(2), pp. 256–273. Copyright 1988 by the American Psychological Association.

Achievement goals and goal orientation. Achievement goals are defined as the cognitive representations that direct individuals in achievement situations (Elliot & McGregor, 1999). A learning (also termed mastery) goal is characterized by a focus on learning and self-improvement whereas a performance (also termed ego) goal is defined by a focus on being judged as competent by others (Schunk, Pintrich, & Meece, 2008). The type of goal an individual is oriented toward has been shown to relate to various motivational, affective, cognitive, and behavioral outcomes. A learning-goal orientation is associated with more adaptive attributional patterns, positive attitudes toward learning, the use of deeper processing strategies and self-regulation, and a willingness to take on challenges or seek help (Schunk et al., 2008). Schunk (1996) also established a causal relationship between goal orientations and achievement outcomes with young children directed to work under a learning-goal orientation displaying higher levels of academic performance and task involvement than children directed to work under a performance-goal orientation (as cited in Covington, 2000).

Typically, a learning-goal orientation is more likely to be seen in younger children and a performance-goal orientation is more likely to be seen in older children (Schunk et al., 2008). Findings of gender differences in goal orientations are unclear (Schunk et al., 2008). Preckel, Goetz, Pekrun, and Kleine (2008) found that gifted boys were more like to demonstrate a mastery-goal orientation than gifted girls. Individuals with an entity theory of intelligence are oriented toward performance goals while those with an incremental theory of intelligence are oriented toward learning goals (Ames & Archer, 1988; Dweck & Leggett, 1988; Elliott & Dweck, 1988).

Attributional patterns. When individuals encounter success or failure, their perceived causes of these outcomes (or attributions) have important effects on their motivation and behavior (Schunk et al., 2008). Although there are many different potential attributions one can make, all attributions can be categorized according to three dimensions: stability, locus, and control. The stability dimension refers to whether the cause is stable or unstable across situations and over time. For example, effort would be considered an unstable cause, whereas ability would be considered a stable cause. The locus dimension concerns whether the cause is viewed as internal or external to the individual. Effort and ability are both considered internal causes; an example of an external cause would be task difficulty. The control dimension refers to whether the cause is perceived as controllable or uncontrollable. For instance, effort is a controllable cause while luck is not. In general, studies have shown that academic achievement is improved when learners attribute both their academic successes and failures to internal causes, specifically attributing success with ability while attributing failure with effort and the use of study strategies (Schunk & Gunn, 1986). However, academic achievement is hindered when individuals attribute their failure to stable causes such as lack of ability and attribute their success to unstable causes such as luck (Graham, 1991).

When given negative feedback, entity theorists are more likely to attribute their successes to external or unstable causes (e.g., task difficulty and luck) and are more likely to attribute their failure to a lack of ability (Hong, Chiu, Dweck, Lin, & Wan, 1999; Robins & Pals, 2002). In contrast, incremental theorists are more likely to attribute their successes to internal causes (e.g., effort and study skills) and attribute failures to a lack of effort (Hong et al., 1999; Robins & Pals, 2002).

Some research suggests that gender differences in attributions are general rather than domain specific. Several studies have shown that females are more likely than males to attribute success to unstable causes and attribute failures to stable causes such as lack of ability; however, other studies have not found this gender difference (Eccles, 1987; Licht, Stader, & Swenson, 1989; Lloyd, Walsh, & Yailagh, 2005; Schunk et al., 2008). One study found that attributions did not vary across academic domains, but rather girls had an overall tendency to attribute their failures to low ability more than boys and attribute their successes to high ability less than boys and to an easy task more than boys (Licht et al., 1989). Some studies have also found that high-achieving girls ("A" students) are more likely than high-achieving boys to attribute their failures to lack of ability (Licht, Linden, Brown, & Sexton, 1984). Other research suggests gender differences in attributions can occur specifically with mathematics achievement, with girls more likely to attribute their mathematics successes to external factors and their failures to lack of ability (Lloyd et al., 2005). In sum, research indicates that both gender and implicit theories can play a role in the types of causes students attribute to their achievement, thereby potentially contributing to the gender gap in math achievement.

Challenge, perceptions of competence, and behavior patterns. An individual's implicit theory of intelligence, achievement goals, and attributions can affect their behavioral responses to challenge and the uncertainty of success. A mastery-oriented behavior pattern[1] is characterized by positive affect and positive expectations of future performance and involves higher persistence and a seeking of challenge (Burhans & Dweck, 1995). When faced with failure, mastery-oriented individuals pursue ways to improve their ability and performance, such as putting forth more effort or taking remedial action (Hong et al., 1999). A helpless behavior pattern is characterized by negative affect and negative expectations for future performance and involves lower persistence and avoidance of risks and future challenge (Burhans & Dweck, 1995).

