

Investigating Young Children's Attitudes toward Mathematics:
Improved Measurement and the Relation to Achievement

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Dedication

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Abstract

Researchers in the field of school psychology have recently emphasized the influence of different academic enablers that may influence how students achieve and perform in school. In this literature, attitudes have not yet received much attention as an enabler. However, students as young as pre-kindergarten enter school with predisposed attitudes towards mathematics. These attitudes may influence their engagement, persistence and performance in mathematics. Evidence also suggests that mathematics performance in kindergarten and first grade can predict performance later in life. Thus, it is important for school psychologists and educators to understand how students perceive their ability and perceive the task of mathematics to help students build their competence to become later successful learners. Understanding the earlier development of these attitudes may help foster more positive perceptions and mathematics learning environments for all students. The purpose of this two-study dissertation was to examine attitudes toward mathematics among young children in kindergarten and first grade. Specifically, the purpose of Study 1 was to develop an assessment instrument to measure attitudes toward mathematics for students in kindergarten and first grade and to examine the reliability and validity evidence for potential use in a school setting. Further, Study 2 aimed to investigate the extent to which different attitudes such as perceived self-competence beliefs, enjoyment, and importance were related to student mathematics achievement as measured by teacher ratings and standardized mathematics assessments. This study is first in an emerging line of inquiry to understand how attitudes influence various achievement outcomes for young children, and, thereby identify if, how, and to what effect attitudes of young children might be targeted for intervention.

Table of Contents

Acknowledgements.....	i
Dedication.....	ii
Abstract.....	iii
Table of Contents.....	iv
List of Tables.....	vii
List of Figures.....	viii
List of Appendices.....	ix
CHAPTER 1.....	1
Defining Attitudes toward Mathematics.....	2
How Attitudes Develop.....	6
Theoretical Foundations.....	8
Relation between Attitude toward Mathematics and Achievement in Mathematics	10
Measurement of Attitudes.....	12
Purpose.....	13
CHAPTER 2. Improved Measurement of Young Children’s Attitudes toward Math.....	16
Defining Attitudes toward Mathematics.....	17
Measuring Attitudes toward Mathematics.....	20
Previous Measures of Attitudes toward Mathematics.....	21
Challenges for Measuring Mathematics Attitudes in Young Children.....	24
Purpose.....	28

Methods	29
Participants and Setting.....	29
Procedures.....	30
Analysis.....	33
Results	36
Descriptive Statistics & Correlations.....	36
Confirmatory Factor Analysis.....	37
Reliability & Readability	40
Discussion	41
 CHAPTER 3. Are Attitudes toward Math an Academic Enabler of Early Math	
Achievement?	50
Attitudes and Achievement in Young Children.....	51
Purpose.....	62
Methods.....	62
Participants.....	62
Measures	63
Procedures.....	67
Results.....	68
Characteristics of the Sample.....	68
Discriminant Validity.....	70
Regression Analysis.....	71
Discussion	73

CHAPTER 4	83
Limitations	85
Implications and Contribution to the Field of School Psychology	86
References.....	88

List of Tables

Table 1. Summary of Survey Instruments Used to Measure Attitudes toward Mathematics	101
Table 2. Demographics of the Sample.....	104
Table 3. Frequency of Responses, Means, Standard Deviations, Skew, Kurtosis, Discrimination and Alpha for Attitudes Survey Items	105
Table 4. Item Correlations across the Three Attitude Scales.....	107
Table 5. Confirmatory Factor Analysis Fit Statistics for Hypothesized Models.....	108
Table 6. Factor Loading Estimates for Three-factor Model	109
Table 7. Item Descriptive Statistics, Scale Descriptive Statistics, Reliability Estimates and Readability	110
Table 8. Means, Standard Deviations and Correlations between Measures.....	111
Table 9. Correlations between Attitudes, Teacher Report, and Direct Measures of Mathematics Achievement.....	112
Table 10. Discriminate Validity across Math Achievement Groups	113
Table 11. Summary of Regression Models for Predicting Spring Mathematics Achievement	114
Table 12. Summary of Change in R^2 : Do Student Attitudes toward Math Enhance Prediction of Math Achievement?	115

List of Figures

Figure 1. Word cloud depicting students' spontaneous comments related to math..... 116

Figure 2. Model of survey items with a unidimensional factor structure. 117

Figure 3. Model of survey items with a three-factor structure where all three factors are correlated..... 118

Figure 4. Model of survey items with two-factor structure where all two factors are correlated..... 119

Figure 5. Structure of hypothesized dimensionality with hierarchical structure and three first order factors..... 120

List of Appendices

Appendix A. List of All Student Responses Related to their Perceptions of Math	121
Appendix B. Young Children's Attitudes toward Mathematics Pilot Survey Items.....	123
Appendix C. Survey Administration Fidelity Checklist.....	125
Appendix D. EarlyMath Observing and Rating Administrator Accuracy	126
Appendix E. Teacher Rating of Student Attitudes toward Math	127
Appendix F. Teacher Rating of Student Math Achievement.....	128

CHAPTER 1

While most children start school eager to learn, many students report negative experiences related to mathematics throughout their schooling. One study reported that 93% of surveyed college freshman reported some negative experience related to mathematics from kindergarten through twelfth grade (Jackson & Leffingwell, 1999). This is not surprising given that many students experience difficulties in learning mathematics (U.S. Department of Education, Institute of Education Sciences, National Center for Education Statistics, 2015). Students with difficulties in mathematics tend to have poorer attitudes toward mathematics compared to their typically achieving peers (Hanich & Jordan, 2004, Zeleke, 2004). These attitudes toward mathematics have the potential to hinder student learning. This reciprocal and compounding effect is problematic since mathematics skills in primary school are a robust predictor of later academic success (Duncan et al., 2007).

Difficulties in mathematics can be observed as early as kindergarten (Jordan, Kaplan, Ramineni, & Locuniak, 2009), and have the potential to persist through primary (Claessens, Duncan & Engel, 2009; Jordan, Kaplan, Oláh, & Locuniak, 2006; Morgan, Farkas, & Wu, 2009), and secondary grades (Claessens, & Engel, 2013) as well as further into adulthood (Geary, 2011). There is evidence that students with mathematics difficulties exhibit persistent low achievement (Geary, 2011), and show difficulties in attention and task persistence (Fuchs et al., 2005), difficulties in reading (Aiken, 1971), low motivation in school (Torgesen, 1994), and an aversion to mathematics that may follow into adulthood (Geary, 2011). Further, students' math difficulties tend to have negative implications for adulthood such as lower paying jobs (Geary, 2011). The

persistence of deficits might be especially robust in the absence of early identification and intervention.

Mathematics difficulties are not only the result of poor cognitive ability but may be moderated by performance and academic enablers. At the time of this study, prominent researchers in the field emphasized academic enablers that may influence how students achieve and perform in school (e.g., DiPerna, Volpe, & Elliot, 2005). In this literature, attitudes have not yet received much attention as an enabler. Still, evidence suggests that mathematics performance in kindergarten and first grade can predict performance later in life (Duncan et al., 2007; Fuchs, Compton, Fuchs, Paulsen, Bryant, & Hamlett, 2005). Further, students as young as pre-kindergarten enter school with predisposed, socialized attitudes towards mathematics (Fisher, Dobbs-Oates, Doctoroff, & Arnold, 2012) and these attitudes may negatively influence their engagement, persistence, and performance in mathematics (Wigfield & Eccles, 1994). Thus, it is important for school psychologists and educators to understand how students perceive their own ability and perceive mathematics tasks to help students build their competence to become later successful learners. Understanding the earlier development of these attitudes toward mathematics may help foster more positive perceptions and learning environments for all students.

Defining Attitudes toward Mathematics

Attitude is a widely studied concept in the social sciences (Campbell, 1963; Eagly & Chaiken, 1998). Yet, definitions of attitude tend to vary and the term is sometimes ambiguous. Some suggested that there were 80 or more concepts or descriptors that share aspects of the definition or characteristics of attitude (Campbell, 1963). In 1935, Gordon

Allport defined attitude as a “mental and neural state of readiness ... exerting a directive or dynamic influence upon the individual's response to all objects and situations with which it is related” (p. 810). While this seminal definition is useful given the emphasis on the relation to behavior, it does not provide much operational utility. In social psychology, it is agreed upon by many researchers that attitudes encompass consistent aspects of cognition, affect, and behavior (Eagly & Chaiken, 1998). In regards to mathematics, the cognitive component involves a person’s belief or knowledge about mathematics (e.g., “I believe math is important”), the affective component involves a person’s feelings about mathematics (e.g., “I hate math”), and the behavior component is the way that attitudes influence how people act (e.g., “I do not like math so I will not do my math homework”). While commonly used, researchers have critiqued this tripartite model of attitudes in regard to how these three components are related, especially regarding the consistency between cognition, affect, and behavior. Thus, other definitions are considered.

Other definitions are more evaluative, such that attitudes are a personal disposition about an object (e.g., mathematics) on a continuum from positive to negative (Aiken, 1970; Ajzen & Fishbein, 2000; McLeod, 1992). Or more simply put – attitudes are likes and dislikes (Bem, 1970, as cited in Ma & Kishor, 1997). This broad definition does not lend itself to practicality in research and researchers often attempt to classify attitudes into different components. For example, Neale (1969) defined attitudes toward mathematics as “a liking or disliking of mathematics, a tendency to engage in or avoid mathematical activities, a belief that one is good or bad at mathematics, and a belief that mathematics is useful or useless” (p. 632). A brief review of the literature indicates that

others have used a similar framework as Neale to describe, define, measure, and study attitude toward mathematics (e.g., Adelson & McCoach, 2011; Fredricks & Eccles, 2002; Ma & Kishor, 1997; Mullis, Martin, Foy, & Aurora, 2012). Further, theory suggests that competence beliefs, enjoyment and importance are key influences of achievement, motivation, and success in mathematics (Wigfield & Eccles, 1994). Each of these components will be discussed below.

Competence Beliefs. Competence beliefs describe the views that students form about their own ability to do and learn mathematics. There is evidence that self-perceptions of ability emerge as early as first grade (Denissen, Zarrett, & Eccles, 2007) and are predictive of later success in mathematics (Stankov, Morony, & Lee, 2014). Competence beliefs may encompass *confidence*, *self-efficacy*, and *self-concept*. Confidence is a person's belief that they are good at or have the ability to succeed in mathematics (e.g., "I am good at math"). Similarly, self-efficacy is one's beliefs about their capabilities to succeed in specific situations (e.g., "Even if a new topic in math is hard, I'm sure that I can learn it" or "I can solve algebraic equations;" Bandura, 1977; Parajes & Miller, 1994). Self-concept is similar but also considers the attitudes, feelings, and perceptions related to mathematics, and is more general than self-efficacy (e.g., I do better in math than other students in my class; Whang & Hancock, 1994). While there are some definitional distinctions between these three terms, there is evidence that these concepts are highly related and cannot be empirically distinguished (Valentine, DuBois, & Cooper, 2004). In fact, some studies that investigate self-confidence in mathematics use similar measures as studies that investigate self-efficacy or self-concept (e.g.,

Adelson & McCoach, 2011), so in this paper the broader term *competence beliefs* is used to describe this aspect of attitudes toward mathematics.

Enjoyment. Perceived enjoyment of mathematics represents the extent that an individual likes, enjoys, and is interested in mathematics (Ganley & Lubienski, 2016, Pinxten, Marsh, DeFraine, Noortgate, & Van Damme, 2014). Students who perceive mathematics as enjoyable and interesting tend to spend more time and effort on mathematics and select more challenging mathematics coursework (Stipek, 2002). Enjoyment might also be an indicator of motivation; those who find mathematics to be interesting and enjoyable tend to be more motivated to spend more time with practice and pursue careers in mathematics (Seaton, Parker, & Marsh, 2014). It is important to consider this aspect of attitudes toward mathematics since students who believe they are good at mathematics might not pursue later mathematics activities if they do not like or enjoy the subject.

Importance. The importance of mathematics indicates how much students value mathematics for their future and everyday life (Pintrich & Schrauben, 1992). Similar to enjoyment, finding mathematics useful tends to influence behavior related to mathematics performance. Specifically, those who find math to be useful for their life put forth more effort in practicing mathematics (Pajares & Miller, 1994). Even if children perceive their abilities in mathematics to be high, they may not engage in the task if they believe that it is of low value (Wigfield & Eccles, 1994). Value, usefulness or importance has been identified as a key variable in fostering positive attitudes toward mathematics, so much so that some researchers have developed scales specifically to measure valuing of mathematics (Aiken, 1974; Fennema & Sherman, 1976; Tapia & Marsh, 2004).

Emotions. It is worthwhile to note that some definitions of attitudes include emotion such as worry or anxiety (e.g., Daskalogianni, & Simpson, 2000; Di Martino & Zan, 2011; Dowker, Bennett, & Thomas, 2012; Hannula, 2004; McLeod, 1992; Reyes, 1984); however, it is important to find some distinctions and refine the definition of attitudes. The research findings in regards to math anxiety are substantially different from those on attitudes (e.g., Ahmed, Minnaert, Kuyper, ver der Werf, 2012; Gierl & Bisanz, 1995). Specifically, published findings regarding math anxiety generally indicate that math anxiety, similar to other performance-based anxieties, hinders student performance in mathematics partly due to a use of working memory resources (Ashcraft et al., 2007). Students' anxious thoughts utilize their working memory capacity, which prevents them from being able to solve complex problems. In contrast, published findings indicate that attitudes influence learning through motivational factors (Dowker et al., 2016). Such findings demonstrate the utility of distinct definitions that delineate attitudes toward mathematics from other emotional influences. Thus, an analysis of emotion is not included in the definition of attitudes toward mathematics used in this paper.

How Attitudes Develop

Attitudes toward mathematics are influenced by a combination of previous experiences and social mechanisms. Younger students tend to hold more positive attitudes toward mathematics compared to students in later grades (Ganley & Lubienski, 2016), suggesting that school-based experiences play a role in how negative attitudes toward mathematics develop. More difficult mathematics curriculum over time yields repeated opportunities for students to experience persistent learning challenges. When such challenges are not accompanied by sufficient resolution or mastery, students may

shift how they perceive mathematics from positive to negative (e.g., Wigfield & Eccles, 2000), thus shaping how they approach future mathematics in the classroom and in real-world settings. Although many students enter school with more positive attitudes toward mathematics, some researchers have reported that students as young as pre-kindergarten are disinterested in mathematics (Fisher, Dobbs-Oates, Doctoroff, & Arnold, 2012). This suggests that factors outside of school experiences also have an impact on how attitudes toward mathematics develop.

Two mechanisms of social experiences include gender socialization and adult-student interactions. Although there is limited evidence of a gender gap in mathematics achievement across the school-age years, boys report higher levels of self-confidence in mathematics as early as third grade (Lubienski, Robinson, Crane & Ganley, 2013), and this gender gap in attitudes remains throughout the school-aged years (Else-Quest, Hyde, & Linn, 2010). Gender socialization ranges from implicit cultural stereotypes that “math is for boys” to explicit messaging that boys and men have natural talent in mathematics (Gunderson et al., 2012). Adult-student interactions also play a role in how attitudes toward mathematics develop. Students who perceive that their parents or teachers believe that math is not valuable, or is too hard tend to hold negative attitudes toward mathematics (Eccles & Jacobs, 1986; Rattan, Good, & Dweck, 2012). Parents and teachers have their own history related to mathematics and how they communicate their attitudes to students has the potential to improve or hinder mathematics learning. Similarly, students who perceive greater support in mathematics from parents and teachers have more positive attitudes and higher self-confidence in mathematics (Rice, Barth, Guadagno, Smith, & McCallum, 2013).

Theoretical Foundations

Attitudes toward mathematics may impact achievement in a number of ways. Attitudes may influence behavior, behaviors may influence attitudes, or both may influence each other reciprocally. There are also other factors that may have an influence on the relationship (e.g., engagement, class environment). While achievement is not necessarily a behavior, it is measured through student performance on a test, which is then inferred to represent achievement. Hence, many turn to theories of attitudes and behaviors to describe the relation between attitudes and achievement. While the following theories are domain general in nature, they are described due to the influence and application that they may have on the relation between attitudes toward mathematics and achievement in mathematics.

How achievement influences attitudes. Attitudes toward mathematics may be shaped by previous achievement or learning history. When students experience difficulties in mathematics, they often receive poor grades and negative feedback. Those who receive consistent patterns of negative feedback are likely to avoid mathematics related tasks and put forth less effort (Wigfield & Eccles, 2000). This aligns with the underlying principle that there is consistency between attitudes, behavior, and consequences; people expect their behavior to be consistent with their attitudes, such that those who perform well on mathematics tests are often assumed to hold positive attitudes toward mathematics. When there is inconsistency, students may experience a sense of discomfort and change their attitudes to match their behaviors to reach consistency (Himmelfarb & Eagly, 1974). Although beyond the scope of this dissertation, this concept is also related to cognitive dissonance theory (cf. Festinger, 1962). This influence

of learning history suggests that the relation between attitude and achievement should become stronger as students age, and their perceptions of their competence in mathematics may be a driving force in the influence on achievement.

How attitudes influence achievement. There are a number of theories that propose attitudes have an influence on shaping human behavior and/or achievement in a related task. Two theories that have application for understanding how attitudes toward mathematics influence achievement in mathematics are expectancy value theory (EVT), and the theory of planned behavior (TPB).

Expectancy value theory. EVT suggests that student's engagement and effort is a result of their expectations of success (e.g., perceived competence), and how much they value the task (e.g., usefulness). Expectations of success and usefulness are also influenced by how much they like the task (e.g., enjoyment; Wigfield & Eccles, 2000). EVT is widely applied across a number of disciplines to both study and predict how expectations, values, and beliefs influence the motivation to engage in a behavior (e.g., achievement). In this case, EVT might be used to predict the probability that children might persist to practice, apply, learn, and achieve within the mathematics domain (Wigfield & Eccles, 2000). Together, the EVT of achievement motivation has been found to influence achievement in mathematics and seems to align with the conceptualization of attitudes used in this dissertation (Wigfield & Eccles, 2000).

Theory of planned behavior. Expectancy value theory was expanded into the theory of reasoned action (Ajzen & Fishbein, 1977), which later influenced the development of the theory of planned behavior (Ajzen, 1991). The TPB suggests that people will behave based on their pre-existing attitudes and behavioral intentions. In

terms of attitudes toward mathematics, students who have positive attitudes will also need to believe that performing the behavior will lead to a specific outcome (e.g., achievement, engagement) to occur. This theory suggests that strong behavioral intentions are associated with increased effort and increased likelihood for success. They also distinguish three factors that affect intention: (1) attitude toward a behavior (e.g., Do I like math?), (2) subjective norms or social pressure (e.g., Do my peers/parents/teachers believe that math is positive and important?), and (3) perceived behavioral control (e.g., How easy or difficult is it for me to improve my achievement in mathematics?). This suggests that beliefs must be in place, and ultimately, a person must have intentions for the behavior to occur (Ajzen & Fishbein, 2005). TPB and EVT both suggest that attitudes have a key influence in determining behavior and influencing achievement in mathematics.

