

THE EFFECT OF PERSONAL AND EPISTEMOLOGICAL BELIEFS ON
PERFORMANCE IN A COLLEGE DEVELOPMENTAL MATHEMATICS CLASS

by

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B.S., Wichita State University, 1981
M.A., University of Kansas, 1983

AN ABSTRACT OF A DISSERTATION

Submitted in partial fulfillment of the requirements for the degree

DOCTOR OF PHILOSOPHY

Department of Foundations and Adult Education
College of Education

KANSAS STATE UNIVERSITY
Manhattan, Kansas

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ABSTRACT

This study explored the effects of personal epistemological beliefs about mathematics and beliefs about the ability to do well in mathematics on achievement in a college-level, developmental mathematics class. The influences of gender, age, and ethnicity on these beliefs as they relate to mathematics achievement were also explored. The Mathematics Belief Scales (MBS) was adapted from the Indiana Mathematics Belief Scales and Self-Description Questionnaire III to measure beliefs about the time it takes to solve mathematics problems, the importance of conceptual understanding in mathematics, the procedural emphasis in mathematics, the usefulness of mathematics, and self-concept about mathematics. MBS was administered to 159 participants enrolled in Intermediate Algebra over two semesters at an urban, state-supported mid-western university and two small private mid-western universities. Responses to the surveys and scores on the final exams for the Intermediate Algebra courses were analyzed using descriptive statistics, the Pearson product-moment correlations, analysis of variance techniques, and hierarchical regression analysis.

Results indicated that students generally held nonavailing beliefs about mathematics and mathematics self-concept. Students typically believed that mathematical problems should be solved within ten minutes. Students generally did not believe that math problems can be solved with logic and reason instead of learned math rules. Over 40% of the students did not believe that mathematics beyond basic mathematics was useful to everyday life. Students were also generally not confident in their ability to solve mathematics problems.

Additionally, men's self-concept was significantly higher than women's self-concept. Adult learners' self-concept was also significantly higher than traditional age students' self-concept. Hierarchical regression analyses revealed that the importance of

understanding mathematical concepts positively influenced final exam scores for men more so than women and self-concept positively influenced final exam scores for women more so than men. These results indicate a need for academic experiences at the college-level that will challenge students' current belief system and provide an environment that is supportive and conducive to building individual self-confidence.

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Additionally, men's self-concept was significantly higher than women's self-concept. Adult learners consistently had higher mean scores than traditional age students for epistemological beliefs about the time it takes to solve mathematics problems, the

importance of understanding concepts, and the usefulness of mathematics. Hierarchical regression analyses revealed that the importance of understanding mathematical concepts positively influenced final exam scores for men more so than women and self-concept positively influenced final exam scores for women more so than men. These results indicate a need for academic experiences at the college-level that will challenge students' current belief system and provide an environment that is supportive and conducive to building individual self-confidence.

TABLE OF CONTENTS

LIST OF FIGURES	xi
LIST OF TABLES.....	xii
ACKNOWLEDGEMENTS.....	xiv
DEDICATION.....	xv
Chapter 1 Introduction	1
Preface.....	1
Theoretical Rationale	1
Personal Epistemological Beliefs	2
Epistemological Beliefs about Mathematics.....	3
Nonavailing Beliefs	4
The Relationship between Epistemological Beliefs, Gender, Ethnicity, and Age.....	6
Self-Concept	8
Developmental Mathematics	11
Statement of Purpose	12
Research Questions.....	12
Research Design.....	13
Significance of the Study.....	14
Limitations/Delimitations of the Study.....	15
Definition of Terms.....	16
Summary	17
Chapter 2 Literature Review.....	19
Introduction.....	19
Personal Epistemology.....	19
Domain Specificity	27
Beliefs about Mathematics.....	28
Nonavailing Beliefs	31
Relationship between Epistemological Beliefs and Achievement.....	33
Epistemological Beliefs, Gender, Age, and Ethnicity	35
Gender.....	35
Age.....	37
Ethnicity.....	40
Beliefs about Self as Part of the Belief System	44
Self-Efficacy and Self-Concept	47
Self-Concept and Mathematics Achievement.....	50
Measures of Self-Confidence and Gender, Ethnicity, and Age.....	53
Gender.....	54
Ethnicity.....	57
Age.....	58
Considerations for Developmental Mathematics.....	61
Summary	65