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[1] A *mastery-oriented behavior pattern* is not to be confused with a *mastery-goal orientation*. The term *mastery-oriented behavior pattern* is used to describe the set of adaptive behavioral outcomes associated with motivational patterns. A *mastery-goal orientation* is another term used in the literature for a *learning-goal orientation*, which describes individuals who have a disposition toward setting learning goals in achievement situations.

Research has shown that mastery-oriented behavior patterns are associated with positive achievement outcomes, while helpless behavior patterns are related to inconsistent or negative achievement outcomes (Elliot & Dweck, 1988).

In the model proposed by Dweck and Leggett (1988), entity theorists who perceive their present ability to be low (or receive negative feedback regarding their competence) exhibit a helpless behavior pattern to challenge or failure, whereas incremental theorists, regardless of how they perceive their ability (or whether they receive positive or negative feedback regarding their competence), exhibit a mastery-oriented behavior pattern to challenge or failure. Several studies have found results consistent with this model, in university students as well as children in their late elementary school years (Elliott & Dweck, 1988; Hong et al., 1999). One study found that entity theorists who believed that they were not performing well in their majors were more likely to choose a new major, a finding also consistent with the idea that entity theorists tend to give up when faced with setbacks (Zuckerman, Gagne, & Nafshi, 2001).

Research indicates children can exhibit helpless responses to achievement outcomes in preschool and the early elementary school years (Burhans & Dweck, 1995). Research also suggests a gender difference in responses to achievement outcomes, with girls more likely to exhibit helpless responses in the face of challenge or failure (Broome, 2001; Ryckman & Peckham, 1987). Girls' vulnerability to challenge is seen as early as grade school (Dweck, 2000). When faced with uncertainty of success, girls display lower confidence in their abilities than do boys (Licht et al., 1989). Broome (2001) found that for eighth-graders, girls evidenced more helplessness than boys and those individuals with an entity theory of their physics ability displayed more helplessness than individuals with an incremental view of their physics ability.

Because research has shown that males and females often display different motivational patterns and that STEM subjects past grade school often involve qualitatively new concepts and a greater leap in level of difficulty, Carol Dweck has hypothesized that motivational patterns contribute to achievement discrepancies in math (Dweck, 1986). As math courses in middle school and high school introduce new skills and concepts that are difficult, those students who hold an entity theory of intelligence begin to encounter more failure and challenges and will respond with helpless behavior patterns. Because girls are more likely to demonstrate these types of behavioral patterns, their achievement in these areas may decline, they may drop difficult math courses, and avoid careers in these areas.

Domain specific implicit theories. Implicit theories of ability may vary by domain (Schunk et al., 2008; Vogler & Bakken, 2007). Younger elementary students tend to hold more generalized implicit theories of their attributes; however, starting with third grade, students begin to develop more differentiated implicit theories of their abilities (Bempechat, London, & Dweck, 1991; Burhans & Dweck, 1995). Although many studies have focused on implicit theories of intelligence, few studies have sought to measure implicit theories about the specific domain of math ability. Chen and Pajares (2010) conducted a study with sixth-grade science students and measured their implicit theories of science ability specifically, a domain not addressed by the current study but one that remains relevant to the discussion. Students with an incremental theory of science ability were more likely to hold a learning-goal orientation, while students with an entity view of science ability were more likely to hold a performance-goal orientation that centered on avoidance. An incremental view of science ability had a positive indirect effect on science achievement, while an entity view of science ability had a negative indirect effect on science achievement (Chen & Pajares, 2010). Chen and Pajares also found that, although in general both boys and girls held more incremental views of their science ability, boys reported more incremental views than did girls.

Broome (2001) conducted a similar study in Germany with eighth grade physics students and measured their implicit theories of physics ability specifically. While there were no gender differences in intelligence or physics knowledge, girls received significantly poorer grades. Both boys and girls with an entity theory of their physics ability showed more helplessness than boys and girls with an incremental theory of their physics ability.

Another recent study measured undergraduate females' implicit theories of intelligence in general and their implicit theories of math ability specifically (Burkley et al., 2010). Burkley et al. (2010) found that after experiencing math failure, females with an entity view of their math ability identified with the math domain less than women with an incremental view of their math ability. Females with an entity view of their math ability also reported less enjoyment of math-related subjects and less interest in pursuing a math major and a math career. Females' implicit theories of intelligence in general were not predictive over and above the specific measure of implicit theories of math ability, which suggests that using domain-specific measures may be more useful when assessing differences in motivational patterns in a particular achievement domain.