Relation between Attitude toward Mathematics and Achievement in Mathematics

The relation between achievement in mathematics and attitudes toward mathematics can be viewed as reciprocal. It is believed that attitude may have an effect on achievement, while achievement may also have an effect on attitude (Aiken, 1970; Ma & Kishor, 1997). Many educators stress the importance of fostering positive attitudes toward mathematics in their instruction; however, the extent to which this would impact achievement among younger children is still unknown. A widely cited meta-analysis analyzed that relationship (Ma & Kishor, 1997). The meta-analysis examined 113 quantitative studies of achievement and attitude toward mathematics, which included 82,941 students across grades 1 through 12. The majority of the included studies were correlational ($N = 108$) and nonrandom in design ($N = 100$). Ma and Kishor (1997) used

Neale's definition of attitudes toward mathematics and extended it to include the difficulty and importance of mathematics. Correlation coefficients, r , were calculated and ranged from $-.61$ to $.76$, suggesting that the relation between attitudes toward mathematics and achievement in mathematics varied from strongly negative to strongly positive. The weighted mean effect size (*WMES*) was reported as small but significant across grades 1 to 4 (*WMES* = $.03$) and grades 5 to 6 (*WMES* = $.14$), while the effect size was stronger but still small for students in middle and high school (*WMES* = $.25$ and $.20$, respectively). The relationship was strengthened by 367% from lower to upper elementary, and 79% from upper elementary grades to junior high grades. This suggests that the attitudes toward mathematics may have a larger impact on achievement in mathematics for older students, or that student report of attitudes may become more accurate and consistent with their achievement as they age.

There were a number of limitations to this meta-analysis. The authors did not code for measurement instruments; they reported that the coding for instruments was "not meaningful" (p. 31) due to the wide range of measures used from 1966 to 1993. The authors proposed that the different instruments were not hypothesized to have negative impacts on the relationship. Further, at the time of the meta-analysis, there were only 14 studies of achievement and attitudes in mathematics at grades 1 to 4, and no studies at the kindergarten level were identified (Ma & Kishor, 1997). The current paper extends this work by conducting research among this younger population of students.

A previous review (Aiken, 1970) showed similar small relations between attitudes and achievement in mathematics at the elementary levels. Although there was no direct evidence, the researchers suggested that their findings might have been mediated by the

relatively poor quality of the measures of attitudes used in the studies. Specifically, students at younger grades may not have had the ability to accurately express their attitudes toward mathematics and measures of attitudes may be less reliable and valid at lower grade levels. Ma and Kishor (1997) repeated these speculations and further posited that the current attitude measures are “very crude approximations to true attitudes, and researchers should put more effort into substantially refining these measures” (p. 40).

Measurement of Attitudes

Without high quality measurement instruments it is difficult to make strong conclusions about the relation of attitudes toward mathematics and other variables like achievement. Past reviews (e.g., Aiken, 1970; Ma & Kishor, 1997) have noted concerns with the measurement of attitudes toward mathematics for younger children. More recent research is beginning to focus on measuring attitudes among younger children (Adelson & McCoach, 2011; Palacios, Arias, & Arias, 2014), yet this research has not yet been extended for children in kindergarten and first grade. It seems that the concern with reliable responses on surveys from young children has been addressed by studies among pre-k, kindergarten, and first grade students, such that researchers utilized other measurement methods such as interviews and observations (Fisher et al., 2012; Kloosterman et al., 1996; Mazzocco et al., 2012). The more qualitative methods were able to uncover a medium to strong relation between attitudes and achievement. Although these methods seem promising, they are inefficient for practical use in schools, as they require extensive training, additional resources and more time spent coding responses. Consequently, improved measurement is still needed or both research and practice.

Purpose

The purpose of this dissertation was to examine attitudes toward mathematics among young children. The purpose was achieved through an integrated two-part study, described as Study 1 and Study 2. The first study focused on developing an improved measure of young children's attitudes toward mathematics. The second study used this tool to investigate the relation of attitudes toward mathematics to achievement among children. The study focused on improving the measurement of attitudes toward mathematics so that educators and researchers can better understand the extent to which attitudes toward mathematics are related to achievement and mathematics learning from early grades. This dissertation study is first in an emerging line of inquiry to understand how attitudes influence various achievement outcomes for young children, and thereby identify if, how, and to what effect attitudes of young children might be targeted for intervention.

Study 1. The purpose of this study was to develop an improved measure of attitudes toward mathematics for young children for both the purposes of educational practice and research. Specifically, the factor structure of attitudes toward mathematics among this population was examined and psychometric evidence was collected. The following research questions guided the study:

1. To what extent can attitudes toward mathematics be measured among students in kindergarten and first grade? Specifically, can a tool be created to yield reliable, valid, and instructionally relevant information about students' perceived enjoyment, competence beliefs, and importance of mathematics?
2. What was the dimensionality of attitudes toward mathematics for young children?

Further, to what extent is this similar or divergent from previous research among older children?

Study 2. The purpose of this study was to investigate the relationship between mathematics achievement and attitudes toward mathematics for students in kindergarten and first grade. Specifically, different attitudinal dimensions were examined based on previous literature: competence beliefs, enjoyment, and importance. The research questions were:

1. To what extent do student-reported attitudes toward mathematics relate to: (a) teacher ratings of student achievement; (b) teacher ratings of student attitudes; and (c) student achievement on standardized measures of math achievement.
2. To what extent do ratings on student attitude measures differentiate between students who were low and high achieving?
3. To what extent do student ratings of their own attitudes toward mathematics enhance models and predictions of student achievement in kindergarten and first grades? Relevant variables and predictors to include in the model include demographic variables along with teacher rating of achievement, teacher ratings of attitude, student ratings of attitude, and present level of achievement.

I hypothesized that attitudes toward mathematics can be adequately measured among young students when they are designed to include simple language and specific vocabulary. Based on a previous literature review, I also hypothesized that self-competence beliefs will have the highest relation to achievement outcomes. Similarly, teachers will rate students with higher achievement as showing more interest in mathematics. Further, students who are low achieving or with difficulties in mathematics

would be differentiated by their attitudes toward mathematics as measured by their self-report and their teachers report. Thus, I hypothesized that the attitude measures will enhance the models and predictions of mathematics performance.

CHAPTER 2

Improved Measurement of Young Children's Attitudes toward Math

Up to 60% of adolescents indicated that they are not good at math, and 30% reported feeling helpless when doing a mathematics problem (OECD, 2013).

Comparably, the results from the 2015 results from the National Assessment of Educational Progress suggest that 60% of fourth-grade students and 67% of eighth grade students were below proficient in mathematics (Nation's Report Card, 2016). Given the recent emphasis on mathematics achievement in the United States it is important to understand influences that contribute to student mathematics performance and their corresponding perceptions of mathematics.

One important influence is students' attitudes toward mathematics. Previous research has indicated that attitudes toward mathematics for students in middle and high school might have a strong influence on mathematics performance. Further, when students do not perceive enjoyment, utility, or perceive themselves as skillful in mathematics they are less likely to be engaged, effortful, and motivated in mathematics class (Aiken, 1970; Fredricks & Eccles, 2002; Tapia & Marsh, 2004). Developmentally, attitudes toward mathematics tend to become more negative over time and have the potential to hinder or foster student learning (Ganley & Lubinski, 2016). Thus, it seems important to explore how these negative attitudes develop and what we can do to foster positive attitudes from a young age.

There is a recent emphasis in the field of education to improve academic beliefs, attitudes and behaviors that may impact learning (DiPerna, 2005; DiPerna, Volpe & Elliot, 2005; Haimovitz & Dweck, 2017; Kilgus, Bowman, Christ & Taylor, 2017). Yet,

at the time of this study, there were few measures with acceptable psychometric evidence to provide data on student attitudes toward mathematics. When used, such measures may have the potential to improve our understanding of student learning. Understanding how students perceive their mathematics ability may be some of the first steps in helping students build their competence to become successful learners in mathematics. Without high quality measurement instruments it is difficult to make strong conclusions about student attitudes toward mathematics.

Defining Attitudes toward Mathematics

Definitions of attitude tend to vary and the term is sometimes ambiguous. In the context of mathematics, Neale (1969) defined attitudes as “a liking or disliking of mathematics, a tendency to engage in or avoid mathematical activities, a belief that one is good or bad at mathematics, and a belief that mathematics is useful or useless” (p. 632). A brief review of the literature indicates that others used a similar framework as Neale to describe, define, and study attitudes toward mathematics (e.g., Adelson & McCoach, 2011; Fredricks & Eccles, 2002; Ma & Kishor, 1997; Mullis, Martin, Foy, & Aurora, 2012). Further, previous research suggests that enjoyment, competence beliefs, and perceived importance of mathematics are critical influences of achievement, motivation, and success in mathematics (Wigfield & Eccles, 1994).

Some recent research supports the concept that attitude toward mathematics is multidimensional (e.g., Adelson & McCoach, 2011; Gierl & Bisanz, 1995). Children and adults do not simply “like” or “dislike” mathematics. There is more to it; there are nuanced cognition, affect, and behaviors towards mathematics. Similar to recent research with elementary aged students (Adelson & McCoach, 2011), this study examined the

measurement of three dimensions: perceived enjoyment, competence beliefs and perceived importance. These dimensions are consistent with early definitions of attitudes toward math (Neale, 1969). Although there is initial evidence and emerging theoretical rationale to support multidimensionality, empirical evidence of a multidimensional measure has yet to emerge for students in kindergarten and first grade. This study aimed to consider a combination of theoretical, empirical, and psychometric perspectives.

Competence Beliefs. Competence beliefs describes the views that students form about their own ability to do and learn mathematics. There is evidence that self-perceptions of ability emerge as early as first grade (Denissen, Zarrett, & Eccles, 2007) and is predictive of later success in mathematics (Stankov, Morony & Lee, 2014). Perceived self-competence may include *confidence*, *self-efficacy*, and *self-concept*. Confidence is a person's belief that they are good at or have the ability to succeed in mathematics (e.g., "I am good at math"). Similarly, self-efficacy is one's beliefs about their capabilities to succeed in specific situations (e.g., "Even if a new topic in math is hard, I'm sure that I can learn it" or "I can solve algebraic equations"; Bandura, 1977; Parajes & Miller, 1994). Self-concept is similar but also considers the attitudes, feelings, and perceptions related to mathematics, and is more general than self-efficacy (e.g., "I do better in math than other students in my class"; Whang & Hancock, 1994). While there are some definitional distinctions between these terms, there is evidence that these concepts are highly related and cannot be empirically distinguished (Valentine, DuBois, & Cooper, 2004). In fact, some studies that investigate self-confidence in mathematics use similar measures as studies that examine self-efficacy or self-concept (e.g., Adelson & McCoach, 2011), so in this study the broader term *competence beliefs* is used.

Enjoyment. Perceived enjoyment of mathematics represents the extent that an individual likes, enjoys, and is interested in mathematics (Ganley & Lubienski, 2016; Pinxten, Marsh, DeFraine, Noortgate & Van Damme, 2014). Students who perceive mathematics as enjoyable and interesting tend to spend more time and effort on mathematics and select more challenging mathematics coursework (Stipek, 2002). Positive affect might also be an indicator of motivation; such that those who find mathematics to be interesting and enjoyable tend to be more motivated to spend more time with practice and pursue careers in mathematics (Seaton, Parker, & Marsh, 2014). It is important to consider this aspect of attitudes toward mathematics because even if students believe they are good at mathematics, they might not pursue later mathematics activities if they do not like or enjoy the subject.

Importance. The importance of mathematics indicates how much students value mathematics for their future and everyday life (Pintrich & Schrauben, 1992). Similar to enjoyment, finding mathematics useful tends to influence behavior related to mathematics performance. Specifically, those who find math to be useful for their life put forth more effort in practicing mathematics (Pajares & Miller, 1994). Even if children perceive their abilities in mathematics to be high, they may not engage in the task if they believe that it is of low value (Wigfield & Eccles, 1994). Value or usefulness has been identified as a key variable in fostering positive attitudes toward mathematics, so much so that some researchers have developed scales specifically to measure valuing of mathematics (Aiken, 1974; Fennema & Sherman, 1976; Tapia & Marsh, 2004).

Measuring Attitudes toward Mathematics

The measurement of attitudes emerged in the midst of controversy. While some argued that attitudes could not be validly measured (Morrisett & Vinsonhaler, 1965), others asserted that attitudes could be quantified (Thurstone, 1928). Thurstone was an early advocate that feelings, dispositions, and ideas can be measured. That is, convert behaviors that are often or always unobservable to others that could be quantified. Since Thurstone's work in the early 1900's, there have been numerous attempts to reliably measure attitudes toward mathematics (e.g., Adelson, & McCoach, 2011; Aiken, 1974; Aiken & Dregar, 1961; Fennema & Sherman, 1976; Palacios, Arias, & Arias, 2014; Tapia & Marsh, 2004). Although there have been many improvements to measure attitudes toward mathematics, much of the progress refined or used measures with students in high school and college.

While educators and researchers have deemed attitudes toward mathematics important, concepts with elusive definitions often bestow substantial challenges for the development or use of measures. Past reviews (e.g., Aiken, 1970; Ma & Kishor, 1997) noted concerns with the measurement of attitudes toward mathematics, especially for younger children. Specifically, Aiken suggested that the published estimates for the relationships between attitudes toward mathematics and mathematics performance were, perhaps, suppressed by the relatively poor quality of the attitudinal scores. Further, the attitudinal scores from the limited measures were even less reliable and less valid at lower grade levels (Aiken, 1970). The conclusions published in a more recent meta-analysis further posited that measures provide "very crude approximations to true attitudes, and researchers should put more effort into substantially refining these

measures” (Ma & Kishor, 1997, p. 40). Although the quality of the measurements may hinder results, it is not yet clear whether students at younger grades may have less developed or stable attitudes. These children also have less developed language and expression of those attitudes regardless of their development and stability. Ongoing research and development to further the creation of instrumentation and procedures to measure the attitudes of students in the very early grades remains a challenge in general. This study focused on attitudes toward mathematics specifically, but might also make a more general contribution toward the measurement of attitudes among young children and students.

Previous Measures of Attitudes Toward Mathematics.

Aiken (1974) developed two of the first measures of attitudes toward mathematics with reliability and validity evidence. Aiken and Dregar’s (1961) original measure of attitudes toward mathematics was Likert-type self-report and unidimensional in nature. Aiken later revised this measure and proposed that attitudes were multi dimensional. The 1974 measure, Mathematics Attitude Inventory, included two dimensions: enjoyment and value of mathematics (Aiken, 1974). Arguably, the most influential measure of attitudes toward mathematics was published 2 years later and is still widely used and cited in research today (Fennema & Sherman, 1976). The Mathematics Attitudes Scales were developed to measure attitudes toward mathematics among middle and high school students. The measure has nine scales, some are related to student perceptions of teacher, parents, and gender attitudes. Relevant subscales include attitude toward success, confidence, anxiety, effectance motivation, and usefulness. Yet, the authors did not provide any factor analytic evidence for the nine-factor structure, and the basis of the

subscale structure is unclear. Although the measure is widely used in research, the measure has little validity evidence and lacks statistical evidence of the factor structure (Fennema & Sherman, 1976).

Since its original development, other researchers have made a number of modifications and revisions to the Mathematics Attitude Scale (e.g., Mulhern & Rae, 1998), yet these revisions have not yet been extended to young children. Given that young children have different social and cognitive influences and are in different stages of development, more research is needed to extend the development of attitude toward mathematics measures to make inferences and claims about the population of younger children.

Almost 30 years later, Tapia and Marsh (2004) developed another widely cited measure of attitudes toward mathematics. Yet, like the Fennema and Sherman Mathematics Attitudes Scales, the Attitude Towards Mathematics Inventory aimed to measure attitudes toward mathematics among high school students. This scale included 40 items and yielded factors of self-confidence, value of mathematics, enjoyment of mathematics and motivation. The scale showed evidence of high internal consistency reliability and test-retest reliability suggesting that attitudes were relatively stable over time. Still, this measure had not been validated for a younger population of students, making it difficult to make claims about students' early attitudes toward mathematics.

Recently, researchers have focused on measuring attitudes among younger students. Specially, Adelson and McCoach (2011) developed the Math and Me Survey (M&MS) to measure attitudes toward mathematics among students in elementary school. The scale consisted of 18 items across two factors: Self-Perceptions and Enjoyment.

Students in third and fifth grade responded to a 5-point Likert scale that ranged from *strongly disagree* to *strongly agree*. Both scales yielded high coefficient alpha reliability of .92 and .88; well above the typically recommended benchmark of .85. The M&MS was also well-grounded in theory of attitude toward mathematics, showed high content validity based on student and expert feedback, and showed evidence of high model fit through both exploratory and confirmatory factor analysis. This was an advancement in the research literature in regards to the measurement of elementary age students' attitudes toward mathematics. The researchers also considered students' reading level and found that the survey had a Flesch-Kincaid grade level of 3.4, indicating that it is appropriate for the average third grade student and the number of items lends itself to efficiency of assessment. This is important given that young children have less capacity for receptive language, which should be considered in the development of such measures of children's perceptions.

The researchers (Adelson & McCoach, 2011) attempted to create a survey scale to assess the extent to which students found mathematics to be useful for their current and future goals. However, the authors found poor model fit and suggested that perhaps the scale was not appropriate for younger students. Specifically, they proposed that perhaps elementary students “do not have a realistic sense of the future or experiences that allow them to have grounded perceptions about their future jobs” (p. 237). Yet, the literature suggests that usefulness of mathematics may still have an important relation to achievement, even among younger children. To assess the Usefulness component of attitudes toward mathematics authors of the M&MS used 9 items, which targeted if students thought that they use mathematics in other contexts (e.g., subjects, outside of

class, as a grown up, in jobs, in everyday life). Perhaps, some of these items were not as relatable to elementary students compared to in studies with middle and high school students. That is, for students in elementary school, it is plausible that they have not yet thought about how they will use mathematics as an adult, that many jobs use mathematics or that knowing mathematics will help them get a good job. These concepts are likely more relatable for older students who have experience or more knowledge of the workforce. Future scales may benefit from revisiting items that may help better target if young children find mathematics as important.

The authors stated that, at the time the manuscript was published, there were “no psychometrically validated instruments specifically designed to measure attitudes in elementary students” (Adelson & McCoach, 2011, p. 225). More recently, there were no other studies that developed *and* validated a scale to measure student attitudes toward mathematics among young students. However, there are a number of scales currently used in the research literature (See Table 1 for a summary). This study aimed to examine this previous work and to create a psychometrically validated measure for targeted use with young children.

Challenges for Measuring Mathematics Attitudes in Young Children

As demonstrated, the measurement of math attitudes is complex. It is a challenge to develop and evaluate developmentally appropriate measures of mathematics attitudes for elementary aged children (McCoach, Gable, & Medura, 2013), which adds to broader challenges to develop attitudinal measures for young children generally (Denham et al., 2009). The accumulation of such challenges may be an influence as to why researchers

have not yet developed reliable and useful scales that yield valid scores for young children.

Validity and evidence. Contemporary approaches to validity focus on the interpretation and use of the score rather than a sole focus on the measure. Some of these challenges can be illustrated by an argument-based approach to validation (Kane 2006; 2013). Given that researchers and educators cannot directly measure a student's attitude toward mathematics, we rely on observations of behaviors that are associated with that target domain. Attitudinal measures are often based on self-report of internalized, or covert, behaviors (e.g., cognitions, affects). Overt behaviors, such as a response to a rating score, are directly observed, scored, and used to infer a generalized disposition with respect to cognitive and affective states. There are a number of errors that might occur in this process and authors of current measures (see Table 1) made decisions that may have different influences on the results.