Chapter 3 Methodology	70
Introduction.....	70
Research Questions.....	70
Research Design Overview.....	71
Participants.....	72
Instrumentation	73
The Indiana Mathematics Belief Scales (IMBS)	73
The Usefulness Scale	75
Modifications to the Indiana Mathematics Belief Scales	76
Self Description Questionnaire III (Mathematics Self-Concept Subscale)	78
The Mathematics Belief Scales Questionnaire	80
Variables of Interest.....	81
Data Collection Procedures.....	83
Assumptions.....	84
Data Analysis Procedures	85
Summary.....	85
Chapter 4 Results	88
Introduction.....	88
Overview.....	88
Internal Consistency Reliability Estimates	88
Population and Sample	90
Demographic Characteristics	91
Dependent Variable	97
Independent Variables	98
Qualitative Responses.....	102
The Interaction of Beliefs with Gender, Age, and Ethnicity	104
Variables Influencing Final Performance	110
Regression Analysis Results.....	120
Summary.....	126
Chapter 5 Discussion	128
Introduction.....	128
Summary of the Study Design	128
Research Questions.....	128
Discussion of the Findings.....	129
The Distinction between Beliefs about Mathematics and Beliefs about Self.....	129
What are Participants Beliefs?.....	130
Do Beliefs Differ Between Genders, Ages, and Ethnicities?	133
Research Question 1	134
Research Question 2	135
Research Question 3	135
Research Question 4	136
Research Question 5	137
Recommendations for Future Research.....	138
Implications.....	140
Appendix A Indiana Mathematics Belief Scales	143

Appendix B Fennema-Sherman Usefulness Scale.....	144
Appendix C Self-Description Questionnaire III Maths Subscale.....	145
Appendix D Mathematics Belief Scales Summary.....	146
Appendix E Survey Instructions	148
Appendix F Informed Consent Form.....	149
Appendix G Personal Data Inventory	151
Appendix H Mathematics Belief Scales	152
Appendix I Intermediate Algebra Course Objectives by School.....	157
Appendix J Intermediate Algebra Final Exam for WSU: Spring 2006	158
Appendix K Intermediate Algebra Final Exam for WSU: Spring 2006.....	165
Appendix L Histograms of Final Exam Scores	172
References.....	173

LIST OF FIGURES

Figure 1 Hierarchical Structure of Self-Concept	49
Figure 2 Age and Sex Effects for the Six Self-Concept Scales Common to the three SDQ Instruments.....	60
Figure 3 Histogram of the Time Scale Scores	99
Figure 4 Histogram of the Understanding Scale Scores	100
Figure 5 Histogram of the Steps Scale Scores	100
Figure 6 Histogram of the Usefulness Scale Scores	101
Figure 7 Histogram of the Self-Concept Scale Scores.....	101
Figure 8 Boxplots of Final Exam Scores by Gender	112
Figure 9 Boxplots of Final Exam Scores by Age	112
Figure 10 Boxplots of Final Exam Score by Ethnicity.....	113