Math Interest

Hidi and Renninger (2006) proposed a four-phase model of interest development and made a distinction between individual and situational interest. Interest is defined as a psychological state that can also develop into a tendency to reengage content. Situational interest is the initial psychological state of focused attention and affect in response to some environmental stimuli. Individual interest refers to the relatively stable tendency to reengage content over time. The first phase of the model is “triggered situational interest” which may evolve into the second phase, recognized as “maintained situational interest”. The third phase, an “emerging individual interest” may then develop, which if sustained, can progress into a “well-developed individual” interest.

Interest can greatly impact students’ learning (Hidi & Renninger, 2006). Interest has been shown to be positively related to achievement on related tasks (Evans, Schweingruber, & Stevenson, 2002). Individual interest can positively affect persistence and effort and academic motivation (Hidi & Renninger, 2006). Interest also predicts many choices, both educational and vocational (Su, Rounds, & Armstrong, 2009).

Interest is also domain specific (Marsh, Trautwein, Lüdtke, Köller, & Baumert, 2005). A small number of studies have been conducted with a specific focus on mathematics interest. High interest in mathematics was shown to correlate with mathematics achievement in Taiwan, Japan, and the United States (Evans et al., 2002). Interest in mathematics has been shown to decline across the developmental period (Frenzel, Goetz, Pekrun, & Watt, 2010).

Eccles and Wigfield (2002) put forth an expectancy-value theory that emphasizes an individual’s expectancies for academic success and their perceived value for academic tasks. The value component of this theory is also referred to as interest and several studies have addressed how the expectancy-value theory could explain gender differences in mathematics achievement, course enrollment, and career selection (Eccles, 1984; Eccles, 1987; Eccles, 1994; Eccles, Adler, & Meece, 1984; Eccles et al., 1993), so findings from this research are relevant to the current discussion.

Eccles et al. (1984) found gender differences in mathematics values among adolescents, with boys valuing math more than girls. Among students headed to college, differences in value for mathematics mediated the gender differences in advanced mathematics course enrollment; girls felt that math was less important, less useful, and less enjoyable than boys. Some studies have found gender differences in mathematics values among elementary school children (Eccles et al., 1993), while others have not (Wigfield & Eccles, 1994).

Recent studies have found gender differences in mathematics interest, with boys showing higher interest in mathematics than girls (Evans et al., 2002; Köller, Baumert, & Schnabel, 2001; Linver & Davis-Kean, 2005; OECD, 2004; Preckel et al., 2008). One study found such gender differences in mathematics enjoyment as early as grade 4 (Frenzel et al., 2010). By adolescence, boys have higher interest levels in mathematics (Frenzel et al., 2010). One study conducted with high school students found that interest and belief about ability predicted math participation, more strongly for girls than for boys (Watt, Eccles, & Durik, 2006). Watt et al. (2006) found no statistically significant gender differences in mathematical achievement; however, boys rated their math abilities and their expectancies of success in math significantly higher than girls.

Frenzel et al. (2010) conducted a longitudinal study with German students in grades 5 through 9 and found that boys had higher individual interest in mathematics than girls throughout the entire period of the study. Frenzel et al. also found a steep drop in girls' interest levels at grade 7, while boys' interest level was stabilized. Another study conducted with German students in grades 7, 10, and 12 found gender differences in interest, with boys being more interested in mathematics than girls (Köller et al., 2001). A third German study of sixth-grade students found gender differences in mathematics interest, with larger differences in gifted students than in average students, and again boys were found to show more interest in math than girls (Preckel et al., 2008).

In 2003, the Programme for International Student Assessment (PISA) assessment showed that boys in all participating countries consistently reported higher interest in math than girls (OECD, 2004). In a comparison among eleventh-grade students in Taiwan, Japan, and the United States, Evans et al. (2002) found that in all three cultures boys were more likely to prefer mathematics than girls. A Germany study with sixth-graders found that girls showed lower interest in math than boys and that this gender gap was even more pronounced in gifted (defined by a rank of at least 95% on a nonverbal reasoning subscale of the German Cognitive Abilities Test) than in average-ability students (Preckel et al., 2008).