First, it is important that the concept of math attitudes is presented in a way that makes sense to young children. If students do not understand the questions being asked, their responses become arbitrary and/or their responses do not adequately capture the internal states of interest. For example, they might simply respond in one consistent direction rather than discriminate between the internal states of their thoughts and feelings that correspond to a particular item. They might generate responses intended as desirable or accommodating to adults. A variety of patterns like that are well-known and described in the literature (Furnam, 1986), but much of what is described was derived from work with adults.

There are a number of ways in which this problem may be addressed. One solution is to administer the survey in small groups so that students are focused. Another strategy that researchers have used is to include a number of negatively worded items as a validity check. For example, a survey may include one item “I like math” and an oppositely phrased item “I dislike math.” This strategy is commonly used in the research literature and in published scales but also has the downside of the negatively phrased item being confusing for young children. Another solution involves the careful development and writing of items. For example, Adelson and McCoach (2011) selected a group of students to review the items of the M&MS prior to a complete study of the measure. This type of review may help gain a better understanding of what positive math attitudes means to young children. Perhaps, some of the items in current surveys are not as applicable to young children. For example, “I will need math to get a good job” may not be relevant for a first grade student, where as “I will need math in second grade” may be more contextually relevant.

Second, reading level and vocabulary must be well thought out so as to limit construct irrelevant information such as reading ability to influence student’s responses of a survey of math attitudes. While survey items may be read aloud to students, it is also important to create items that are succinct and at an appropriate reading level to limit potential influences such as listening comprehension and attention. The M&MS survey (Adelson & McCoach, 2011) considered reading level in the development but also cautioned that items should be read aloud for third grade students. If developing a scale for younger children, this is even more important to consider as their reading skills may just be developing. In terms of using common vocabulary, survey authors and researchers

may consider consulting teachers so that the items are relevant for the school setting as well as students to gain insight into childrens' use of vocabulary (McCoach et al., 2013).

Lastly, it is important that the rating scale response make sense to the students. Typical Likert scales utilize responses on a scale from *strongly disagree* to *strongly agree* or *never* to *always*. It is plausible that some kindergarten and first grade students may not be familiar with these terms and may need simpler language. Another consideration is the inclusion of pictorial representation of responses (e.g., smile faces). Some researchers have utilized this (e.g., Dowker, Bennett & Smith, 2012; McKenna & Kear, 1990), while others have not (e.g., Adelson & McCoach, 2011; Harari, Vukovic & Bailey, 2013). When utilizing a pictorial representation of response items it is important to consider the children's familiarity with the picture as well as the wording of each item to ensure that the picture aids in the understanding of the response rather than confusing it (McCoach, et al., 2013). One possible solution may be to include explicit instructions with easy to understand examples of the variability of attitudes prior to children answering the survey on their own.

Although there are many challenges associated with the development of measures of mathematics attitudes for young students, such a measure would be an important contribution to the research literature. Educators are beginning to focus on academic enablers that influence the context of learning. Measuring math attitudes may have a role toward improving mathematics outcomes for children in a prevention and early intervention framework. Previous research in the area of attitudes toward mathematics suggests that when working with younger children, researchers tend to utilize less developed measures or qualitative interviews (e.g., Kloosterman, 1996). While these

techniques provide useful insight to the nature of young children's attitudes, it limits the use that such measures can provide reliable and valid scores for use in schools. Aligned with Kane's framework (2006; 2013), measures of attitudes toward mathematics should have evidence both that observations are representative of the target domains (e.g., factor analysis, test development), and that student responses are consistent or generalizable (e.g., test-retest reliability, internal consistency reliability). Research in other areas such as math anxiety suggests that affective components of mathematics performance can be reliably and validly measured among young children (e.g., Ganley & McGrew, 2016; Harari et al., 2013; Ramirez et al., 2016). Yet, high quality scales have not yet been developed and evaluated for young children's attitudes toward mathematics. These tools may be useful for educational practices as well as improved research on early mathematics learning.

Purpose

The purpose of this study was to develop an improved measure of attitudes toward mathematics for young children for both the purposes of educational practice and research. Specifically, the dimensionality of attitudes toward mathematics among this population was examined and psychometric evidence was collected. The following research questions guided the study:

1. To what extent can attitudes toward mathematics be measured among students in kindergarten and first grade? Specifically, can a tool be created to yield reliable and valid information about students' enjoyment, competence beliefs, and importance of mathematics?

2. What was the dimensionality of attitudes toward mathematics for young children?

Further, to what extent is this similar or divergent from previous research among older children?

Methods

Participants and Setting

This study was conducted in one elementary school in a single suburban district in the Midwestern United States. Data collected occurred in January. The study was described to teachers and they were given the option to participate. A total of 149 students in kindergarten and first grade from seven classrooms were recruited to participate in this study. Active parental consent was obtained for 80% of students resulting in a sample of 119 students ($M_{age} = 75$ months). The sample was approximately 45% female. The majority of the sample was White (82%) with 6% of students identifying as Black, 6% Hispanic, 4% Asian, and 1% American Indian. Nine percent of participating students were eligible to receive special education services. Further, 4% of students were receiving tier 2 support interventions in mathematics. Chi-square tests indicated that gender ($\chi^2 = 2.67, p = .10$), ethnicity ($\chi^2 = 3.02, p = .56$), or special education status ($\chi^2 = .26, p = .61$) did not significantly vary by grade level at $p < .05$. Table 2 includes this demographic information by kindergarten, first grade and the total sample.

Based upon prior research, the size of the sample needed for the factor analyses is sufficient. It is notable there are a lack of consistent guidelines in regards to the sample size required for confirmatory factor analysis. For example, some guidelines indicate that the sample size should be at least 100 (Kline 1979; MacCallum, Widaman, Zhang, &

Hong, 1999), other guidelines state that there should be a ratio of 10:1 for participants to items (Arrindell & van der Ende, 1985; Costello & Osborne, 2005; Everitt, 1975), and some guidelines suggest that the number of subjects should be larger than 5 times the number of items (Hatcher, 1994).

Procedures

Survey development. The Young Children's Attitude toward Mathematics Survey was developed based on previous research with older children and theory in regards to attitudes toward mathematics (Adelson & McCoach, 2011; Aiken, 1970; Fennema & Sherman, 1979; Tapia & Marsh, 2004). Twenty-two items were developed by the author with influences from previous research (Table 1) and based on a hypothesized three-factor structure of attitudes toward mathematics: Enjoyment, Competence Beliefs, and Importance. Some of the items were adapted from existing measures of math attitudes. Some of the items may also be the same as from existing measures (e.g., I like math, Math is boring) as these are common statements made by children. Three graduate students with experience in item writing and test development reviewed the items and provided feedback. In addition, a subset of items was shown to a small focus group of rising second grade students at a different school district. The author read each item to students and asked if it "made sense." In addition, those students were asked their opinions on different response options and formats. Students indicated their preference of responses such as *strongly agree* to *strongly disagree* or *yes* to *no*. These students were asked open-ended questions to gain insight into their perceptions about mathematics. For example, students were asked "what does it mean to be good at math?" and "why is it important to do math?" In addition to the focus group, 87 kindergarten and

first grade students from the present sample were also asked what they did and did not like about math. Feedback from both young children and from graduate students was considered when creating and revising the item bank for the data collection.

In the developmental stages of the survey, students tended to respond in short answers (“I just like it!”). About 23% of students mentioned words such as “fun” or “boring” which corresponded with the enjoyment dimension of attitudes. Twenty-one percent of students commented on the difficulty of math (i.e., hard, easy, challenge). Many students also mentioned learning (18%) or solving problems (7%). Only three students spontaneously mentioned that math would be helpful for being a grown up. A word cloud of student responses is presented in *Figure 1*. Specific student spontaneous responses in regards to math are presented in Appendix A.

Appendix B presents a list of the 22 items piloted in this study. The original 22 items had an average readability grade level of 1.4 as determined by Flesch-Kincaid Index of readability (Kincaid et al., 1975). This indicates that the items are appropriate for the average student in first grade. Administrators still read all items aloud to limit any construct irrelevant variance of student reading ability. The scale included 22 items with the presumption that items will be removed through item analysis and factor analytical procedures. This was also intended to improve efficiency of the measure.

Students responded on a four point Likert scale using the responses: *Yes, Kind Of, Not Really* and *No*. While this is not a traditional Likert response set, it was selected with aim of being understood by young children. This response set is consistent with previous work in measuring children’s math anxiety (Ganley & McGraw, 2016; Harari et al., 2013). In the present study, children spontaneously suggested these words when

describing their feelings toward math and reading. Children responded to items using a four-point Likert scale from: *No*, *Not Really*, *Kind of*, and *Yes*. The survey used these responses based on feedback from young children in the focus groups and qualitative questions. These options indicate language that the students used when describing their agreement with survey items and were previously used in survey measures with young children (i.e., Ganley & McGraw, 2016; Harari, et al., 2013). A three-point format was considered to limit the cognitive understanding of the scale needed for the developmental age of the young children; however, a four-point scale was selected to maintain variability in student responses. A two-point response scale was also considered (i.e., *No*, *Yes*) but this option was not selected, as it would potentially limit the amount of information captured by the survey.

Data Collection. The primary researcher trained graduate students in school psychology to administer the survey by following a standardized script. The examiner read an initial set of directions with examples and then each item aloud to students in a small group of three or four students. Students responded on paper forms (see Appendix B) at a pace set by the examiner. Three example items were also presented to ensure that students understood how to respond to each item. Data were collected either in the students' classroom or in a quiet space in the hallway. Location varied based on teacher preference and teachers selected the time of administration to avoid missing explicit instruction. The administration of the survey took about 5 minutes and students received a sticker for participating. Delayed test-retest from winter to spring was also calculated. All responses were scored and entered into an excel spreadsheet. All surveys were double scored and data entry was checked for fidelity through frequency tables.

Analysis

Item analysis. Classical test theory was used to determine the quality of each survey item. Item-level statistics were computed. Item-total correlations were used to identify low quality items. Items with item-total correlations below .25 were considered inadequate and were removed (McCoach, Gable, & Madura, 2013). The item analysis also considered items with high skew (>1.96) or kurtosis (>3). These items were examined but not necessarily removed given that weighted least squares is more sensitive to non-normal data.

Confirmatory factor analysis. A confirmatory factor analysis (CFA) was used to assess model fit of four different factor structures based on previous research and a priori hypotheses (McCoach, Gable, & Madura, 2013; Thompson, 1997). Confirmatory was selected instead of Exploratory Factor Analysis given that the items were developed using a priori theory. Exploratory factor analysis is more appropriate when there is not yet a hypothesized factor structure (Kline, 2010). Further, some recent psychometric and statistical research has proposed that exploratory factor analysis is not as scientifically rigorous (Henson & Roberts, 2006). Analyses were conducted using the Lavaan package in R (R Core Team, 2017; Rossel, 2012). First, the fit of a unidimensional model was tested (*Figure 2*). Then the hypothesized three factor first order model (i.e., competence beliefs, enjoyment, importance) was tested (*Figure 3*). Next, two alternative models were tested: a two factor model (i.e., competence beliefs, enjoyment; *Figure 4*), and a higher order model with a second order factor of attitudes toward mathematics (see *Figure 5*). These models were selected to determine the dimensionality of the survey measure based

on previous research. Given that little factor analytical work of attitudes toward mathematics has been conducted for young children, alternate models were tested.

Model 2 and Model 3 were compared to determine if the dimensionality with and without the usefulness factor was a better fit. This was based on previous work by Adelson and McCoach (2011), which found that, among third and fifth grade students, the factor analytical model showed better fit without the usefulness factor. A unidimensional model was also tested to see if perhaps for young children the three hypothesized factors of attitudes towards mathematics could not be distinguished statistically and a simpler model was appropriate. Lastly, a higher-order model was tested to compare to Model 2 to see if the hierarchical nature of the factors improved the fit of the items and structure. If the hierarchical model did not improve the fit, the simpler model was selected to limit the number of parameters that needed to be estimated in the measurement model (McCoach, Gable, & Madura, 2013).

The models were evaluated using four model fit indices: root square mean error of approximation (RSMEA), comparative fit index (CFI), Tucker Lewis index (TLI), and the proportion of chi-square/*df* (Hu & Bentler, 1999; McCoach, Gable, & Madura, 2013; Schreiber, Stage, King, Nora & Barlow, 2006). RSMEA indicates the amount of unexplained variance, or residual, which should be equal or less than .06. CFI and TLI indicate model fit relative to the null or fully saturated model and are compared against the criterion of .95 (Hu & Bentler, 1999). Given that previous research has found χ^2 as an indicator of fit can be biased (Hu & Bentler, 1999), a ratio of χ^2/df was calculated (Asparouhou & Mutten, 2010). Models with a χ^2/df ratio of less than two were desirable. These indices were used to determine the best fitting model.

The assumption for local independence was met through high fidelity administration to ensure that the errors do not correlate. An administration checklist was used to demonstrate the quality of administration (Appendix C). Given that the survey responses were on an ordinal Likert-scale, the assumptions for linearity and normality were not met. To account for this, factor analysis parameters were estimated with Robust Diagonal Weighted Least Squares (DWLS), which utilizes a polychoric covariance matrix (Katsikatsou, Moustaki, Yang-Wallentin & Joreskog; Li, 2016; Mîndrilă, 2010). At times it is acceptable to treat the Likert scale responses as continuous data and use Maximum Likelihood; however, research suggests this may only be appropriate for scales that have 7 or more response options (DiStefano, 2002; Dolan, 1994). Thus, Robust DWLS estimation was utilized. The models were first fit and then items with low factor loadings ($< .20$) were removed and the models were re-fit (McCoach, Gable, & Madura, 2013). The final model was selected by examining which had the best fit indices as well as the simplicity of the models. For example, if two models had comparable fit indices the simpler model was selected to reduce error in parameter estimation.

Reliability. To estimate the reliability of the scores for each of the three factors and the total score, two types of analyses were conducted. Reliabilities were calculated for the overall survey score as well as factor scores (i.e., competence, enjoyment, importance). Values were compared to a typically acceptable level of .70 for research (Salvia, Ysseldyke, & Witmer, 2009). First, internal consistency was evaluated with coefficient alpha (Cronbach, 1951) in the winter. Further, a delayed test-retest reliability was calculated as modest estimate of consistency of scores across time from winter to spring.

Results

Descriptive Statistics & Correlations

Means, standard deviations, skew and kurtosis were calculated for each of the 22 survey items (Table 3). Item means ranged from 1.75 to 3.86. Two items were identified to have significant kurtosis and skew (i.e., Items 20 & 11). Item 21 also had slightly skewed responses (skew = -2.09). Item discrimination indicated the extent to which items correlated to the overall scale (i.e., Enjoyment, Competence Beliefs, Importance). On the Enjoyment scale, items generally had adequate item discrimination ranging from .36 to .78 (*Mdn* = .57). The proposed Competence Beliefs scale contained items with discrimination ranging from .13 to .58 (*Mdn* = .50). The Importance scale contained items with discrimination ranging from .05 to .50, but overall items in this scale seemed to have lower discrimination (*Mdn* = .35). The alpha if removed column indicates the alpha internal consistent reliability coefficient if that particular item was removed. This statistic was considered when considering deletion of items such that if removing an item significantly improved the alpha coefficient, it was considered for removal from the scale. Frequency counts of student responses are also provided in Table 3. Overall, the sample can be characterized by having generally high attitudes toward mathematics as the majority of students tended to respond most positively across the items. Across the 22 items, 5 to 25% (*Mdn* = 15%) of responses were indicated as “not really” or “kind of.” Given that students selected these responses to indicate their attitudes it is evidence that a two-option response format (i.e., yes, no), which is perhaps easier for young children to understand, may have limited the variability present in their attitudes toward mathematics.

Item correlations were also calculated and are presented in Table 4. Correlations between items in the Enjoyment scale ranged from .14 to .68. Correlations between items in the Competence Beliefs scale ranged from .01 to .55. Correlations in the Importance scale ranged from -.06 to .43. To assess student consistency in responding the correlation between diverging items: Math is boring; Math is fun. The correlation between the items was .56 and was statistically significant.

Based on the descriptive statistics and correlations presented in Table 3 and Table 4, as well as teacher and expert review, four items were removed prior to the CFA. Item 10 (i.e., “I will never be good at math”) exhibited a low item correlation (.13) and the removal of this item improved the internal consistency reliability of the scale. Further, this item had low correlations coefficients with other items (range = .01 to .17). Item 8 (i.e., “People use math outside of school”) yielded a low item correlation (.05) and the removal of this item improved the internal consistency reliability of the scale. This item had negative correlation coefficients with other items (range = -.06 to .15). Items 20 and 22 were also removed as they were determined to be unrelated to the construct measured by the scale as indicated by research assistants and teachers. Thus, 18 items were examined in the CFA.

Confirmatory Factor Analysis

The following models were tested using Robust Diagonal Weighted Least Squares estimator procedures (Katsikatsou, Moustaki, Yang-Wallentin, & Joreskog; Li, 2016; Mîndrilă, 2010) using the Lavaan package in R (R Core Team, 2017; Rossell, 2012) and items were treated as ordered categorical. The results of the models are presented in Table 5.

Unidimensional model. First, a unidimensional solution was tested to examine the hypothesis of attitudes toward mathematics for young children was unidimensional or multidimensional. Using criteria for interpretation of model fit, the unidimensional model yielded acceptable fit. The χ^2/df ratio (1.59) was lower than 2.0. The WRMR (.82) met the standard of <1.00. The RSMEA (.07; 90% CI: .05 - .10) met the acceptable standard of .08 but was greater than the ideal level of .05. The CFI (.95) met the standard of .95 and the TLI (.94) fell just below the ideal of .95. While this model met some of the acceptable and ideal standards for model fit, the three-factor model was also tested to examine if attitudes toward mathematics for young children can be distinguished across factors similar to previous research (e.g., Mullis, Martin & Foy, 2009; Adelson & McCoach, 2011).

Three-factor model. The three-factor model was tested to examine the hypothesized model. The three factors were allowed to correlate with each other. Using criteria for interpretation of model fit, the three-factor model yielded good fit. The χ^2/df ratio (1.28) was lower than 2.0. The WRMR (.71) met the standard of <1.00. The RSMEA (.05; 90% CI: .01 - .08) met the ideal standard of .05 and the upper limit of the confidence interval met the criteria for acceptable. The CFI (.96) exceeded the standard of .95 and the TLI (.94) fell just below the ideal of .95.

Two-factor model. Previous research with older elementary students found that model fit improved when the usefulness/importance scale was removed (Adelson & McCoach, 2011). Thus, the two-factor hypothesis was tested to examine if model fit improved with a younger elementary sample. In the present study, the two-factor model showed the poorest model fit when compared to the unidimensional and three factor

models. The χ^2/df ratio (2.08) was higher than 2.0. The WRMR (.80) met the standard of <1.00. The RSMEA (.10; 90% CI: .07 - .13) exceeded the ideal and acceptable standards of .05 and .08, indicating a high level of unexplained variance. The CFI (.96) exceeded the standard of .95 and the TLI (.94) fell just below the ideal of .95.

Higher-order model. Given that the unidimensional model and the three-factor model both showed acceptable fit, a higher-order model was attempted. In this model, a global second order factor of attitudes toward math was added to the model as the sum of the Enjoyment, Competence and Importance scales. The global factor was allowed to correlate with each of the three first order factors. The model did not converge and some estimated variances were negative. Further, some cells in the covariance matrix were empty. These results suggest a potential lack of power due to sample size or limited variance across responses to specific items. Thus, the results from this model are not presented.