Relation to implicit theories. While few studies have focused specifically on math interest, even fewer studies have addressed the relation between implicit theories of abilities and math interest. A study conducted in Germany found that boys were more interested in their physics education than girls at the end of eighth grade (Broome, 2001). Additionally, both boys and girls with an incremental view of physics ability were more interested in their physics education than those students who held an entity view of physics ability. Another study conducted with female college students found that women with a fixed view of their math ability reported less enjoyment of math-related subjects, less likelihood of pursuing a math major, and less likelihood of pursuing a math career (Burkley et al., 2010).

Math Achievement

Concerns about gender differences in mathematics achievement began in the 1970s (Hyde, Fennema, Ryan, Frost, & Hopp, 1990). According to Hyde (2005), studies from the 1970s through 1990 indicated that gender differences in mathematics performance were small or nonexistent during the elementary school years and the gender difference favoring boys appeared around ages 12 and 13. These studies also indicated boys were better at complex mathematical problems, while females were better at math computation. However, a more recent meta-analysis by Hyde (2005) revealed a small gender difference favoring girls in computation in elementary school and middle school and no gender difference in computation in the high school years. Additionally, no gender difference in complex problem solving was found in elementary school or middle school, though a small gender difference favoring males emerged in the high school years.

Many studies have found that boys show slightly greater variability in their scores (Hyde et al., 2008). The greater male variability hypothesis was proposed in the 1800s to explain why there are more males at both tails of the distribution of scores. It suggests that the disproportionate number of males scoring at each end of the distribution is due to a combination of a small average difference in math performance favoring males and a larger standard deviation for males. Gender differences favoring boys in science and math achievement and ability are indeed smaller for individuals of average achievement and ability than they are for those with the highest levels of achievement and ability (Halpern et al., 2007). However, even at the highest levels this difference remains small (Hyde & Mertz, 2009).

Some researchers have offered evidence against the greater variability hypothesis (Hyde & Mertz, 2009). These studies suggest females have reached parity with males, with a considerably reduced difference in mean achievement scores between girls and boys (Hyde, 2005; Hyde et al., 2008; Hyde & Linn, 2006). Achievement scores at the low end of the distribution are now essentially equal between the two sexes (Hyde & Mertz, 2009). Under the greater variability hypothesis, one would expect to see differences at both ends of the distribution, not just one. Hyde and Mertz argue that research indicates that greater male variability in regards to mathematics is not universal and that greater male variability correlates with several measures of gender inequality.

The gender similarities hypothesis maintains that males and females are similar in most of their abilities, including math ability (Hyde, 2005). Hyde (2005) reviewed 46 meta-analyses and found evidence to support the gender similarities hypothesis. Hyde et al. (2008) found that no gender difference in math skills is found for the general population for students in grades 2 through 11.

Research suggests that gender differences favoring boys in mathematics achievement are thought to appear at the end of middle school and beginning of high school, although such gender differences have been found in early elementary school by some studies (Penner & Paret, 2008). Researchers have found that boys show higher achievement in math beginning as early as first grade (Penner & Paret, 2008). Penner and Paret (2008) argue that even if these early gender differences are small compared to gender differences found later in school, their existence is important because such early gaps could lead to even larger gaps later. Therefore, research on the nature and extent of gender differences in math achievement is of great value.

Purpose

In achievement situations, there are emotional, cognitive, and behavioral patterns of responses associated with the different implicit theories of ability, with some responses being more maladaptive than others (Henderson & Dweck, 1990). Dweck (2006) has hypothesized that a gender gap in mathematics achievement is related to the gender difference in implicit theories of intelligence. While some studies have explored how gender and achievement relate to implicit theories of intelligence, few studies have examined the relation of gender and achievement with implicit theories of specific abilities, such as math, particularly at the elementary level. The first purpose of this study is to explore how gender may be related to implicit theories of math ability and math achievement among elementary students. The following hypotheses will be tested:

Hypothesis 1. Girls will be more likely to have an entity view of math ability, while boys will be more likely to have an incremental view of math ability.

Hypothesis 2. Girls will have lower math performance, while boys will display higher math performance.

Given that research supports a relatively strong correlation between interest in math and academic performance in that domain, it is surprising that only a small number of studies examining implicit theories of math ability have also explored its relation to interest in the domain of math, with research at the elementary level being limited. The second purpose of this study is to examine how elementary students' implicit theories of math ability are related to math interest. The following hypotheses are put forth:

Hypothesis 3. An entity view of math ability will be associated with less interest in math.

Hypothesis 4. An entity view of math ability will be associated with lower math achievement.