Selecting a model. After examining the tested models (Table 5), the three-factor model was selected. This model showed acceptable to good model fit across the various fit indices and aligns with hypotheses in the literature in regards to the structure of attitudes toward mathematics (e.g., Adelson & McCoach, 2011; Fredricks & Eccles, 2002; Ma & Kishor, 1997; Mullis, Martin, Foy, & Aurora, 2012). The unidimensional model also demonstrated acceptable fit on three of the four fit indices. Statistical tests to compare the fit of the unidimensional and three-factor model were not conducted because the two models were not nested (McCoach, et al., 2013). Therefore, the fit indices and previous theory were considered when selecting the model.

Once the model was fit, the variance estimates were reviewed. Three items had estimates well outside of the recommended range of .30 and .90 (McCoach, et al., 2013). These three items (Items 1, 16, 12) were removed as they were not parsimonious with the other items in the factor and the model was refit. The estimates for the final three-factor model are presented in Table 6. In the final three-factor model, the variance estimates for the three factors were .48 for enjoyment, .27 for confidence, and .28 for importance. These variances were statistically significant. The co-variances were .30 between Enjoyment and Competence Beliefs, .30 between Enjoyment and Importance, and .20 between Competence Beliefs and Importance. This suggested that all the factors were important in the model and not providing redundant information.

Reliability & Readability

Table 7 presents descriptive information about the final scale. Each scale had a total of 5 items with a potential maximum score of 20. The Importance scale had the highest mean score across the participating students. Alpha internal consistency reliability was calculated for each factor scale. The alpha reliability of the Enjoyment scale was .73, which met the criteria for acceptable reliability. The alpha reliabilities for the Competence Beliefs and Importance scale were .67 and .68 respectively. The reliability was slightly lower than the threshold for acceptable use (i.e., .70). While there are guidelines for acceptable reliability, the interpretation of these values should be guided by the proposed use of the scores. Given that these scales are intended to be used as a research tool or as non-formal formative assessment tools for low stakes decisions, these reliability coefficients are likely acceptable for low stakes decisions. The alpha internal consistency reliability for the total survey scale was improved, at .88. Delayed test-retest reliability was calculated for the final sample to determine the consistency of

student responses overtime. Reliability correlations were calculated over a 4-month period. Across the three scales, reliability coefficients ranged from .29 to .46. Specifically, the Enjoyment scale yielded the highest coefficient and the confidence scale yielded the lowest coefficient. While the reliabilities were low, they are considered a minimal estimate given the long time between testing occasions. Further, the mean absolute difference in scale scores ranged from 2.43 to 3.38. Interestingly, while the Importance scale yielded the lowest test-retest coefficient, it had the lowest absolute mean difference in scores from winter to spring.

The Flesch-Kincaid readability level is measured by examining sentence length, syllables and word length (Kincaid et al., 1975). The Flesch-Kincaid grade level was 0.6 for the Enjoyment scale, 0.0 for the Competence scale and 0.8 for the Importance scale. If a student were to take all three scales at the same time, the total survey yielded a readability level of 0.4 suggesting that it is appropriate for both typical kindergarten and first grade students.

Discussion

The purpose of this study was to develop an improved measure of attitudes toward mathematics for young children for both the purposes of educational practice and research. Specifically, the dimensionality of attitudes toward mathematics among this population was examined and psychometric evidence was collected. Findings suggest that attitudes toward mathematics can be measured efficiently among students in kindergarten and first grade. The survey yielded acceptable internal consistency but had limitations in regard to test-retest reliability. Further, results provide support of a three

factor model for students as young as kindergarten. Validity and reliability evidence in the context of prior research are discussed.

Young Children’s Attitudes toward Mathematics: Three-Factor Model

Early research defined attitudes toward mathematics as “a liking or disliking of mathematics, a tendency to engage in or avoid mathematical activities, a belief that one is good or bad at mathematics, and a belief that mathematics is useful or useless” (Neale, 1969; p. 632). A review of the literature indicates that others have used a similar framework as Neale to describe, define, measure, and study attitude toward mathematics (e.g., Adelson & McCoach, 2011; Fredricks & Eccles, 2002; Ma & Kishor, 1997; Mullis, Martin, Foy & Arora, 2012). Further, theory suggests that importance, competence beliefs, and enjoyment are important influences of achievement, motivation, and success in mathematics (Wigfield & Eccles, 1994). The present study is the first to apply this model to a measure of attitudes toward math for children in kindergarten and first grade. This is an important advancement in being able to better understand the early development of children’s attitudes toward mathematics. While there are a number of widely used scales in the research literature (e.g., ATMI, MAS), they have not been validated with young children nor were they developed with young children in mind. The development of a new survey measure for younger children has the potential to aid future research by better examining developmental trajectories.

A recent study had a similar purpose to extend the development of theory-based surveys of attitudes toward mathematics to younger grades. Adelson & McCoach (2011) developed the Math and Me Survey (M&MS) for use with third and fifth grade students. They first hypothesized a three-factor model of enjoyment, competence and usefulness,

but found that the usefulness factor did not function as intended for the younger population. The present study was able to utilize a similar, research based, model of attitudes toward mathematics and found good model fit with a three-factor model. This is an important advancement because being able to identify students' perception of the importance of mathematics at a young age may have implications for educational practice. Teachers may use this information to guide their instruction and if they continue to emphasize the practicality of mathematics in everyday life. Another reason why this is important is because if importance or usefulness relates to students' achievement later in their education, we may not be able to better understand developmental trajectories and target when students tend to show a decrease in their perception of importance of mathematics. This is an improvement from previous research with young children that use only one to two components of attitudes toward mathematics or those that are not psychometrically validated. This evidence from the CFA is one source of validity evidence in regards to the content and structure of the developed survey. The present study also adds to the literature by improving the efficiency, considering developmental level in the development and considering reliability of measures.

In this study the three-factor and unidimensional model had similar fit, with the three-factor model showing slightly improved fit. There are advantages and disadvantages to selecting the three-factor model. One advantage is that this decision allowed for an extension of a robust literature base. Specifically, previous research has supported this three-factor model among older students and the findings in this study provide evidence that the model can be extended to lower age groups. Second, research for older children has found that there is a distinction between student enjoyment,

competence and importance. The three-factor model allows for an investigation of those domains in future research.

One disadvantage in selecting the three-factor model is the limited reliability evidence for each individual factor. The full scale yielded strong reliability ($r = .88$); while the reliability of the domains approached but did not reach acceptable internal consistency reliability. Educators in schools may choose to use the unidimensional model to gain more insight into children's attitudes toward math as it is more reliable at this time. Further development of the scale may target how to improve the reliability of subscores. Another consideration is that exploratory factor analysis may be beneficial to provide additional evidence as to if the factor structure is indeed the same for this younger group of children. It is possible that an alternate model may also fit the data. However, that was not the current purpose of this study and may be explored in future research.

Improved Measurement of Young Children's Attitudes is Feasible

Without high quality measurement instruments it is difficult to make strong conclusions about the relation of attitudes toward mathematics and other variables like achievement. As indicated in the introduction, past reviews (e.g., Aiken, 1970; Ma & Kishor, 1997) noted concerns with the measurement of attitudes toward mathematics, especially for younger children. The measurement of attitudes is complex. Difficulties often arise in two areas: (1) how attitudes are defined, and (2) inferring student beliefs and thoughts from a score, which derives from a measurement procedure. As discussed, if researchers do not agree on a definition of attitudes it is difficult to understand and integrate research findings. This is well illustrated in a recent editorial in the journal of

Social Cognition titled, “Attitudes Can be Measured! But What is an Attitude?” (Gawronski, 2007). The second difficulty is perhaps even more complex and can be illustrated by Kane’s argument based approach to validation (2006; 2013). Kane proposed that there are a number of psychometric inferences associated with the interpretation and use of scores. Given that researchers and educators cannot directly measure a student’s attitude toward mathematics, we rely on observations of behaviors inferred from rating scale responses that are associated with that target domain (i.e., attitudes toward mathematics). Then, these observations are scored and generalized to represent a student’s attitude toward mathematics. There are a number of errors of inference that might occur. It is the pursuit of psychometric development to test and provide evidence of those inferences; Kane describes this as validation. For example, students may respond to indicate what they think is the desirable answer (e.g., my teachers think math is important so I will say that I think math is important), or students might not understand the questions being asked and respond in an arbitrary manner or in one consistent direction (e.g., respond “agree” to all survey questions). These are potential threats to valid interpretation of scores.

The present study aimed to develop and improve existing measures of attitudes toward mathematics. As discussed previously, the use of surveys with young children is complex due to the inferences that must be made to generalize student responses as an indication of their actual behaviors and beliefs. Previous scales showed a wide range of development considerations. One decision is the number of items. In the previous literature this ranged from 3 items (Upadyaya & Eccles, 2014) to 42 items (Math Attitude Scale). While using more items can lend it to a more robust indication of attitudes as

well as improved internal consistency reliability, it has limitations as for younger students answering forty-two items could be difficult in terms of their attention and cognitive processing. Using too little items has benefits in terms of efficiency but limitations, as it is unable to capture current theoretical conceptualization of attitudes toward mathematics. This scale has a benefit of brevity, given that there are only 15 items, and a short administration time if the measure is to be used in school practices.

Another improvement in the development of the current study is the reading level of the survey. Similar to another study (Adelson & McCoach, 2011), the current study considered children's developmental level and children's feedback and language while selecting the wording used for the items in the survey. Further, the results from the current study indicate that it is possible to utilize Likert type surveys with younger children and there does not need to be a complete reliance on qualitative methods (e.g., Fisher et al., 2012; Kloosterman et al., 1996). In this study, qualitative methods such as focus groups were used to inform the development of the Likert type items as well as the response options. Using children's language may have helped them better understand the survey. This helps ensure less room for misinterpretation of items. The full 15 items survey developed as part of this study was at a .4 Flesch-Kincaid grade level. This suggests that an average student in their 4th month of kindergarten would likely be able to understand the questions asked. This is an improvement from previous research (e.g., Adelson & McCoach, 2011). The survey was also administered in small groups and students were provided with relatable example questions to ensure that students understood the meaning of the question as well as the meaning of the response set.

Another limitation in the current research was that some scales showed high evidence of a comprehensive sampling of the content validity but lacked evidence of reliability (e.g., Gierl & Bisanz, 1995), while others showed high consistency in observations but little evidence of domain representation in regards to attitudes toward mathematics (e.g., Upadyaya & Eccles, 2014). Aligned with Kane's framework (2006; 2013), measures of attitudes toward mathematics should have evidence both that observations are representative of the target domains, and that student responses are consistent or generalizable. The present study filled a gap in the literature by developing a theory-based scale that aligns with both expected content as well as some preliminary evidence of reliability. The current Young Children's Attitude toward Mathematics Survey includes of balance of acceptable reliability. The reliability indices of the three scales ranged from .67 to .73, which was consistent or improved compared to previous studies (Table 1). The entirety of the scale had a high internal consistency reliability of .88. While the scale yielded acceptable to strong internal consistency reliability, test re-test showed a limitation. Given a delayed re-test of 4 months, the winter to spring administration of the survey yielded a reliability of .46. While .46 represents an estimate of the lower bounds of reliability, it does not meet acceptable guidance for reliability of measures (AERA, APA, NCME, 2014). Interestingly, when examining specific scales (i.e., enjoyment, competence beliefs, importance) the competence beliefs scale showed the lowest consistency in scores over time. Perhaps, student's perceptions of the enjoyment and importance of mathematics is more consistent because students' competence beliefs may vary as a function of the mathematics content being addressed in the classroom at the time of the survey administration. For example, a student may like

math and view it as important but their confidence in their abilities may vary on the content area of instruction. One student may find addition to be easier for them but may struggle with telling time. Another explanation of the low reliability may be that for young children, their perception of their own attitudes toward mathematics may be still developing and more malleable. This is a promising hypothesis as it suggests that interventions may be effective in improving students' attitudes at this age. These results call for more research in regard to longitudinal research as well as additional reliability analyses using shorter time between testing periods.

Limitations

As with all research, there are limitations to the present study. First, as discussed in the results, the sample size was not sufficient to evaluate a hierarchical model through CFA. This would be beneficial, as it would allow for a more sophisticated measurement model. A larger sample may also have provided opportunities for cross validation to better verify the model fit in the current student. Another consideration for future research may be to test a three-response option survey (i.e., *Yes, Kind of, No*). While a proportion of students selected the *kind of* and *not really* options, participating teachers suggested that three options may be easier to understand by students and may also yield more efficient data collection. Given that this is a fairly new set of Likert type options, further investigation of the options among young children is warranted.

Another limitation is that the sample in the current study was predominantly white. Previous research, in regards to student attitudes toward mathematics, indicated that there are racial differences; however, those differences could not be examined in the current study. To increase the generalizability of the current results, research may benefit

from larger more diverse populations to examine if the factor structure is consistent across groups. This is especially important given that attitudes may be influenced by socialization with family and teachers. Another reason that the consideration of the present sample composition is important is that the sample appeared to predominantly respond positively. It is unknown if this is because younger students have more positive perceptions of mathematics. Perhaps, findings are also influenced by the achievement levels of the sample or the specific survey that was developed. Further research is necessary to test these hypotheses to better determine developmental trends and trends across sub samples. This is especially important given that correlations and reliability estimates are sample specific.

Implications

The Young Children's Attitudes toward Mathematics Scale provides a method of measurement of how attitudes toward mathematics may impact achievement and other academic behaviors. It may be used by educators as a method of formative assessment to gain information on their students' attitudes toward mathematics. Given the developmentally appropriate vocabulary, the efficiency of the scale (i.e., 15 items to measure 3 factors), and that the scale was guided and influenced by young children's feedback and reported experience, it is anticipated that this scale will be useful to both researchers and educators alike. The scale provides a tool to examine the extent to which students enjoy math, believe that they are competent in math and find math useful. Future research is warranted to help further investigate to extent to which students' attitudes toward mathematics has an impact on their achievement.

CHAPTER 3

Are Attitudes toward Math an Academic Enabler of Early Math Achievement?

Although expert groups (e.g., National Research Council, 2001) place emphasis on attitudes in the content area of mathematics, the extent of its influence on achievement at a young age is not clear (Aiken, 1970; Ma & Kishor, 1997). Some researchers propose that negative attitudes do not have a practical influence on achievement until later grades, after students have been exposed to formal instruction or have a history of receiving negative feedback (Ma & Kishor, 1997). Yet, there is emerging evidence to indicate that attitudes may develop as early as pre-kindergarten and kindergarten (Fisher, Dobbs-Oates, Doctoroff & Arnold, 2012; Upadyaya & Eccles, 2014; Valeski & Stipek, 2001). Ecological systems theory proposes that children are influenced by many social networks such as parents, community, society, and culture (Bronfenbrenner, 1989). Children are exposed to these influences prior to their entry to school, and these influences may shape their beliefs and attitudes. Further, evidence shows that performance in kindergarten mathematics can predict later academic success (Fuchs et al., 2005). Thus, in a prevention and early intervention framework, it seems important to understand how attitudes toward mathematics develop from a young age and how they may impact achievement.

Examining attitudes may be particularly important for students with difficulties in mathematics, as these students tend to have poorer attitudes and achievement compared to their normal-achieving peers (Hanich & Jordan, 2004; Zeleke, 2004). Difficulties in mathematics may be the result of skill deficits (i.e., students have not yet acquired the skill to perform accurately and/or fluently) or performance deficits (i.e., students have the skill

but do not want to perform the skill). I propose that attitudes may be an important influence for students with performance deficits. Previous theoretical frameworks have proposed that students with negative attitudes toward mathematics tend to show lower engagement, perform lower on academic tasks, and do not persist on tasks as long as students with more positive attitudes (Wigfield & Eccles, 2000). Further, researchers (DiPerna, Volpe, & Elliot, 2005) have examined other academic enablers in the context of elementary school mathematics. Academic enablers are academic beliefs, attitudes, and behaviors that may impact learning. Specifically, they proposed a model of academic enablers that influence engagement, motivation, study skills, and interpersonal skills (DiPerna et al., 2005). They found that engagement had moderate effects for younger children in kindergarten through second grade, but small effects in third to sixth grade. Further, study skills had moderate effects in the later grades, but negligible effects in elementary schools. These findings suggest that different academic enablers may be important in predicting academic achievement than those that are important in later grades. While attitudes were said to be important, the authors did not include a measure of attitudes and did not examine attitudes as a potential academic enabler. Thus, it seems important for the school psychology literature to further examine these influences of performance deficits, especially at a young age to emphasize early intervention and prevention.

Attitudes and Achievement in Young Children

In a recent literature review (Kiss, 2016), only three studies at the elementary age included all three components of attitudes toward mathematics of interest in this study: perceived competence, enjoyment, and usefulness (i.e., Gierl & Bisanz, 1995;

Kloosterman et al., 1996; Mazzocco, et al., 2012). The three studies are described here in detail. Two of these studies used interview methodology and qualitative methods (i.e., Kloosterman et al., 1996; Mazzocco, et al., 2012), and all three studies evaluated the attitude-achievement relation between more than one grade using longitudinal or cross-sectional designs.

Gierl and Bisanz (1995) evaluated attitudes toward mathematics in relation to mathematics achievement across 47 third-grade and 48 sixth-grade students. All students took the Mathematics Attitude Survey (MATS), which was researcher-designed to assess six categories of attitudes toward mathematics based on previous research and other developed scales (e.g., Fennema & Sherman, 1976; Sandman, 1973; Wigfield & Meece, 1988). Students responded to items about the usefulness of mathematics and value of mathematics in society, intrinsic value, worry, confidence in learning math, perceptions of parents' attitudes toward math, and attitude toward success. The three variables of particular interest for this study were usefulness (i.e., students' beliefs about the usefulness and value of mathematics), intrinsic value (i.e., students' interest in exploring mathematics in and out of school) and confidence (i.e., students' confidence in their ability to learn and perform well in math). Students also took a mathematics achievement test, which was created by the school district mathematics teachers and included 50 items intended to measure understanding of mathematical knowledge, application to real-world situations, awareness of patterns, solution of non-routine problems, and communication using math language. Researchers did not provide psychometric information for this test. Thus, the quality of the measure is unknown and presents a great limitation for interpreting the results.

In third grade, none of the correlations between achievement and attitudes were significant; however, sixth grade students who reported higher levels of confidence tended to score higher on the achievement test ($r = .31, p < .05$; Gierl & Bisanz, 1995). In third grade, the most robust relationships between achievement and attitudes were success ($r = .25$) and usefulness ($r = .20$). While these might have practical implications, the coefficients were not statistically significant. Given the small to moderate size of the correlation, the non-significant findings may relate to the small sample size, which established low power for the correlational analysis. Of the three components of attitudes, the results from Gierl and Bisanz (1995) suggest that confidence may be the most important aspect of attitude in terms of providing information to inform mathematics development, though it may not be as important until later elementary school. Specifically, the findings indicate that attitudes toward mathematics are not significantly related to achievement for students in third grade, and usefulness and liking of mathematics seemed to be unrelated in both grades. These results should be interpreted with caution as validity or reliability was not reported for the achievement measure and the internal consistency of the usefulness scale was quite low, especially for third grade ($\alpha = .30$). This suggests that about 70% of the scores of the usefulness scale were attributed to measurement error; a reliability of .70 is considered adequate and reliability of .80 is typically considered good.