Because gender differences in implicit theories of intelligence and specific abilities have both been shown to appear as early as the late elementary level, the third purpose of this study is to examine if grade level differences exist in implicit theories of math ability among students in grades 2 through 6. The following hypothesis will be tested:

Hypothesis 5. An entity view of math ability will be associated with higher grade levels (e.g., second-grade students will display higher incremental beliefs about math ability, while sixth-grade students will display higher entity beliefs about math ability).

Method

Participants

Project GEMS (Gifted Education in Math and Science; Roberts, 2008) is a model demonstration project funded by the Jacob K. Javits Gifted and Talented Students Education Program. Project GEMS intends to foster science and math interest and achievement in elementary children from low-income backgrounds and minorities who are underrepresented in STEM careers (Roberts, 2008). Students enrolled in grades 2 through 6 in six elementary schools from one south central Kentucky district were chosen to participate in Project GEMS and served as the subjects for this study. Schools participating in Project GEMS were selected based on having a student population with at least 50% taking part in a free and/or reduced lunch program (Roberts, 2008). The sample consisted of a total of 1802 students, which included 934 males and 868 females. There were 332 second grade students, 363 third grade students, 406 fourth grade students, 390 fifth grade students, and 311 sixth grade students.

Measures

Implicit theories of math ability scale. A six-point Likert scale to measure implicit theories of math ability was adapted from the three-item Implicit Theories of Intelligence Scale for Children – Self Form (Dweck, 2000). High values on this measure indicate high incremental beliefs. The three questions from this scale were revised to emphasize a focus on views of math ability instead of intelligence (see Appendix A). The questionnaire was then piloted with small groups of students from different grade and ability levels at two of the schools in order to gather feedback and to help ensure student understanding of the wording of the measure.

Validation studies have shown that the three-item questionnaire measuring implicit theories of intelligence has high internal reliability, with alphas ranging from .94 to .98 (Dweck, Chiu, & Hong, 1995). One study indicated test-retest reliability for the three-item implicit theories of intelligence measure was .80 over a two-week interval (Dweck et al., 1995). Additionally, the measure is unrelated to measures of other constructs such as confidence in intellectual ability and self-esteem, which provides evidence of discriminant validity. These studies suggest the three-item questionnaire is both a reliable and valid measure of implicit theories of intelligence.

The questionnaire was then administered in the spring of 2011. A composite of the implicit theories of math ability items was created and its internal consistency reliability (coefficient alpha) was evaluated. The coefficient alpha was .70. Due to the measure having 3 items, this is not an unexpected value. Furthermore, a study in Greece used the original three-item questionnaire in two phases and the coefficient alphas for phases 1 and 2 of the study were .67 and .72, respectively (Gonida, Kiosseoglou, & Leondari, 2006).

Math interest inventory. As part of the Project GEMS identification protocol, an interest inventory was developed in the content area of mathematics and was used in this study (Snow, 2011). The construct of interest in this inventory was based on the four-phase model of interest proposed by Hidi and Reninger (2006). The inventory uses a five-point Likert scale and has a total of 20 items (see Appendix B) which load into four factors: emotion, value, knowledge, and engagement. The overall internal consistency reliability of this measure was .916 in the study by Snow (2011).

The math interest measure was administered in the spring of 2011. Prior to conducting our analyses, Items 4 and 11 on the math interest measure required reverse scoring. Frequencies were obtained for all items and no impossible values were found. Internal consistency reliability analyses for the overall interest composite were then computed. An overall reliability analysis resulted in a coefficient alpha of .87. Items 4 and 11 were removed because of low item correlations. The overall reliability analysis then resulted in a coefficient alpha estimate of .91. This suggests the math interest measure yields reliable scores.

Additional internal consistency reliability analyses were obtained for each of the four factors of the math interest measure. The Emotion factor (items 1-3 and 5) had a coefficient alpha of .89. The Value factor (items 6-8 and 21-23) had a coefficient alpha of .77. The coefficient alpha for the Knowledge factor (items 9, 10, 12, and 13) was .84. The Engagement factor had a coefficient alpha of .87.

Iowa Test of Basic Skills. Participants were administered the Iowa Test of Basic Skills (ITBS), a standardized, norm-referenced test of achievement in the spring of 2011. The ITBS Math test was used to measure math achievement. The ITBS Math test consists of three sections: Math Concepts and Estimation, Math Problem Solving and Data Interpretation, and Math Computation. Overall, the ITBS is a psychometrically sound and well-developed assessment (Lane, 2007). Internal consistency reliability coefficients for the ITBS subtests are in the .80s and .90s, and most of the estimates for the Totals (including Math) are in the .90s. The equivalent forms reliability coefficient for Forms A and B Math Total scores across Levels 9 through 14 ranged from .811 to .942. Test-retest reliability coefficients were mostly in the .70s and .80s. Content validity was evidenced by the development of the ITBS, which followed national standards for test design and corresponds with national curriculums. Internal validity correlations were moderate to high, with higher correlations within subject areas than across subject areas.