Mazzocco et al. (2012) used a more qualitative approach to examine the relation between attitudes and achievement in mathematics for students in second and third grade. The researchers interviewed 207 children in second grade and collected longitudinal data through third grade. Students were asked to define math and reading (i.e., “What is

math?") and their responses were coded for spontaneous references to likability, difficulty, and specificity. Only the results in mathematics will be reported for the purposes of this paper. Researchers used the likability codes when there was reference to liking or enjoyment of mathematics (e.g., "I love math!"), they used difficulty to code responses related to the difficulty or ease associated with mathematics (e.g., "something that is very hard for me"), and they used specificity to code responses indicating the usefulness of mathematics (e.g., "you need to know math to get a job"). Students also took two tests of mathematics achievement, the Test of Early Math Ability – second edition (TEMA-2), and the Woodcock Johnson – Revised Calculations (WJ-R Calc), both highly reliable tests with validity evidence for use in educational practice and research. The researchers conducted two regression models using the WJ-R Calc as the outcome they found that in second grade a combination of likability, difficulty, and specificity accounted for about 5% in the variation in third grade calculation scores; however, specificity was the only variable to significantly contribute uniquely to the model. The second regression model examined the concurrent relation between predictors and found that in third grade the variation explained by the three attitude variables was smaller ($R^2 = .028$), but both specificity and likability had small, yet significant effects in relation to third grade mathematics achievement.

In addition to predicting scores on the WJ-R Calc, the TEMA-2 was used to assign students to three groups based on achievement level: mathematics learning disability (MLD; <10th percentile), low achievement (between 10th to 25th percentile), and typically achieving (>25th percentile). Over time, students with MLD showed more negative ratings in terms of likability and difficulty of mathematics compared to other

low or typically achieving students. They also found that MLD status contributed significantly to the variation in specificity coding through the interviews such that students with MLD provided less specific definitions. Overall, evidence from this study suggested that all three components of attitudes toward mathematics had an important influence toward achievement in mathematics as measured by both tests of early numeracy and of calculation. The novel method of measuring attitudes toward mathematics may have had an influence on how student attitudes toward mathematics were interpreted, and as highlighted by previous reviews (Aiken, 1970; Ma & Kishor, 1997) the consideration of measurement instruments is warranted.

In a third study, researchers investigated all three areas of attitudes using a longitudinal, qualitative design. They examined how beliefs influenced student motivation and effort to learn (Kloosterman et al, 1996). Twenty-nine students in first, second, and third grade were followed for 3 years. Both belief and achievement data were collected during the first year of the study, and only belief data were collected in the following 2 years. A series of standardized test scores and other individual testing measured achievement in mathematics. All students took the California Achievement Test (CAT), which measures concepts and applications, and computation in mathematics. Students also took two researcher-developed three-item problem-solving tests. This information was used to classify students as a high (>70th percentile on CAT), medium (30th to 70th percentile on CAT) or low achiever (<30th percentile on CAT). Students were interviewed to assess five categories of beliefs, three of which are particularly of interest in the present review. First, students were asked questions about liking mathematics and their favorite subjects. Second, students were asked how important is it

to study mathematics, and third, students were asked about their self-confidence in learning mathematics. The other two categories involved attitudes toward growth mindset and cooperative group learning. Interviews were analyzed for possible themes independently by each author and consistent themes were reported.

Key trends noted by authors included that students tended to report enjoying mathematics as it became more difficult, and that across time students reported more specific and personal examples of usefulness of mathematics. They also observed stability in attitudes across the three years, and that students seemed to be honest about their ability and confidence in learning mathematics. Interviews suggested that there was no relation between self-confidence and achievement for students in first grade, but this relation appeared strong for older students in third grade in particular such that low achievers in mathematics also reported low confidence. Of students in third grade or above, about half showed perfect agreement with ratings of confidence and achievement, and in all other students there was only a one step difference in which students rating their confidence higher than their achievement was rated. The authors did not identify any trends between liking mathematics or usefulness of mathematics with mathematics achievement.

In summary, it is difficult to derive strong conclusions of the relation between attitudes toward mathematics and achievement in mathematics due to the variability in results and thus, more research is warranted. While Gierl and Bisantz (1995) reported no significant correlation between attitudes toward mathematics and achievement among third grade students, results from Kloosterman et al. (1994) as well as Mazzocco et al. (2012) suggest that the relationship may exist as early as second and third grade. Thus,

there is a need to conduct more sound studies, with larger samples and more reliable measures, of the relation among elementary students to better understand the importance and be able to directly compare the various components of attitudes to better inform mathematics development at a young age. Perhaps the present Likert scales such as those used by Gierl and Bisantz are insufficient to capture the attitudes of younger children due to high language need or complexity of responses. These three studies revealed inconsistencies in results, and design limitations of the studies suggest a need for additional studies to examine multiple components of attitudes toward mathematics. While only three studies were identified to examine all three components of attitudes toward mathematics, a number of additional studies have examined 1-2 of the three components.

Perceived self-competence and achievement in mathematics. Self-confidence may be the most important affective predictor of mathematics achievement (Valentine et al., 2004). This positive relation has been consistently found across different measures of achievement. For example, Adelson and McCoach (2011) found a positive relation between student reported self-perceptions of abilities and teacher ratings of achievement ($r = .21$), and Gierl and Bisantz (1995) found a positive relation between confidence in mathematics and a district made mathematics test for sixth grade students ($r = .31$). Similarly, Whang and Hancock (1994) found that among non-Asian students, self-concept explained 34% of the variation of student scores on a standardized assessment (i.e., Metropolitan Achievement Test).

Some researchers examined the relation between mathematics achievement and student confidence in mathematics across multiple measures of achievement (i.e., Herbert

& Stipek, 2005; Shores & Shannon, 2007; Valeski & Stipek, 2001). These studies are described here to uncover patterns of results with different achievement measures using the same population of students. Herbert and Stipek (2005) examined the relation among students in kindergarten, first, third, and fifth grade using teacher ratings of achievement, parent ratings of achievement, and an achievement measure based on various standardized, normed tests (i.e., Peabody Individual Achievement Test-Revised, WJ, TEMA). The findings indicated that teacher ratings of achievement in kindergarten and first grade were the only significant predictor of children's ratings of their competence in third grade ($r = .16, p < .01$). When predicting student confidence in fifth grade, parent and teacher ratings were both significant ($r = .19$ and $.25$, respectively), while scores on the achievement test were not. In this study, teacher and parent ratings of achievement were more predictive of children's perceptions of their competence than standardized achievement tests were. This highlights social influences of attitudes toward mathematics. Perhaps, parents and teachers perceive student competence may have an impact on shaping student attitudes toward mathematics due to social experiences and interactions, while standardized tests with no feedback or reinforcement for students may not influence student attitudes.

Valeski and Stipek (2001) used similar measures to compare the relation using both standardized tests and teacher ratings and competence in mathematics among students in kindergarten and first grade. They found that, in first grade, students' perceived competence in mathematics was significantly related to both mathematics academic skills ($r = .34$) and teacher ratings ($r = .35$), but this relationship was not significant in kindergarten. Lastly, Shores and Shannon (2007) examined the relation

among fifth and sixth grade students using scores on a teacher made mathematics test and students' mathematics class grades. While both were significant, there was a stronger relation between self-efficacy and mathematics grades ($r = .42$) compared to scores on the teacher made test ($r = .27$). The reasons for the differences in results between achievement measures are not clear. Based on theory of attitude change and development, perhaps the distinctions were related to the varying levels of socialization and reinforcement involved in different achievement measures. For example, parents and teachers who perceive students have low competence may express this to students either explicitly or implicitly and thus their views may be more impactful on student attitudes. Similarly, mathematics grades in elementary school may incorporate observations and other informal methods allowing for direct feedback and reinforcement of performance, while standardized tests are often summative and do not lend to feedback and socialized experiences for students.

Overall, the research suggests that students' perceived self-competence or self-confidence in mathematics does have an important relation with achievement in mathematics for children as young as kindergarten. Consequently, it is important for educators and parents to help foster student confidence in learning mathematics. It is notable that, depending on the measure of achievement, the strength of this relation may vary and this should be considered in future reviews of research.

Enjoyment and achievement in mathematics. Students who reported higher interest and enjoyment tended to obtain significantly higher scores on measures of achievement in mathematics from pre-kindergarten through sixth grade. In regards to longitudinal findings, Upadyaya and Eccles (2014) found that interest in mathematics

declined as students progressed from kindergarten through sixth grade, while Kloosterman et al. (1996) concluded that students appeared to like mathematics as it became more difficult as they aged. Thus, based on the present findings, the developmental trajectory of attitudes in elementary school seems unclear. More longitudinal work may help researchers and practitioners better understanding how enjoyment and interest in mathematics impacts students' success.

The studies provided some evidence of the attitude – achievement relationship across measures of both positive affect and confidence. Findings show that confidence seems to be the stronger predictor of achievement (Adelson & McCoach, 2011; Ganley & Lubienski, 2016; Gierl & Bisanz, 1995; Kloosterman et al., 1996; Mazzocco et al., 2012). Yet, positive affect or enjoyment still seems to have an important relation to achievement and might help explain why some students engage more in mathematics than others. This is consistent with previous findings that there is a separation of enjoyment and competence when examining attitudes toward mathematics (Pinxten et al., 2014). These components of attitudes may have different effects on achievement such that competence beliefs may have effects on achievement and perceived effort, while enjoyment may have effects on perceived effort and math competence beliefs (Pinxten et al., 2014). As such, both may be important for educators to consider when engaging their students. Similarly, research may benefit from examining both of these components together to better understand the distinctions among young children.

Usefulness of mathematics and achievement in mathematics. Studies that investigated students' perceptions of the usefulness of mathematics among young children are limited (Gierl & Bisanz, 1995; Kloosterman et al., 1996; Mazzocco et al.,

2012; Shores & Shannon, 2007). This is surprising given the emphasis on measuring usefulness of mathematics since the 1970s (Aiken, 1974) and the importance of encouraging students to find math as useful emphasized by mathematics educators and experts (NRC, 2001). The results of these studies are mixed. For example, Adelson and McCoach (2011) considered including a scale of value perceptions of mathematics in their Math and Me Survey, but found that the addition of the scale led to poor model fit among students in third through sixth grade.

In contrast, Mazzocco et al. (2012) found that usefulness significantly and uniquely predicted mathematics computation scores among second and third grade students even more so than positive affect or perceptions of competence did.

Interestingly, this study was of qualitative design and students were able to produce their own responses. Perhaps, improved item writing for Likert-type scales of the usefulness of mathematics would help reach stronger conclusions of the relation between valuing mathematics and achievement in mathematics among younger children. One speculated strategy may be to hold focus groups and allow students to describe the usefulness of mathematics in their own vocabulary, which could then be used to create a Likert-type scale (Di Martino & Zan, 2010). At this point in the literature, it is difficult to make strong claims of the importance of perceived usefulness in relation to math achievement.

Given the mixed findings and limited research among the early elementary age group, it is important to continue to examine the relation between attitude towards mathematics and achievement in mathematics among young children. With the limitations of child self-report measures it is also warranted to examine teacher ratings of child attitudes. This may help provide useful information in a prevention and early

intervention framework to help develop students' confidence and abilities in mathematics.

Purpose

The purpose of this study was to investigate the relation between mathematics achievement and attitudes toward mathematics for students in kindergarten and first grade. Specifically, different attitudinal dimensions (i.e., competence beliefs, enjoyment and importance) were examined based on previous literature. The research questions were:

1. To what extent do student reported attitudes toward mathematics relate to: (a) teacher ratings of student achievement; (b) teacher ratings of student attitudes; and (c) student achievement on standardized measures of achievement.
2. To what extent do ratings on student attitude measures differentiate between students from different demographic groups and those who were low and high achieving?
3. To what extent do student self-report ratings on attitude measures enhance models and predictions of student achievement in early grades? Relevant variables and predictors to examine in the model include control variables (e.g., gender, sped status, reading, early numeracy) along with teacher rating of achievement, teacher ratings of attitude, and student ratings of attitude.

Methods

Participants

The study was conducted in one elementary school in a single suburban district in the Midwest area. The study was described to teachers and they were given the option to participate. Seven of 10 teachers opted to participate. Overall, 149 students in

kindergarten and first grade from 7 classrooms were recruited to participate in this study. Active parental consent was obtained for 80% of students resulting in a sample of 119 students ($M_{age} = 75$ months). The sample was approximately 45% female. The majority of the sample was White (82%) with 6% of students identifying as Black, 6% Hispanic, 4% Asian, and 1% American Indian. Nine percent of participating students were eligible to receive special education services. Further, 4% of students were receiving tier 2 support interventions in mathematics. Chi-square tests indicated that gender ($\chi^2 = 2.67$, $p = .10$), ethnicity ($\chi^2 = 3.02$, $p = .56$), or special education status ($\chi^2 = .26$, $p = .61$) did not significantly vary by grade level at $p < .05$. Table 2 includes this demographic information by kindergarten, first grade and the total sample.

Measures

Young Children's Attitudes toward Mathematics. For attitudes toward mathematics, students responded to a researcher-developed Likert scale survey. The survey included a total of 15 items and yielded three scales: enjoyment, competence beliefs and importance (Table 6; Table 7). The enjoyment scale included 5 items to assess the extent to which students' report liking math (e.g., Math is boring; Math is my favorite time of the day). The competence beliefs scale included 5 items to assess the extent to which students' report their abilities related to math (e.g., I am good at math). The importance scale included 5 items to assess the extent to which students perceive math to be important (e.g., Math will help me in second grade). Alpha internal consistency reliability was moderate, ranging from .67 to .73 across the three scales. The internal consistency of the total scale was .88. The survey was read to students and the task included minimal reading and age appropriate language as determined through informal

focus groups with young children and readability statistics. Other developmental considerations include that the scale was short in length of items and response options were developed with feedback from student focus groups. Students responded to a four point Likert scale including *no*, *not really*, *kind of* and *yes*. A set of items was administered to identify inconsistent responses: “I love math” and “Math is boring.” These responses were reviewed across students and no inconsistencies (e.g., “yes” in response to both items) were identified. See Study 1 for more details in regards to the development of the scale.

Teacher ratings. To investigate the relation between student attitudes (Appendix E) and achievement in mathematics (Appendix F), teachers rated the students in their class from those who have the most positive to the least positive attitudes toward mathematics. Teachers grouped students in their class into four groups: Likes math a lot, likes math a little, dislikes math a little and dislikes math a lot/does not like math at all. Responses were coded from 1 to 4. Teachers also rated their perceptions of student achievement on a scale of 1 (Does not meet grade level expectations in math) to 4 (exceeds grade level expectations in math). Teachers provided their ratings prior to viewing any student mathematics data from the study and were asked to not reference any student data while completing the rating. Teachers were told to rate their students based on the past 2 weeks so that ratings were more consistent across teachers.

earlyMath. The earlyMath assessment was developed by the Formative Assessment System for Teachers (FAST) and is intended for use among students in kindergarten and first grade (TJCC, 2015). earlyMath measures early numeracy skills from three mathematics domains defined by the NRC (2009; Number, Relations, and

Operations). The composite measures of earlyMath are the most robust indicators of early numeracy skills in kindergarten and first grade. The winter composite measure in kindergarten included measures of Numeral Identification (identifying written numerals), Number Sequence (counting forward, backward, and understanding the mental number line), and Decomposing (linking quantities to written numerals). The first grade composite included Number Sequence, Decomposing (composing and decomposing numerals and quantity representations), and Place Value. All measures were administered individually with the exception of Place Value which was group administered in all first grade classrooms. The composite scores are vertically scaled within each grade across the fall, winter, and spring screening periods ($M = 50$, $SD = 15$), which is useful to measure growth within grade. The measures were not vertically scaled between kindergarten and first grades.

EarlyMath exhibits strong reliability and validity evidence comparable to similar academic based screening measures. The publisher reported that test-retest reliability for the composite measures range from .62 to .87 in kindergarten, and .71 to .91 in first grade. Internal consistency reliability for individual subtests is generally high with coefficient alpha and split-half reliabilities ranging from .52 to .98. Average inter-rater reliability is high, ranging from .91 to .99 ($Mdn = .95$). The composite measures show evidence of moderate to strong criterion-related validity with broad mathematics measures such as the GMADE, MAP and state wide tests (e.g., MCA-III) across kindergarten and first grade (TJCC, 2015).

Math achievement. Three measures were selected to measure a range of early mathematics achievement.

Story problems. Students were administered eight story problem items with four addition and four subtraction problems. The task was modified from the Number Sense Brief and the Story Problems task (Jordan, Glutting & Ramineni, 2010; Locuniak & Jordan, 2008). For example, students were asked, “Sally has 4 crayons. Stan gives her 3 more crayons. How many crayons does Sally have now?” The measure was administered in small groups of four to five students. Students were instructed to “keep their answers a secret.” Students were able to work out the problems using paper and pencil and the task was untimed. Previous research indicates that the measure had moderate predictive validity of later calculation fluency ($r = .51$). The task was modified for this study by having children write down the answer to each problem rather than responding orally; examiners were trained to help students write the numeral if the student asked for help or if the number was not legible.

Calculation. Students also completed the Calculation subtest of the Woodcock Johnson Tests of Achievement-4. The Calculation measure is normed and raw scores are converted to standard scores. The subtest includes written calculation problems in a paper pencil format. Students were tested by graduate students who were trained in standardized administration procedures.

Applied Problems. Applied mathematics was assessed using the Applied Problems subtest of the Woodcock Johnson Tests of Achievement-4. The Applied Problems measure is normed and raw scores are converted to standard scores. The test is untimed and the subtest was administered individually. Administration time was about 5-15 minutes per student. Questions involved a variety of skills of mathematics

achievement presented in orally presented word problems including calculations, time, rate and problem solving in real-world contexts.

The Applied Problems and Calculation subtests are combined to yield a more reliable composite score: Math Composite.

Procedures

Trained graduate students in school psychology collected data in the winter and spring. All test administrators had previous experience with standardized testing and working in schools and were trained using the FastBridge Learning training certification system. All administrators attended a 2-hour training with the primary researcher. Testing typically occurred in one testing session in a quiet location in the school hallway. Students were encouraged with stickers and were provided with breaks if needed. Fidelity checklists (Appendix G; FastBridge Learning, 2017) were collected for at least one administration for each examiner during the data collection and each examiner was observed to follow administration with 100% fidelity.

In the winter, earlyMath, student attitudes toward mathematics, and teacher ratings of students were collected. In the spring, all three math achievement measures were administered. Five students were either absent or no longer attending the school during the spring data collection and thus are excluded from analyses resulting in a total of 114 participants. All measures were administered by trained graduate students with supervision of the author. After the achievement measures were administered, the attitude scale was administered to all students in the winter. Simultaneously, ratings of student attitudes and student achievement in mathematics were collected from the classroom teachers. Data were checked for fidelity for 100% of the final sample, and inter-rater

reliability was collected for the early numeracy measure. All data entered was double-scored and checked using frequency tables to find any potential entry errors.

Results

Characteristics of the Sample

To address research question 1, means, standard deviations, and correlations between measures were conducted. Further, *t*-tests were conducted to identify any between group differences in regards to grade, gender, race and special education status. Distributions of dependent measures proved to be normal with no abnormal skew or kurtosis (i.e., *z-score* < |1.96|). Table 8 presents the means, standard deviations, and correlations between the measures. With regard to math achievement, students in the current sample were slightly above average when compared to the normative samples (i.e., 58th percentile).