Procedures

Before data collection, parental informed consent was requested. Once informed consent was obtained from the parent, student participants were asked for their informed assent. The implicit theories of math ability and math interest measures were distributed to each school's curriculum coordinator, who provided these measures to the teachers. Teachers administered both measures and read the directions aloud to the participants, who then completed an online version of the measure on a school computer.

Research Design and Analysis

A one-way ANOVA will be used to examine potential mean differences in overall composite scores on the implicit theories of math ability measure between males and females. If the first hypothesis is supported, there should be a statistically significant difference in implicit theories of math ability composite scores between males and females, with females being more likely to hold entity beliefs and males being more likely to hold incremental beliefs. A one-way ANOVA will also be used to examine potential mean differences in overall composite scores on math achievement measure between males and females. If the second hypothesis is supported, there should be a statistically significant difference in math achievement composite scores between males and females, with females displaying lower math performance than males.

To evaluate the third and fourth hypotheses, overall composite scores from the implicit theories of math ability measure will be correlated with overall composite scores from the interest measure and the math achievement scores. If the third hypothesis is supported, there should be a statistically significant and positive correlation between implicit theories of math ability and math interest, where students with strong entity beliefs display lower math interest while students with strong incremental beliefs display higher math interest. If the fourth hypothesis is supported, there should be a statistically significant and positive correlation between implicit theories of math ability and math achievement, where students with strong entity beliefs display lower math achievement while students with strong incremental beliefs display higher math achievement.

To evaluate the fifth hypothesis, a one-way ANOVA will be used to examine the potential mean differences in implicit theories of math ability between grade levels. If the fifth hypothesis is supported, there should be a statistically significant and positive correlation between implicit theories of math ability and grade level, with students from higher grade levels displaying strong entity beliefs while students from lower grade levels display strong incremental beliefs.

Results

Descriptive statistics were calculated for all three variables and summarized in Table 2. In order to evaluate the first hypothesis, potential gender differences for implicit theories of math ability were examined using a one-way ANOVA. The alpha level was set at .01 for all statistical tests. Contrary to the first hypothesis, there was no statistically significant difference between males and females in implicit theories of math ability, $F(1, 1433) = .05$, $p = .829$. To evaluate the second hypothesis, potential gender differences for math achievement were examined using a one-way ANOVA. There was no statistically significant difference between males and females in math achievement, $F(1, 1422) = .03$, $p = .869$.

Table 2

Descriptive Statistics of the Study Measures by Gender

	Male			Female			Total		
Measure	*n*	*M*	*SD*	*n*	*M*	*SD*	*n*	*M*	*SD*
ITBS Math[a]	753	203.62	29.93	671	203.88	29.42	1424	203.75	29.68
Implicit Theories[b]	751	7.65	2.31	684	7.62	2.39	1435	7.64	2.35
Interest[c]	647	3.43	0.70	604	3.56	0.63	1251	3.49	0.67

[a]Possible scores range from 150 to 276.
[b]Possible scores range from 3 to 12.
[c]Possible scores range from 1 to 5.

Next, the relationship between implicit theories of math ability, math interest, and math achievement was examined by calculating correlations among the three measures, which are found in Table 3. As predicted by the fourth hypothesis, there was a statistically significant positive correlation between the implicit theories measure and the math achievement measure, *r*(1376) = .20, *p* < .001. However, contrary to the third hypothesis, a non-significant negative correlation was observed between the implicit theories measure and the math interest measure, *r*(1213) = -.04, *p* = .138.

Table 3

Correlations for the Study Measures

Measure	1	2	3
1. ITBS Math	1.0		
2. Implicit Theories	.20*	1.0	
3. Interest	-.06	-.04	1.0

**p* < .01

To evaluate the fifth and final hypothesis, the potential differences between grade levels for implicit theories of math ability were examined using a one-way ANOVA. Descriptive statistics for each grade were obtained and can be found in Table 4. Counter to the fifth hypothesis, there was no statistically significant difference among grade levels for implicit theories of math ability, *F*(4, 1429) = 3.19, *p* =.013.