Group differences were analyzed to guide later regression analyses. The difference in self-reported student attitudes toward mathematics between kindergarten and first grade emerged but did not reach significance ($t = -1.848, p = .067$). On average, first grade students rated themselves slightly more positively. There was a significant difference between kindergarten and first grade students based on their report of their perceived Competence Beliefs in mathematics ($t = -2.497, p = .014$). There was no significant difference between grades in regard to student reported Enjoyment of mathematics ($t = -1.075, p = .285$). Kindergarten and first grade students rated themselves similarly in regards to their enjoyment of mathematics but first grade students reported slightly higher levels of confidence.

Given that previous research reported differences in student attitudes toward math based on group membership (e.g., Gunderson et al., 2012) a series of *t*-tests were conducted in the present sample. This information was examined to guide a selection of predictors in later regression models. In regard to gender, there was a significant difference in student reported attitude toward math for students in first grade ($t = -2.675$; $p = .010$) such that girls reported more positive attitudes toward math. For students in kindergarten, there was no significant difference ($t = 1.215$, $p = .229$). With regard to ethnicity, there were no significant differences in student attitudes toward math between white and non-white students in kindergarten ($t = .685$; $p = .496$) nor first grade ($t = 1.449$; $p = .154$). Lastly, there were not significant differences between students who were eligible to receive special education services and those who were not for kindergarten ($t = 1.753$; $p = .085$) nor first grade students ($t = .698$; $p = .489$).

Student-reported attitudes toward mathematics were significantly correlated with all five achievement measures (i.e., earlyMath, Story Problems, Math Composite, Applied Problems, Calculation; Table 9). The highest correlation of student reported attitudes toward math was with the Story Problems measure ($r = .44$). Teacher report of student attitudes toward math tended to be more highly correlated with achievement measures ($r = .42$ to $.58$) compared to student report of their own attitudes ($r = .20$ to $.44$). Notably, although teachers were asked to rate the extent to which their students liked mathematics, there was a statistically significant relationship with student reports of perceived competence in mathematics ($r = .32$, $p < .01$). Teachers' ratings of their students' mathematics achievement were significantly correlated with measures of student attitudes toward math ($r = .27$ to $.31$) and direct measures of their achievement ($r = .47 - .73$).

Discriminant Validity

Discriminant validity was analyzed using one-way-ANOVA to examine the extent to which student reported attitudes toward math and teacher reported attitudes toward math discriminated between students who were in different achievement groups. Achievement groups were determined by performance on the Woodcock Johnson Tests of Achievement. If students performed below the criterion percentile rank on either of the two subtests, they were considered to be in the at-risk range. Students were grouped into two groups: Math Difficulties or Math Learning Disabilities (1st to 25th percentile) and Typically Achieving (26th percentile and above). These groups are similar to common cut-offs used in the math research literature (Nelson & Powell, 2017). Analyses were also conducted to compare students below and above the 40th percentile as that is often used as criteria in the screening and intervention literature to identify at-risk students who may require further intervention supports (e.g., Miller & Kaffar, 2011; Jitendra, et al. 2013). Further, Higher cut-offs such as the 40th percentile are often used by school professionals and published assessment systems in aims of identifying more students with potential risk (e.g., Fastbridge Learning, 2017; NWEA, 2015). Results are presented in Table 11.

Self-rated and teacher-rated student attitudes toward math significantly differentiated between students in the Math Difficulties (<26th percentile) and Typically Achieving groups (>25th percentile). Specifically, the Competence Beliefs and Importance scales showed a significant difference between low and higher achieving students. The difference between groups was not significant for the Enjoyment scale. When using the 40th percentile as the group cut-off to correspond with frequently used school based decision making, only the teacher report of student attitudes toward math

significantly differentiated between groups. When using either cut-off to distinguish risk (i.e., 25th, 40th), students who were rated by their teachers as having higher attitudes toward math in the winter tended to have higher scores on standardized math measures in the spring. Student self-reported attitudes discriminated only between the groups when the 25th percentile was used.

Regression Analysis

To address Research Question 3, the data were modeled with multiple linear regressions using a sequential procedure. The outcomes were the four math achievement measures (i.e., Story Problems, Math Composite, Applied Problems, Calculation). Students were nested within only seven classrooms, which implies a lack of power for hierarchical modeling. Further, the research questions in this study did not involve hypotheses at the classroom level. Therefore, simple multiple regression was sufficient to model the data (i.e., rather than a hierarchical model; Raudenbush & Bryk, 2002). Prior to analysis, model assumptions were checked. Dependent variables showed evidence of normality, homoscedasticity and linearity.

The analysis tested which combinations of prior mathematics achievement in the winter and attitudes best predicted later achievement in mathematics in the spring. Control variables included gender, grade, a gender by grade interaction early numeracy skills, and teacher ratings of student achievement. During model building, it was determined that only early numeracy skills, as measured by earlyMath, were a significant predictor of the dependent variables. To preserve power for the analyses, non-significant control variables were removed from the analysis. After earlyMath was controlled for in the model, student reported Enjoyment, Competence Beliefs and Importance were added

to the model. Model 1 and Model 2 were compared using change in R^2 . Lastly, after earlyMath skills were controlled for, teacher ratings of student attitude toward math were added in the model (Model 3). Model 1 and Model 3 were compared using change in R^2 to evaluate if teacher reported student attitudes toward math improved the prediction of later math achievement skills beyond the early numeracy screening. Finally, the model was fit controlling for earlyMath and including student reported and teacher reported student attitudes toward mathematics.

A full summary of the results for the multiple regression analyses is presented in Table 11. **Error! Reference source not found.** includes a summary of change in R^2 to explicit address Research Question 3. Overall, the predictors explained the most variance in the WJ Math Composite ($R^2 = .51$). The least amount of variance explained by the predictors was in regards to the Calculation measure ($R^2 = .34$). These results are considered further in the discussion.

Story Problems. After controlling for early numeracy skills, teacher ratings of students' attitudes toward math did account for a unique amount of variance ($\Delta R^2 = .082$, $p = .000$). In Model 2, student self-reported rating of Competence and Importance was significant. The student attitude variables explained significant additional variance in outcome scores ($\Delta R^2 = .121$, $p = .000$). Enjoyment was not a significant predictor.

Applied Problems. After controlling for early numeracy skills teacher ratings of students' attitudes toward math did not account for a unique amount of variance ($\Delta R^2 = .017$, $p = .075$). Student self-reported rating of Competence Beliefs was significant. However, overall, the student attitude variables did not add additional explained variance ($\Delta R^2 = .035$, $p = .081$). Enjoyment and Importance were not significant in the full model.

Calculations. After controlling for early numeracy skills, teacher ratings of students' attitudes toward math accounted for a unique amount of variance ($\Delta R^2 = .030, p = .037$). Students' self-reported ratings of attitudes toward math also added a significant amount of variance explaining scores beyond early numeracy ($\Delta R^2 = .101, p = .002$). Student reported Enjoyment and Importance were significant predictors of Calculation scores. Student competence beliefs and teacher report of student attitudes were not significant in the final model.

Math Composite. After controlling for early numeracy skills, teacher ratings of students' attitudes toward math accounted for a unique amount of variance ($\Delta R^2 = .035, p = .008$). Student self-reported rating of attitudes toward math was also significant and explained an additional 8% of variance in math scores ($\Delta R^2 = .075, p = .002$). In the full model, student reported competence beliefs significantly explained unique variance in math scores while Enjoyment, Importance and teacher report did not.

Discussion

The purpose of this study was to investigate the relationship between mathematics achievement and attitudes toward mathematics for students in kindergarten and first grade. Specifically, competence beliefs, enjoyment and importance were examined in relation to early numeracy, calculation, story problems and applied problem solving skills. Results suggested that young children's self-reported competence beliefs and perceived importance of mathematics were most robust in their relation to measures of mathematics achievement. This finding was consistent across correlations, discrimination analysis and regression analysis. This indicates that for students in kindergarten and first grade, their perceptions of their own abilities (e.g., I am good at math) and their

perceptions of the importance of mathematics (e.g., Math will be important for second grade) has implications for student achievement in mathematics as well as how teachers perceive student achievement and student attitudes. Results are discussed further in relation to the research questions.

Attitudes are related to achievement in early grades

Findings from correlations and one-way ANOVA suggest that in general, student attitudes toward mathematics were related to their achievement on a number of measures. Student reported Enjoyment was most strongly related to their performance on the Calculation measure ($r = .31, p < .01$). Enjoyment was not significantly related to early numeracy skills or Applied Problems. This may perhaps be due to the curriculum or instruction used in the specific school setting. It is possible that classroom teachers utilize more game like instruction or practice involving calculation. It is also possible that, consistent with expectancy value theory, calculation comes easier to some students, compared to more complex problems, and because it is easier they find it more enjoyable (Eccles & Wigfield, 2000). Student reported Competence Beliefs were more strongly related to their performance on the Story Problems measure ($r = .34, p < .01$) and the overall Math Composite ($r = .38, p < .01$). This factor of attitudes toward mathematics was significantly related to all achievement measures. This is consistent with previous research that confidence or competence beliefs seems to be the stronger predictor of achievement (Adelson & McCoach, 2011; Ganley & Lubienski, 2016; Gierl & Bisanz, 1995; Kloosterman et al., 1996; Mazzocco et al., 2012). Some suggest that competence beliefs directly effect achievement and effort while Enjoyment may effect achievement

through competence beliefs (Pinxten et al., 2014). Further research is warranted to examine this relation among young children.

Student reported Importance of mathematics was also significantly related to all achievement measures in the present study. It was most strongly correlated with the Story Problems measure and the Calculations measure ($r = .37, p < .01$). These findings were discrepant from some previous research, which suggested that competence beliefs and enjoyment are more robust indicators of student achievement in mathematics (e.g., Adelson & McCoach, 2011). Previous researchers have proposed that the importance or usefulness of mathematics may not be relevant for young children; however, perhaps the previous scales did not provide a definition of importance and usefulness that was understandable or developmentally appropriate for young children. It was surprising that the Enjoyment scale was most related to student performance on Calculation measures when calculation is often a skill perceived as repetitive practice to mastery fluency. Future research is warranted to examine if this finding generalizes across various curriculums and teacher strategies. One may hypothesize that the Enjoyment scale was not as related to achievement due classroom practices. Perhaps students have not yet differentiated enjoyment for different subjects (e.g., math, reading, science) because overall they have positive perceptions of school.

Given that student self-report measures for young children are sometimes inaccurate, teachers also provided a report of the extent to which students had positive attitudes toward mathematics. Interestingly, the teacher rating was more strongly related to direct measures of student achievement compared to students' own report of their attitudes ($r = .42$ to $.59$). This finding supports previous research suggesting that teacher

perceptions of student performance and beliefs may have implications for student actual performance. While casual relationships cannot be made from the present study, it is likely, like other aspects of student attitudes that the relation is bidirectional. Given theories of social psychologist, such as expectancy value theory (Wigfield & Eccles, 2000), it is also plausible that students perceive how their teachers view their performance and beliefs then match their own behaviors with the perceptions of teachers. While student-reported attitudes tended to have lower correlation coefficients related to the earlyMath measure, teacher reported attitudes were most strongly associated with earlyMath ($r = .59$) compared to other direct measures of achievement. This is perhaps due to the focus of instruction in the kindergarten and first grade classroom. Notably, the highest association across the measures was between teachers ratings of student achievement and teacher ratings of student attitudes ($r = .70, p < .01$). Perhaps, teachers perceive that if their students are achieving to a higher level in mathematics they must also like or be confidence in mathematics. This hypothesis is consistent with the theory of planned behavior, which suggests that people will behave based on their pre-existing attitudes and behavioral intentions (Ajzen & Fishbein, 2005). In terms of attitudes toward mathematics, students who have positive attitudes will also need to believe that performing the behavior will lead to a specific outcome (e.g., achievement, engagement) to occur. Thus teachers may think, if students are achieving as expected and they are putting forth effort in the classroom, students must also like math and feel confident in their abilities. This finding warrants further investigation in future research as it may have implications for how teachers teach and interact with their students, which can shape their learning trajectories.

The findings from the discrimination analysis provided similar evidence. Students who had difficulties or disabilities in mathematics (i.e., those performing at or below the 25th percentile) to those that are more typically achieving (i.e., those performing above the 25th percentile) had significantly lower competence beliefs about their mathematics performance as compared to students who were higher achieving. Those who were lower achieving also viewed mathematics as less important and teachers perceived less positive attitudes toward mathematics. With regard to at-risk students (< 40th percentile), only teacher perception of student attitudes was significantly different between groups. This finding is important for educational practices. If lower performing students as early as kindergarten and first grade show less competence beliefs and importance of mathematics, then they may be less likely to invest in recovery or future improvement. This builds on previous research, which connects student perceptions and academic achievement to their effort and persistence in the classroom (Seaton, Parker & Marsh, 2014; Stipek, 2002; Wigfield & Eccles, 1994). Early intervention and prevention of such negative attitudes is important in fostering more motivated and resilient learners.

Student reported attitudes improved prediction of later achievement

The final research question examined the extent to which student ratings on attitudinal measures and teacher ratings of student attitudes enhanced models and predictions of student achievement in early grades. Findings indicated that adding student reported attitudes to the prediction model explained an additional 8 to 12 percent of variance in Total Math scores, Story Problems performance or Calculation measures. Further, teacher report of student attitudes significantly explained an additional three to eight percent of unique variance in schools across those same measures. Attitudes toward

mathematics did not add unique variance to student scores in regard to Applied Problem Solving.

Consistent with previous research, student competence beliefs appear to have a strong relation to multiple aspects of student mathematics achievement. A previous review of 15 studies (Kiss, 2016) found that of the three components of attitudes, perceived self-competence may have the most robust influence on achievement, followed by perceived enjoyment and then usefulness. In contrast, the current study found that student perceptions of the importance of mathematics had stronger relations and predictions of achievement in mathematics compared to student reported enjoyment. One potential explanation is that students reported their levels of enjoyment based on class activities related to math (e.g., using an iPad) instead of the topic of mathematics in itself. Perhaps when asked if they liked math, students thought about math class instruction and activities rather than the construct of mathematics. Another hypothesis is that the school community that the sample participated in encouraged the importance of mathematics in their instruction. This relates to the limitations of external validity of the present study. Current results are sample dependent and further research to address threats to external validity is warranted. At this point, the findings in the research base are still mixed. Some studies have found limited evidence that valuing mathematics was related to achievement in mathematics (Gierl & Bisanz, 1995; Kloosterman et al., 1996). However, the measures used in previous studies with elementary school did not have adequate psychometric properties (Table 1). Still, improved measurement in grades 3-5 did not seem to detect a strong relation of importance or usefulness of mathematics with achievement (Adelson &

McCoach, 2011). More research is warranted to examine the relation between perceived importance of mathematics and subsequent achievement in mathematics.

Limitations and Future Research

There are a number of limitations in the present study that may be address by future research. Future research may benefit from larger sample sizes and longitudinal research to examine the development of attitudes toward math as well as any differences across developmental trajectories. Some research has examined these developmental differences (e.g., Ganley, et al., 2013); however, it has not yet been thoroughly examined for students as young as kindergarten and first grade. Future research may also examine the relationship between attitudes and achievement across groups of students at various school settings and from different backgrounds. The current sample was predominantly white, generally high achieving and held mostly positive attitudes toward mathematics. Whether or not these findings generalize to more diverse samples is unclear at this time.

Further research may also aim to examine other academic enablers along with attitudes toward math. These academic enablers may build off previous research and include, interpersonal skills, motivation, study skills or engagement (DiPerna, Volpe & Elliott, 2005). Future studies may also include a measure of general self-concept as well as attitudes toward reading. Some research suggests that attitudes toward mathematics are distinct from attitudes toward learning in general; and that students may have poor attitudes towards mathematics, and generally high attitudes toward school and reading but this has not yet been investigated at the kindergarten and first grade level (Aiken, 1970; Belbase, 2013; Di Martino, & Zan, 2015; Moller, Streblov, & Pohlmann, 2009). This may provide additional insights to the developmental trajectory of student attitudes.

Another topic for future study is the causality between attitudes and achievement. As previously stated in the introduction, the relationship between attitudes and achievement appear to be cyclical. Intervention research may provide a new perspective in examining this relationship. Further, there are limitations with self-report measures of student attitudes toward mathematics. While the measure used in this study was selected to be developmentally appropriate and theoretically based, self-report measures yield a number of limitations. Given that researchers and educators cannot directly measure a student's attitude toward mathematics, we rely on observations of behaviors that are associated with that target domain. Attitudinal measures are often based on self-report of internalized, or covert, behaviors (e.g., cognitions, affects). Overt behaviors, such as a response to a rating score, are directly observed, scored, and used to infer a generalized disposition with respect to cognitive and affective states. There are a number of errors that might occur in this process and authors of current measures.

Implications

The current study addresses a current gap in the research literature in regard to the extent that different components of attitudes toward mathematics are related to various achievement measures for students in their first years of formal schooling. The results suggest modest associations between student attitudes toward math and subsequent achievement in mathematics as early as kindergarten and first. Given that students who have difficulties in mathematics in early years tend to have persisting difficulties later in schooling (e.g., Duncan et al., 2007) and students with less positive attitudes tend to show less effort and participation in mathematics (Wigfield & Eccles, 2000), it is critical that educators and researchers continue to address and evaluate the impact that students

perceived enjoyment, competence beliefs and importance and considered in early years. Since attitudes can be influenced by adult socialization and learning behaviors, an important consideration is how adults talk about mathematics. Teachers and parents can encourage students to focus on the process and mastery of learning over test scores or specific assignments (Fast et al., 2010). It is not that wrong answers are bad and correct answers are good, but rather that learning mathematics is a process, and errors are expected. Thinking such as “I’m not good at math” tends to limit student achievement, while a growth mindset approach such as “I can be good at math if I work hard” helps motivate students and foster positive attitudes (Boaler, 2013; Dweck, 2006; Rattan, Good, & Dweck, 2012).

In the present study, findings from the discrimination analysis and correlations suggest that teacher perception of student attitudes was more strongly related to student achievement compared to students’ own reported perceptions. While the influence of accuracy of student ratings can not be ruled out at this time and causality can not be inferred, these results may suggest that perhaps teacher’s views of student attitudes may have an even stronger impact on their achievement compared to students own views of their attitudes. Another consideration is how training can be provided to school staff on the importance of attitudes toward learning and how to foster positive attitudes in their classrooms. If evidence suggests that students in middle and high school have lower attitudes toward mathematics and that those students engage less and practice less mathematics, it seems critical to understand the earlier development of these attitudes to be able to foster more positive perceptions of mathematics and improve mathematics learning environments for all students. Understanding attitudes toward mathematics in

elementary school is important given the potential for early intervention. Perhaps, if educators can foster positive attitudes toward mathematics from a young age, the decline in interest and self-perceptions will be less steep as children age and mathematics becomes more difficult.

CHAPTER 4

The purpose of the two integrated studies was to examine attitudes toward mathematics among young children. The study focused to improve the measurement of attitudes toward mathematics so that educators and researchers can better understand the extent to which attitudes toward mathematics are related to achievement and mathematics learning from early grades. Examining this relationship as early as kindergarten and first grade is relevant to multi-tiered systems of supports. If findings from previous research suggest that students develop more negative attitudes toward mathematics overtime, as educators we can utilize earlier information to help intervene early and prevent the development of more persistent difficulties in mathematics (Fuchs et al., 2005).