Table 4

Descriptive Statistics for Implicit Theories Measure by Grade

Grade	n	M	SD
2	278	7.65	2.63
3	276	7.23	2.42
4	310	7.62	2.22
5	321	7.88	2.27
6	249	7.77	2.12
Total	1434	7.64	2.35

Discussion

The purpose of this study was to explore the potential effects of gender and implicit theories of math ability on math interest and math achievement among elementary students. By exploring these factors, this study may help identify those students vulnerable to math disengagement and lower achievement and add to our understanding of why the gender gap in mathematics achievement and STEM career choice persists. In this study, males and females did not differ in their implicit theories of math ability, unlike what was specified in the first hypothesis. Additionally, males and females did not differ in their overall math performance. Although this finding was contrary to the second hypothesis, it is consistent with current findings from other studies. The gender gap in math achievement has been shown to have largely disappeared at the grade levels we studied (Hyde, 2005). When examined together, these findings may be an encouraging sign that gender differences in math have diminished at the elementary level.

The third hypothesis was not supported by the present study's findings. There was no relationship between math interest and implicit theories of math ability. This finding was unexpected considering some current research indicates domain interest is related to domain trait beliefs (Broome, 2001; Burkley et al., 2010). However, these studies did not examine the domain of math or were conducted with different grade level populations. Clearly, more studies are needed regarding the relationship between trait beliefs and domain interest.

Furthermore, math interest did not correlate with student math achievement. This finding was also surprising when compared to literature on the relationship between these constructs. However, it is important to consider that the measure of math interest used in the present study was developed for the purposes of identifying students for Project GEMS. Although the measure is based on a theoretical model and may serve its purpose to identify individuals from underrepresented populations in math, the validity of the measure for its use as an outcome variable is still in the developmental phases. Our study could be improved by further efforts to establish validity of the math interest measure, such as a longitudinal study of the measure (Snow, 2011) or by a correlational study of the measure with other math interest measures.

The fourth hypothesis was supported by the current study's results, which showed that students with more of an incremental view of their math ability displayed higher math achievement scores. The observed magnitude of the relationship between math achievement and implicit theories of math ability was $r = .20$. This finding is consistent with findings from previous studies evaluating the relationship between general implicit theories of intelligence and achievement. A short longitudinal study in Greece found that students with high mean achievement in math and language adopted higher incremental views of intelligence in grades 5-6 and when they were assessed a year later, with the magnitude of the correlation being $r = .223$ in the first phase and $r = .191$ in the second phase (Gonida et al., 2006). Another longitudinal study found that higher incremental views of intelligence were associated with higher math achievement on a standardized assessment of math achievement for middle school students, with a magnitude of the correlation ranging from $r = .12$ in seventh-grade to $r = .20$ when students were assessed again in eighth-grade (Blackwell et al., 2007). The present study is unique in that it shows that domain specific trait beliefs are also connected to domain performance at the elementary level.

Counter to the fifth hypothesis, there were no grade level differences in implicit theories of math ability. Some research on implicit theories of intelligence indicates that children do not significantly differ in their views across the elementary grade levels (Bempechat et al., 1991; Kinlaw & Kurtz-Costes, 2007). Therefore, elementary students' domain specific views may not differ significantly either, though more research on children's implicit theories of specific abilities at this level is needed.

Limitations and Future Directions

The present study had some limitations which readers should consider. The study sample, which consists of students who come from one school district in Kentucky, may not be representative of the overall population. This may reduce its generalizability to students from other regional and cultural backgrounds. The current study was also correlational in nature; therefore the results should be interpreted with caution when considering the causality between the variables studied. Future studies should experimentally test Dweck and Leggett's (1988) full model of motivational patterns and their achievement outcomes in relation to implicit theories of math ability, as the present study did not examine student goal orientations or attributions related to math. These studies could explore the causal relationship between implicit theories of math ability, other motivational variables, and math achievement.

The current study also used self-report measures to assess math interest and implicit theories of math ability. Self-report measures in general have several known weaknesses, including the potential for a social desirability response bias, which is defined as "the tendency on the part of individuals to present themselves in a favorable light, regardless of their true feelings about an issue or topic and a tendency for individuals to overgeneralize their responses” (Podsakoff, MacKenzie, Lee, & Podsakoff, 2003, p. 881). Although students were assured that there were no right or wrong answers, potential biases could be further controlled through the use of measures that come from other sources, such as parents and teachers, in combination with the self-report measures. Additionally, the use of a single self-report measure for motivational variables such as interest and implicit theories of abilities has been criticized because of the complexity of such constructs (Bong, 1996). Using multiple indices to assess target variables could improve the representation of these constructs.