Specifically, in Study 1 a survey assessment was developed to measure attitudes toward mathematics for students in kindergarten through first grade and to examine the reliability and validity evidence for potential use in a school setting. Without high quality measurement instruments it is difficult to derive strong conclusions about the relation of attitudes toward mathematics and other variables like achievement. Past reviews (e.g., Aiken, 1970; Ma & Kishor, 1997) have noted concerns with the measurement of attitudes toward mathematics for younger children. More recent research began to focus on measures of attitudes among primary age students, yet that research has yet to extend to children in kindergarten and first grade. These studies did just that. The findings provide preliminary evidence that attitudes toward mathematics can be measured among younger children using a three-factor model with moderate estimates of reliability, which is consistent with previous research with older students. This fills an important gap in the research literature and Study 2 illustrates the contribution and potential future

value.

In Study 2, the developed survey was used to investigate the extent to which different components of attitudes toward mathematics (i.e., perceived self-competence beliefs, enjoyment, and importance) were related to student mathematics achievement as measured by teacher ratings and standardized mathematics assessments. Examining attitudes may be particularly important for students with difficulties in mathematics that tend to have poorer attitudes and achievement compared to their normal achieving peers (Hanich & Jordan, 2004; Zeleke, 2004). Thus, students with math difficulties and poorer attitudes may have a compounding level of risk and may not be as effortful and persistent in the face of challenging content. Difficulties in mathematics may be the source of skill-deficits (i.e., students have not yet acquired the skill to perform accurately and/or fluently) or performance deficits (i.e., students have the skill but do not want to perform the skill). While the results from Study 2 were not experimental in nature, findings suggest that attitudes are related to performance deficits, which may influence their effort and engagement in mathematics. Findings support that even for very young students in kindergarten and first grade, self-report attitudes toward mathematics as well as teacher perceptions of students' attitude contribute to predict of mathematics achievement. Further, when comparing achievement groups, there were significant differences of student attitudes and teacher perceptions of attitudes. If this differentiation of student performance and beliefs is present in the first years of primary school, it is important for educators to consider student attitudes and perceptions. As a field we may need to devise more robust supports to foster more positive attitudes that may increase motivation and task persistence as mathematics becomes more challenging. Such supports might

contribute to recovery and improved future achievement.

Limitations

A limitation across both studies is the sample of participants that the results are based off of. As with most exploratory research, the findings presented in this paper are sample specific and more research is warranted to determine if the findings generalize across diverse samples. Given that previous research with older students (e.g., Ma & Kishor, 1997; Mullis, Martin & Foy, 2009) suggest that there may be cultural differences in regards to both students' reporting of their own attitudes as well as between the relation of attitudes and achievement, replication research is necessary. A diverse sample also would benefit and advance the findings not only due to diverse demographics, but due to diverse educational and instructional practices. If research suggests that attitudes can be socially developed, research with young children should continue to investigate these social influences such as teacher and parent attitudes as well as instructional practices in the classroom that may foster or hinder student attitudes toward mathematics.

Another limitation is that the present findings are correlational in nature. Future experimental research as well as more longitudinal research would be beneficial in advancing future research and practice. Longitudinal research would be beneficial in regards to better understanding developmental trajectories of student mathematical learning. Experimental research would also add to the field. Specifically, investigating differences in student attitudes toward mathematics in response to intervention strategies or instructional practices would provide information in how teachers and educators may work to help improve student attitudes toward mathematics. Given that up to 93% of adults reported feeling uncomfortable with mathematics some point in their schooling

and that mathematics has important implications for success later in life, utilizing this research in a prevention and early intervention framework may have large implications for how students perceive their own learning of mathematics.

Implications and Contribution to the Field of School Psychology

Some researchers have emphasized the influence of academic enablers of student achievement and performance in school, especially in mathematics (DiPerna, 2005; DiPerna, Volpe & Elliot, 2005; Haimovitz & Dweck, 2017; Kilgus, Bowman, Christ & Taylor, 2017). Teachers and practitioners may find it particularly useful to understand their students' perceived competence beliefs, importance and enjoyment in mathematics since these variables can provide helpful information in understanding student engagement, interest, effort and motivation (Parajes & Miller, 1994; Seaton, Parker & Marsh, 2014; Stipek, 2002; Wigfield & Eccles, 1994). Yet, there is a lack of instructionally relevant, efficient, and psychometrically sound survey tools to provide this important data that, when used, may have the potential to improve student learning. Understanding how students' perceive their ability may be the first steps in helping students build their competence to become later successful learners. This will also support future research to help provide reliable, valid, and efficient tools to measure multiple domains of attitudes toward mathematics. If school psychologists and educators don't have adequate measurement tools to assess these aspects of learning and their influences on academic skills it is difficult to help fully support these skills. A better understanding of attitudes towards mathematics among young children also has important implications for prevention of difficulties in mathematics within a multi-tiered system of supports.

If we know that students in middle and high school have less positive attitudes toward mathematics and that those students engage less and practice less mathematics, it seems important to understand the earlier development of these attitudes to be able to foster more positive perceptions and mathematics learning environments for all students. As such, this study is first in an emerging line of inquiry to understand how attitudes influence various achievement outcomes for young children, and, thereby, identify if, how, and to what effect attitudes of young children might be targeted for intervention.

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Table 1

Summary of Survey Instruments Used to Measure Attitudes toward Mathematics

Attitude Measure	Study	Grade(s)	Attitude Variables	Reliability (N items)	Scale
Likert Scale Questionnaires					
Math and Me Survey	Adelson & McCoach (2011)	3 – 6	Enjoyment of Mathematics Mathematics Self- Perceptions	$\alpha = .92$ (10) $\alpha = .88$ (8)	5-point scale: strongly agree to strongly disagree
Adapted Likert Survey (Beghetto, 2006; 2007; 2009; Meece, Wigfield, & Eccles, 1990; Tierney & Farmer, 2002)	Beghetto & Baxter (2012)	3 – 5	Perceived Competence Creative Self-Efficacy ^a	$\alpha = .73$ (3) $\alpha = .89$ (5)	5-point scale: not at all true to very true
Dutton Attitude Scales	Cain-caston (1993)	3	Attitudes toward Math	NR (11)	Yes for agree, No for disagree
Mathematics Attitudes and Anxiety Questionnaire	Dowker & Bennett & Smith (2012)	3, 5	Self-rating for math, anxiety about math, liking for math, unhappiness about poor performance	NR (28)	Pictorial rating scale of various pictures.
Adapted Likert Survey (Pajares & Miller, 1995; Midgley, 2000)	Fast et al. (2010)	4 – 6	Self-Efficacy	$\alpha = .84$ (4)	5-point scale: not at all true to very true

Select items from Self-Descriptive Questionnaire (SDQ)	Ganley & Lubienski (2010)	3, 5	Math Confidence Math Interest	$\alpha = .79 / .86$ (4) $\alpha = .90 / .92$ (4) ^a	4-point scale: not at all true to very true
Mathematics Attitudes Survey (MATS; Adapted from Fennema & Sherman, 1976; Sandman, 1973)	Gierl & Bisanz (1995)	3, 6	Usefulness Intrinsic Value Confidence	$\alpha = .30 / .63$ (7) $\alpha = .78 / .82$ (7) $\alpha = .73 / .89$ (7) ^b	5-point scale: strongly disagree to strongly agree
Self-Perception Profile for Learning Disabled Students (SPP-LD; Renick & Harter, 1988)	Hanich & Jordan (2004)	3	Perceived Competence	$\alpha = .83$ (4)	Children selected one of two statements to describe themselves, then rated as really true or sort of true. Children were given 1 to 4 points for each response.
Feelings about School (Stipek & Valeski, 2001)	Herbert & Stipek, (2005)	K, 1	Perceived Competence	K: $\alpha = .66$ (3) 1 st : $\alpha = .70$ (3)	5-point scale: not much at all to a lot or, not good at all to very good
	Valeski & Stipek (2001)	K, 1	Perceived Competence	$\alpha = .68 / .63$ (3)	

Research-developed survey	Harari, Vukovic & Bailey (2013)	1	Attitude toward mathematics	$\alpha = .76$ (5)	4-point: yes, kind of, not really, no
Adapted Likert Survey (Wigfield, 1997)	Herbert & Stipek (2005)	3, 5	Perceived Competence	3 rd : $\alpha = .68$ (4) 5 th : $\alpha = .75$ (5)	5-point scale: not good at all to very good or, one of the worst to one of the best
TIMSS ^c	House (2006)	4	Attitudes toward mathematics	NR (3)	4-point scale: strongly disagree to strongly agree
Adapted Likert Survey: (Motivated Strategies for Learning Questionnaire)	Shores & Shannon (2007)	5, 6	Self-Efficacy Intrinsic Value	$\alpha = .67$ (9) $\alpha = .80$ (8)	5-point scale: almost never to almost always
2-3 questions researcher developed questions	Upadyaya & Eccles (2014)	K – 6	Interest in math	$\alpha = .73, .80, .85$ (three waves)	7-point likert scale: a little to a lot, and boring to interesting
Adapted Likert Survey (Shoenfeld, 1989)	Whang & Hancock (1994)	4 – 6	Self-concept of ability	NR (5)	5 point scale

Note. NR = not reported

^a Reliabilities reported for 3rd and 5th grade, respectively

^b Reliabilities reported for 3rd and 6th grade, respectively.

^c Results were reported by item, thus there is no reliability to report and no formal scale is proposed.

Table 2

Demographics of the Sample

	Kindergarten	First Grade	Total
<i>N</i> Students	67	52	119
<i>N</i> Classrooms	4	3	7
Age (in months)	<i>M</i> = 70.34 (<i>SD</i> = 3.74)	<i>M</i> = 82.04 (<i>SD</i> = 3.70)	<i>M</i> = 75.45 (<i>SD</i> = 6.91)
Gender			
Male	61%	46%	55%
Female	40%	54%	45%
Ethnicity			
American Indian/Alaskan Native	0%	2%	1%
Asian/Pacific Islander	4.5%	4%	4%
Hispanic	4.5%	8%	6%
Black	9%	2%	6%
White	82%	83%	82%
Receiving Special Education	10%	8%	9%
Receiving Tier II Supports in Math	0%	10%	4%
Receiving Tier II Supports in Reading	21%	17%	19%

Table 3

Frequency of Responses, Means, Standard Deviations, Skew, Kurtosis, Discrimination and alpha for Attitudes Survey Items

Item	No	Not really	Kind of	Yes	<i>M</i>	<i>SD</i>	Skew	Kurt.	Item Disc.	α if removed
Enjoyment										
2. I like to practice math.	20%	7%	16%	58%	3.11	1.20	-0.93	-0.80	.53	.82
3. I like to share my math thinking.	29%	12%	13%	46%	2.76	1.30	-0.35	-1.64	.43	.83
4. Math is boring ^a	54%	0%	11%	35%	2.27	1.41	0.28	-1.86	.52	.82
12. Math is fun.	21%	7%	15%	56%	3.06	1.22	-0.84	-1.00	.67	.80
13. Math is my favorite time of the day.	33%	11%	14%	42%	2.65	1.32	-0.21	-1.73	.60	.81
16. I love math.	26%	6%	12%	56%	2.98	1.29	-0.70	-1.31	.78	.78
17. I like to do math at home for fun.	29%	6%	9%	56%	2.92	1.33	-0.59	-1.50	.61	.81
20. I like my teacher in math.	6%	1%	8%	85%	3.73	0.74	-3.01	8.20	.36	.84
Competence beliefs										
1. I can do well in math if I try hard.	12%	6%	6%	76%	3.46	1.05	-1.68	1.17	.54	.62
5. I like to help my friends with math.	10%	10%	8%	71%	3.41	1.03	-1.46	0.59	.31	.67
6. I am good at math.	15%	6%	13%	67%	3.32	1.10	-0.39	-1.73	.53	.62
7. Math is hard ^a	54%	3%	12%	30%	2.19	1.37	0.39	-1.73	.30	.69
10. I will never be good at math ^a	71%	5%	4%	21%	1.75	1.24	1.17	-0.52	.13	.73
18. I am good at solving tricky problems.	19%	5%	15%	61%	3.18	1.19	-1.07	-0.54	.58	.60
21. I am a good student in math.	9%	3%	10%	78%	3.57	0.93	-2.09	2.99	.50	.64

Importance

8. People use math outside of school.	34%	6%	11%	50%	2.77	1.36	-0.36	-1.72	.05	.69
9. Learning math will help me be a grown up.	19%	4%	3%	75%	3.34	1.19	-1.37	-0.01	.35	.57
11. Learning math is important.	6%	2%	3%	89%	3.86	1.23	-3.22	9.09	.29	.59
14. Getting good grades in math is important.	10%	4%	10%	76%	3.51	0.97	-1.88	2.06	.50	.52
15. You need to know math to be smart.	9%	6%	6%	78%	3.53	0.97	-1.87	1.99	.33	.58
19. Learning math will help me in 2nd grade.	8%	4%	7%	81%	3.61	0.91	-2.21	3.44	.57	.51
22. Math is important to buy things.	21%	6%	19%	55%	3.06	1.21	-0.87	-0.91	.38	.56

Note. Item Disc = Item Discrimination, Kurt. = Kurtosis.

^aReversed Item

Table 4
Item Correlations across the Three Attitude Scales

Enjoyment	2	3	4	12	13	16	17	20
2. I like to practice math.	–	.33	.38	.38	.35	.51	.38	.15
3. I like to share my math thinking.		–	.26	.34	.23	.34	.32	.36
4. Math is boring. ^a			–	.56	.32	.49	.29	.22
12. Math is fun.				–	.46	.60	.47	.35
13. Math is my favorite time of the day.					–	.68	.61	.14
16. I love math.						–	.60	.38
17. I like to do math at home for fun.							–	.18
20. I like my teacher in math.								–
Competence Beliefs	1	5	6	7	10	18	21	
1. I can do well in math if I try hard.	–	.31	.55	.20	.03	.55	.32	
5. I like to help my friends with math.		–	.20	.09	.08	.20	.38	
6. I am good at math.			–	.13	.17	.48	.44	
7. Math is hard. ^a				–	.11	.34	.27	
10. I will never be good at math. ^a					–	.08	.01	
18. I am good at solving tricky problems.						–	.42	
21. I am a good student in math.							–	
Importance	8	9	11	14	15	19	22	
8. People use math outside of school.	–	-.01	-.02	.03	-.06	.15	.09	
9. Learning math will help me be a grown up.		–	.11	.32	.16	.36	.30	
11. Learning math is important.			–	.18	.25	.42	.17	
14. Getting good grades in math is important.				–	.42	.48	.31	
15. You need to know math to be smart.					–	.31	.19	
19. Learning math will help me in second grade.						–	.25	
22. Math is important to buy things.							–	

^aReversed Item

Table 5

Confirmatory Factor Analysis Fit Statistics for Hypothesized Models

Statistic	Uni-dimensional	Three-factor	Two-factor	Acceptable Values
<i>Absolute Indices</i>				
χ^2/df ratio	1.59	1.28	2.08	<2.0
Weighted Root Mean Square Residual (WRMR)	.82	.71	.80	< .90
<i>Parsimonious Fit Indices</i>				
Root Mean Square Error of Approximation (RMSEA)	.07 90%CI [.05 - .10]	.05 90%CI [.01 - .08]	.10 90%CI [.07 - .13]	$\leq .06 = \text{Good};$ $\leq .08 = \text{Acceptable}$
<i>Incremental Fit Indices</i>				
Comparative Fit Index	.95	.96	.96	$\geq .95 = \text{Good}$
Tucker-Lewis Index	.94	.94	.94	$\geq .90 = \text{Acceptable}$

Note. CI = Confidence Interval

Table 6

Factor Loading Estimates for Three-factor Model

Item	Factor Structure		
	Enjoyment	Competence	Importance
I like to practice math.	.52	-	-
I like to share my math thinking.	.62	-	-
Math is boring.	.56	-	-
Math is my favorite time of the day.	.53	-	-
I like to do math at home for fun.	.34	-	-
I like to help my friends with math.	-	.72	-
I am good at math.	-	.40	-
Math is hard.	-	.69	-
I am good at solving tricky problems.	-	.44	-
I am a good student in math.	-	.71	-
Learning math will help me be a grown up.	-	-	.72
Learning Math is important.	-	-	.49
Getting good grades in math is important.	-	-	.33
You need to know math to be smart.	-	-	.61
Learning math will help me in second grade.	-	-	.23

Table 7

Item Descriptive Statistics, Scale Descriptive Statistics, Reliability Estimates and Readability

	Item				Scale		Reliability		
	<i>N</i>	<i>M</i>	Min <i>M</i>	Max <i>M</i>	<i>M</i>	<i>SD</i>	Alpha	Test-Retest ^a	Readability ^b
Enjoyment	5	2.84	2.65	3.11	14.17	4.51	.73	.46	0.6
Competence	5	3.26	2.82	3.57	16.29	3.68	.67	.29	0.0
Importance	5	3.55	3.34	3.77	17.77	3.17	.68	.32	0.8
Total	15	-	-	-	48.22	9.65	.88	.46	0.4

^a Test-retest was calculated using a delayed model (4 months) indicating an estimate of the lower bounds of reliability

^b Readability Grade Level is indicative of Flesch-Kincaid level. A level of .6 indicates readability appropriate for a student in their sixth month of kindergarten.

Table 8

Means, Standard Deviations and Correlations between Measures

	Score <i>M</i>	Score <i>SD</i>	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
1. Enjoyment	14.29	4.55	–	.60**	.55**	.20*	.23*	.14	.17	.27**	.14	.31**
2. Competence	16.37	3.73		–	.43**	.28**	.27**	.22*	.34**	.38**	.31**	.33**
3. Importance	17.81	3.20			–	.29**	.22*	.19*	.37**	.34**	.21*	.37**
4. Teacher rated ATM	2.94	1.04				–	.70**	.59**	.52**	.53**	.48**	.42**
5. Teacher rated Ach.	2.69	1.10					–	.73**	.37**	.60**	.56**	.47**
6. earlyMath	56.29	17.45						–	.48**	.65**	.64**	.48**
7. Story Problems	6.01	2.41							–	.59**	.57**	.43**
8. Math Composite	102.90	12.33								–	.87**	.88**
9. Applied Problems	104.40	14.36									–	.56**
10. Calculation	101.37	10.33										–

Note. ATM = attitude toward math; Ach. = Achievement

* $p < .05$; ** $p < .01$

Table 9

Correlation between attitudes, teacher report, and direct measures of mathematics achievement

	Attitude Measure			Teacher Ratings
	Enjoyment	Competence	Importance	
Teacher rated Attitudes	.20*	.28**	.29**	–
Teacher rated Ach.	.23*	.27**	.22*	.70**
earlyMath	.14	.22*	.19*	.59**
Story Problems	.17**	.34**	.37**	.51**
Math Composite	.27**	.38**	.34**	.53**
Applied Problems	.14	.31**	.21*	.48**
Calculation	.31**	.33**	.37**	.42**

Note. Ach. = Achievement

* $p < .05$; ** $p < .01$

Table 10

Discriminate Validity across Math Achievement Groups

	<26th Percentile	>25th Percentile			<41st Percentile	>40th Percentile		
	<i>n</i> = 24	<i>n</i> = 90			<i>n</i> = 46	<i>n</i> = 68		
	<i>M</i> (<i>SD</i>)	<i>M</i> (<i>SD</i>)	Hedges' <i>g</i>	Sig.	<i>M</i> (<i>SD</i>)	<i>M</i> (<i>SD</i>)	Hedges' <i>g</i>	Sig.
Enjoyment	12.75 (5.03)	14.70 (4.35)	--	.062	13.61 (4.56)	14.75 (4.52)	--	.190
Competence	13.74 (4.96)	17.06 (2.99)	.95	.000*	15.71 (4.30)	18.82 (3.25)	--	.120
Importance	16.47 (3.87)	18.18 (2.92)	.54	.020*	17.45 (3.22)	18.07 (3.19)	--	.313
Teacher Report ATM	2.13 (1.12)	3.16 (0.91)	.81	.000*	2.37 (1.10)	3.32 (0.80)	.43	.000*

Note. Hedge's *g* was calculated only when the mean difference between groups was significant. Achievement groups were determined by performance on Woodcock Johnson Tests of Achievement.