The current findings contribute to the currently limited amount of literature regarding the relation between gender and math trait beliefs at the elementary level. Future work should seek to corroborate our findings with larger sample sizes and more diverse samples of the student population. The long-term relationship between implicit theories of math ability and achievement outcomes would also be useful to explore using a longitudinal study with the same students across the elementary, middle school, and high school years. There are disadvantages to such a study, including expense and the length of time it would take to conduct, but such a study could help identify the potential emergence of gender differences in implicit theories across age and grade levels and how these relate to the gender gap in math achievement and student decisions related to pursuing interests in the STEM field.

Although gender was the focus of this study, researchers should also examine how other student variables (such as race), social variables (for example, parent income level), and situational variables (for instance, the semester administered) relate to math trait beliefs and achievement outcomes. These studies would be useful in the development of tools to help identify students that are vulnerable to poor achievement outcomes and potentially students who may have the ability to achieve in the STEM fields, but may choose not to pursue a career due to their maladaptive response to challenging achievement situations.

Further research is needed to examine how students learn or develop a particular implicit theory of math ability. Some research has explored how praise for student abilities versus praise for student effort influences student implicit theories of intelligence, but further research is necessary on how implicit theories of specific abilities may be influenced by praise or other types of influence from peers, parents, and teachers (Kamins & Dweck, 1999; Mueller & Dweck, 1998). Perhaps certain parenting and teaching styles, home and classroom environments, and peer relationships promote a more incremental view of math ability. For example, some studies have explored how teacher's implicit theories about children's intelligences relate to their classroom environment (Deemer, 2004; Leroy, Bressoux, Sarrazin, & Trouilloud, 2007). However, further research is needed in relation to how this may subsequently affect students' implicit theories of intelligence and specific abilities.

Some studies have shown that implicit theories may be experimentally manipulated in order to improve outcomes (Bempechat et al., 1991; Hong et al., 1999), but determining if implicit theories are amenable to long-lasting change is an area that needs further exploration. If (a) vulnerable students may be identified, (b) a causal relationship with implicit theories of math ability to student outcomes is shown over time, and (c) implicit theories are found to be amendable to change and influence by parents and teachers, then exploring whether interventions that target student trait beliefs are effective in improving outcomes is important. Some evidence exists that interventions that seek to amend implicit theories of intelligence are successful in improving outcomes in the short-term (Blackwell et al., 2007; Good, Aronson, & Inzlicht, 2003), but examining the long-term positive effects on student outcomes in the math domain is vital, particularly with girls and other underrepresented individuals in the STEM fields. Outcomes that should be examined include student achievement (not only grades, but standardized test performance), domain interest, course selection, and other factors related to the decision to pursue a STEM career.

Researchers should explore other types of interventions, particularly those that target parents and teachers and not just the students themselves. The results could be useful in the further development of individual and classroom interventions, parent intervention, and teacher interventions that may improve student outcomes and increase student resiliency in the face of challenge and difficulty in school. Such interventions may also subsequently improve the number of women and other underrepresented individuals who choose to pursue STEM studies and careers.

In conclusion, the present study expands on prior research and shows that math achievement is related to specific ability beliefs in the math domain as early as the elementary level. This finding has a variety of important implications for the way we understand student motivation and its relationship to student outcomes. It should also remind educators to consider the variety of factors that relate to student success at an individual level and other ways that success in STEM subjects in school may be promoted.

APPENDIX A

Implicit Theories of Math Ability Scale

Read each sentence below and then select the one number that shows how much you agree with it. There are no right or wrong answers.

1	2	3	4	5	6
Strongly Agree	Agree	Mostly Agree	Mostly Disagree	Disagree	Strongly Disagree

1. You have a certain amount of math ability, and you really can’t do much to change it.
2. Your math ability is something about you that you can’t change very much.
3. You can learn new things, but you can’t really change your basic math ability.

APPENDIX B

Math Interest Inventory

Please answer the questions below honestly; there are no right or wrong answers.

1	2	3	4	5
Never	Rarely	Sometimes	Most of the time	Always

1. Math is interesting
2. I like math.
3. Math is fun.
4. Math is boring.
5. Math is cool.
6. Learning about math is important.
7. Learning about math is helpful.
8. What I learn in math is useful.
9. I know a lot about math.
10. I am good at math.
11. Math is hard for me.
12. I do well in my math classes.
13. Math is easy for me.
14. I talk to my family or friends about things I learned in math class.
15. I watch television shows about math outside of school.
16. I look at websites about math outside of school.
17. I play math computer games outside of school.
18. I read books about math outside of school.
19. I go places to learn about math outside of school.
20. I like to do math problems outside of school.

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