*. The mean difference is significant at the .05 level

Table 11
Summary of Regression Models for Predicting Spring Mathematics Achievement

	Model 1 <i>Numeracy</i>		Model 2 <i>Student ATM</i>		Model 3 <i>Teacher ATM</i>		Model 4 <i>Stdnt & Tchr</i>	
Story Probs	B (SE)	β	B (SE)	β	B (SE)	β	B (SE)	β
Intercept	2.31 (.68)*		-2.17 (1.20)*		1.51 (.68)*		-2.04 (1.17)	
earlyMath	.07 (.01)*	.48	.05(.01)*	.39	.04 (.01)*	.27	.04 (.01)*	.25
Enjoyment			-.10 (.06)	-.20			-.10 (.06)	-.19
Competence			.15 (.06)*	.24			.14 (.06)*	.21
Importance			.23 (.07)*	.30			.20 (.07)*	.26
<i>Tchr</i> Rating					.82 (.23)*	.35	.62 (.22)*	.27
R^2	.23		.35		.31		.39	
Appl. Probs	B (SE)	β	B (SE)	β	B (SE)	β	B (SE)	β
Intercept	74.74 (3.52)*		63.06 (6.61)*		72.61 (3.68)*		63.39 (6.59)*	
earlyMath	.53 (.06)*	.64	.49 (.06)*	.60	.45 (.07)*	.55	.44 (.07)*	.53
Enjoyment			-.33 (.31)	-.10			-.32 (.31)	-.10
Competence			.81 (.35)*	.21			.76 (.35)*	.20
Importance			.29 (.39)	.07			.21 (.39)	.05
<i>Tchr</i> Rating					2.20 (1.22)	.16	1.66 (1.25)	.12
R^2	.41		.45		.43		.45	
Calculation	B (SE)	β	B (SE)	β	B (SE)	β	B (SE)	β
Intercept	85.33 (2.89)*		68.71 (5.22)*		83.28 (3.01)		68.95 (5.21)*	
earlyMath	.29 (.05)*	.48	.24 (.05)*	.41	.21 (.06)*	.36	.20 (.06)*	.34
Enjoyment			.20 (.24)	.09			.21 (.24)*	.09
Competence			.25 (.28)	.09			.22 (.28)	.08
Importance			.67 (.31)*	.21			.61 (.31)*	.19
<i>Tchr</i> Rating					2.11 (1.00)*	.21	1.23 (.99)	.13
R^2	.23		.33		.26		.34	
Math Total	B (SE)	β	B (SE)	β	B (SE)	β	B (SE)	β
Intercept	77.05 (2.99)*		59.42 (5.40)*		74.39 (3.07)*		59.78 (5.34)*	
earlyMath	.46 (.05)*	.65	.41 (.05)*	.58	.36 (.06)*	.51	.35 (.06)*	.50
Enjoyment			-.03 (.25)	-.01			-.03 (.25)	-.01
Competence			.62 (.29)*	.19			.57 (.29)*	.17
Importance			.60 (.32)	.16			.50 (.32)	.13
<i>Tchr</i> Rating					2.74 (1.02)*	.23	1.87 (1.01)	.16
R^2	.42		.50		.46		.51	

Note. ATM=Attitudes toward Math; B(SE) are unstandardized values and represent the amount by which dependent variable changes if the independent variable is changed by one unit keeping the other variables constant. β indicates the standardized coefficient, which eliminates the difference in units of measurement of independent and dependent variables. This indicates a rank of importance such that larger values are more important in relation to the dependent variable. For example, a β of .58 indicates that a change in one standard deviation in the independent variables results in a .58 standard deviation increase in the dependent variable. * $p < .05$

Table 12

Summary of Change in R^2 : Do student attitudes toward math enhance prediction of math achievement?

Dependent Variable	Model 1 to Model 2		Model 1 to Model 3	
	ΔR^2	p	ΔR^2	p
Story Problems	.121	.000**	.082	.000**
Applied Problems	.035	.081	.017	.075
Calculation	.101	.002**	.030	.037*
Math Total Score	.075	.002**	.035	.008**

Note. Model 1 predictor = earlyMath; Model 2 predictors = earlyMath, Enjoyment, Competence, Importance; Model 3 = earlyMath, Teacher rating of student attitudes. Model 1 to Model 2 comparisons indicate the extent to which student attitudes enhanced prediction models. Model 1 to Model 3 comparisons indicate the extent to which teacher perceptions of student attitudes enhanced prediction models.

* $p < .05$, ** $p < .01$

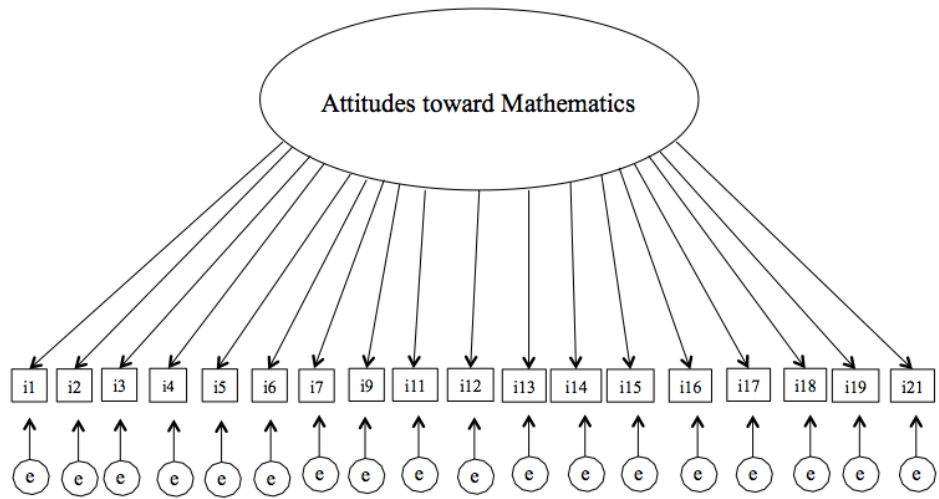


Figure 2. Model of survey items with a unidimensional factor structure.

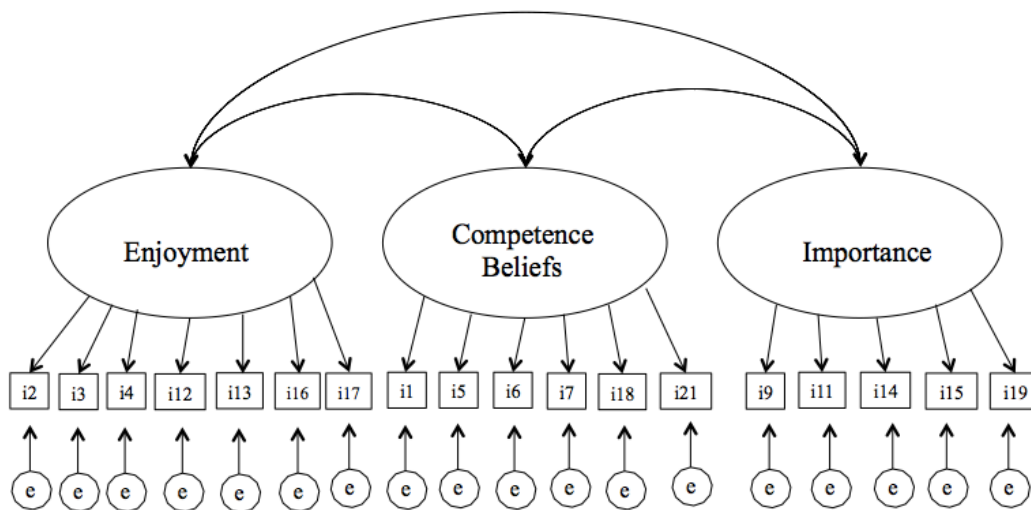


Figure 3. Model of survey items with a three-factor structure where all three factors are correlated.

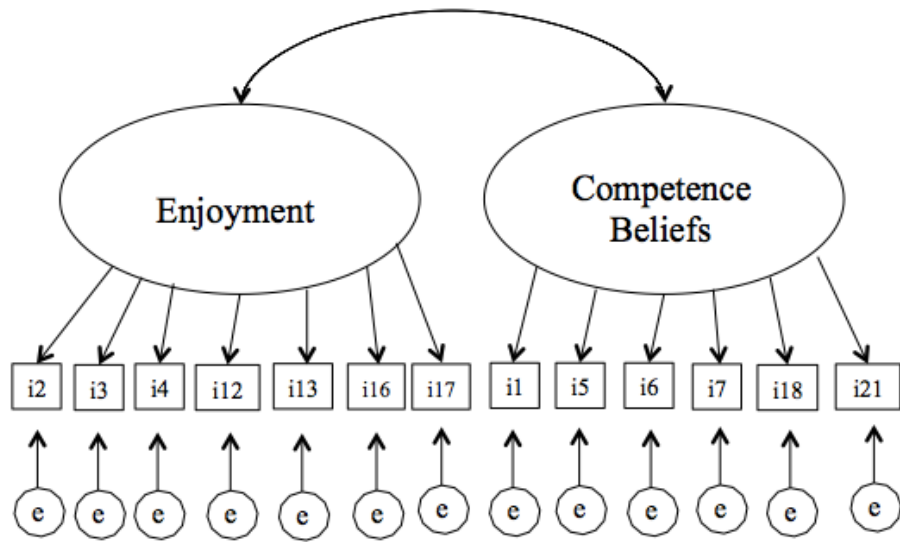


Figure 4. Model of survey items with two-factor structure where all two factors are correlated.

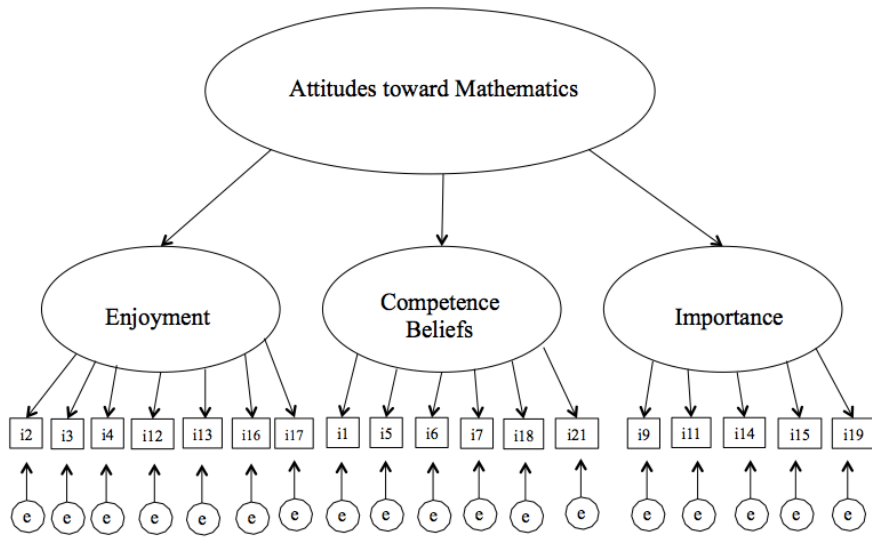


Figure 5. Structure of hypothesized dimensionality with hierarchical structure and three first order factors.

Appendix A





List of All Student Responses Related to their Perceptions of Math

- Boring; do lots of stuff you don't like
- It helps me it will help me as a grown up
- It will help me be a grow up; reading is important too
- Coding gives colors for toys and stuff; parts are unknown; game ozmo
- I like all the problems - I lie math; I don't like when I don't get to do math
- I like everything!
- We get to play ozmo on the ipad
- There are a lot of math equations so I don't always have to do the same thing; I don't like that sometimes it's too easy
- I like doing it for like hours & hours
- I like that math is fun; I like counting; I like that I do it in school
- Math is fun!
- I like that I get to learn more; There is not really anything I don't like about it
- It's fun!
- It's fun to solve even if you get it wrong
- I like to answer hard questions that I never learned
- I like doing math problems with 10s and 1s and making thousand math problems and figuring them out
- I like solving bigger problems and sharing ideas; don't like when you can't concentrate
- I like that you can make up your own strategies and use different strategies; I don't like getting problems wrong
- I like that it really helps me think; it sometimes takes a long time to do
- I like challenging myself
- I just like it
- My favorite thing in math is hard math problems to solve
- I like all of it
- I love about math when we do plus and minus and math mountain makes it fun to do math at school and at home
- Do fun things like math equations
- I like that its kind of easy. Sometimes I say the right answer
- It's fun and sometimes I practice at home by myself
- Can use white boards
- I like the games; I don't like when I don't know the answer
- I get bored with it a lot
- I like everything times a million
- Math is not my thing, not really a fun activity; I don't like math because I like video games and because there is no movement
- I like it because we get to be smarter
- I like that you do a lot of problems, our teacher teaches us new ways to learn math
- Everything! I like how we do a bunch of story problems and they are always just kind of at my level
- I like doing equations; I dislike nothing
- I like addition and subtraction because then I learn the answers
- I don't like math because you always have to look at your paper and I can't do that
- I like to solve problems
- I like solving math problems but I don't like hard problems
- I don't like math at all because it is boring
- Yes I like math because I want to learn more and be in first grade
- I just don't like it





- Math is hard but I like doing math
- Because it is fun and you get to learn some more
- I like math when we have to do hard stuff, not little stuff
- I don't like math because it is hard
- I don't like math
- I like minus and plus and that you can do bigger numbers
- because it is fun to add stuff together and subtraction
- I like strategies
- I don't like when I get to the end of the page
- I like writing math and playing games
- I like fun games and making stuff, I don't like writing it
- I like that I get to count; homework is hard sometimes (don't like)
- Don't like that it's so hard, I like when it's easy
- I like that I'd good at math
- I don't like working for a long time and I like when I do a good job
- I love counting but I don't like counting down from 100
- I like fun activities; don't like so much lbig and hard problems
- I like that I can learn a lot of different maths
- it's boring
- I like that I get to do fun things besides learning
- I like math because I can be whatever I want to be if I learn math
- It's fun, you get to learn
- it's boring, we have to listen and can't draw what we want
- Yes, I like math because it helps you be a grown up
- I like reading problems and helping someone do problems
- I like it because it is sometimes hard; even when it is super hard I can get through the problems
- It is fun to do; you get to solve math problems
- I don't like reading in math, it's too hard
- I like math because it makes you smart
- I like math because it makes you learn more; I don't like math because it is challenging
- I can do any math problem! I did all my math workbooks!
- I like to count
- I like using ipads
- I like learning; I don't like writing in math because my head hurts sometimes
- All of math is good
- It's very fun
- I like that I get to learn new things; there is nothing I don't like
- I like learning; math will help me in first grade
- I like that we can sort the marbles, I don't like writing math
- I like learning about math
- I like getting to do math activities with my sisters
- Math is really hard
- I like math it helps me learn
- I like writing math

• Appendix B

Young Children's Attitudes toward Mathematics Pilot Survey Items

	No	Not Really	Kind of	Yes
				
I like to play soccer.	No	Not Really	Kind of	X
I am good at dancing.	No	Not Really	Kind of	Yes
Writing is fun.	No	Not Really	Kind of	Yes

	No	Not Really	Kind of	Yes
1. I can do well in math if I try hard.	No	Not Really	Kind of	Yes
2. I like to practice math.	No	Not Really	Kind of	Yes
3. I like sharing my math thinking.	No	Not Really	Kind of	Yes
4. Math is boring.	No	Not Really	Kind of	Yes
5. I like to help my friends with math.	No	Not Really	Kind of	Yes
6. I am good at math.	No	Not Really	Kind of	Yes
7. Math is hard.	No	Not Really	Kind of	Yes
8. People use math outside of school.	No	Not Really	Kind of	Yes
9. Learning math will help me be a grown up.	No	Not Really	Kind of	Yes

	No	Not Really	Kind of	Yes
				
10. I will never be good at math.	No	Not Really	Kind of	Yes
11. Learning math is important.	No	Not Really	Kind of	Yes
12. Math is fun.	No	Not Really	Kind of	Yes
13. Math is my favorite time of the day.	No	Not Really	Kind of	Yes
14. Getting good grades in math is important.	No	Not Really	Kind of	Yes
15. You need to know math to be smart.	No	Not Really	Kind of	Yes
16. I love math.	No	Not Really	Kind of	Yes
17. I like to do math at home for fun.	No	Not Really	Kind of	Yes
18. I am good at solving tricky problems.	No	Not Really	Kind of	Yes
19. Learning math will help me in second grade.	No	Not Really	Kind of	Yes
20. I like my teacher in math.	No	Not Really	Kind of	Yes
21. I am a good student in math.	No	Not Really	Kind of	Yes
22. Math is important to buy things.	No	Not Really	Kind of	Yes

Appendix C

Survey Administration Fidelity Checklist

Procedure	Observed?
✓ Each example item was read and demonstrated until students did not have any questions	0 1
✓ Students were instructed to circle only one response and were reminded throughout the survey.	0 1
✓ Administrator read each item aloud	0 1
✓ Items were read aloud at a steady and slow pace.	0 1
✓ Items were repeated when requested by students.	0 1
Total = X / 5 = _____%	

Appendix D

earlyMath Observing and Rating Administrator Accuracy

Examiner: _____ Date: _____

1 = Completed Accurately 0 = Completed Inaccurately

Testing Procedure	Number Seq. K/1	Decomp K	Decomp 1	Numeral ID K/1
Places practice items in front of student	NA			NA
Places copy of materials in front of student	NA			
Seated appropriate distance from student				
Scoring device is not visible to the student				
Follows standardized directions; reads directions verbatim				
Starts timer when indicated				
Examiner marks items as correct or incorrect as student responses				
Applies discontinue rule when needed				
Does NOT provide any other guidance to student				
Stops timer when indicated OR administers for correct time			(1min)	(1min)
Total Score:	/8	/10	/10	/9

Appendix E

Teacher Rating of Student Attitudes toward Math

Please order students in your class from (1) Likes math the most to (19/20) Does not like math at all. This is based on your opinion of student performance in the classroom over the past month. While ranking, please first consider which group the student falls into: Likes math a lot, likes math a little, dislikes math a little and dislikes math a lot. Then, consider the order. You can place however many students in each group as you would like.

Likes math a lot
1. 2. 3. # # #
Likes math a little
#
Dislikes math a little
#
Dislikes math a lot / Does not like math at all
#. #. 17. 18, (19.) (20.)

Appendix F

Teacher Rating of Student Math Achievement

Please order students in your class from (1) Exceeds expectations to (19/20) below expectations in math. This is based on your opinion of student performance in the classroom over the past month. While ranking, please first consider which group the student falls into: Exceeds grade level expectations in math, meets expectations in math, partially meets expectations, or below expectations in math. You can place however many students in each group as you would like.

Exceeds grade level expectations in math
1. 2. 3. # # #
Meets grade level expectations in math
#
Partially meets grade level expectations in math
#
Below grade level / does not meet expectations in math
#. #. 17. 18, (19.) (20.)