LIST OF TABLES

Table 1 Epistemological Beliefs and Corresponding Levels of Belief.....	3
Table 2 Percentage of High School Seniors Demonstrating Mastery of Specific Mathematics Knowledge and Skills, by Selected Student Characteristics: 2004.	64
Table 3 Summary Statistics and Reliabilities (Cronbach’s Alpha) for the Mathematics Belief Scales.....	89
Table 4 Summary Statistics and Reliabilities (Cronbach’s Alpha) for the Mathematics Belief Scales.....	90
Table 5 Population and Sample Sizes by Institution and Semester	91
Table 6 Frequencies by Institution and Gender	92
Table 7 Frequencies by Institution and Age	92
Table 8 Frequencies by Institution and Ethnicity	93
Table 9 Totals for Traditional Age Students and Adult Learners by Gender and Institution	94
Table 10 Frequencies for Survey Item 35.....	95
Table 11 Frequencies for Survey Item 36.....	95
Table 12 Frequencies for Survey Item 37.....	96
Table 13 Frequencies for Survey Item 38.....	96
Table 14 Frequencies for Survey Item 39.....	97
Table 15 Summary Statistics for Belief Scales and Self-Concept.....	99
Table 16 Summary Statistics for Belief Scales and Self-Concept by Gender	105
Table 17 t-Tests for the Mean Differences in Mathematics Belief Scales between Men and Women	105
Table 18 Summary Statistics for Belief Scales and Self-Concept by Age	106
Table 19 t-Tests for the Mean Differences in Mathematics Belief Scales between Traditional Age Students and Adult Learners	107
Table 20 Summary Statistics for Belief Scales and Self-Concept by Ethnicity	108

Table 21 t-Tests for the Mean Differences in Mathematics Belief Scales between Caucasians and African-Americans.....	108
Table 22 Mean Self-Concept Scores by Gender and Age	109
Table 23 Tests of Between Subject Effects for Self-Concept Against Age, Gender, and Age x Gender	110
Table 24 Correlations of Final Exam Score, the Belief Scales, and Self-Concept.....	111
Table 25 Mean Final Exam Scores by Gender and Understanding	114
Table 26 Tests of Between Subject Effects for Final Exam Score against Understanding, Gender, and Understanding x Gender.....	115
Table 27 Mean Self-Concept Scores by Gender and Age	115
Table 28 Mean Final Exam Score by Self-Concept and Gender	116
Table 29 Correlation Analysis of Beliefs and Self-Concept with Final Exam Scores (Men Only)	117
Table 30 Correlation Analysis of Beliefs and Self-Concept with Final Exam Scores (Women Only)	117
Table 31 Mean Final Exam Scores by Age and Understanding	118
Table 32 Mean Final Exam Scores by Age and Self-Concept.....	119
Table 33 Tests of Between Subject Effects for Final Exam Score against Age, Self-Concept, and Age x Self-Concept.....	119
Table 34 Mean Final Exam Scores by Ethnicity and Self-Concept.....	120
Table 35 Model Summary for Model 1 and Model 2 (Men Only)	122
Table 36 Hierarchical Regression Coefficients for Model 1 and Model 2 (Men Only).	122
Table 37 Model Summary for Model 1 and Model 2 (Women Only).....	123
Table 38 Hierarchical Regression Coefficients for Model 1 and Model 2 (Women Only)	124
Table 39 Model Summary for Models 1, 2, 3, and 4 (Men and Women).....	125
Table 40 Hierarchical Regression Coefficients for Models 1, 2, 3, and 4 (Men and Women).....	126

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DEDICATION

...To my parents, Paul and Shirley Carrick, for their unending love and support.

Chapter 1

Introduction

Preface

This study explored the effects of personal epistemological beliefs about mathematics and beliefs about the ability to do well in mathematics on achievement in a college-level, developmental mathematics class. The influences of gender, age, and ethnicity on these beliefs as they relate to mathematics achievement were also explored. This chapter provides an overview of the study including an overview of the theoretical rationale, statement of purpose, research questions, significance of the study, research design, limitations and delimitations of the study, and definition of terms.

Theoretical Rationale

Mathematics is a barrier to success in college for many students (Stage, 2001). It is viewed as a difficult subject to master due to its symbolic and abstract nature. Stage (2001, p. 203) discusses, “A student who is unsuccessful in mastering mathematics skills loses opportunities to enroll in a broad range of college courses, thus limiting career choice.” A significant number of students entering college are underprepared for college mathematics and need to begin their college experience with a developmental mathematics course (National Science Board, 2004; National Science Board, 2006). The student’s success in a developmental mathematics course has a direct effect on success in subsequent mathematics courses and ultimately persistence in college (Penny & White, 1998). Factors that can affect students’ success in mathematics are the students’ personal epistemological beliefs about mathematics (Buehl & Alexander, 2005; Mason & Boscolo, 2004; Schoenfeld, 1989; Szydlik, 2000) and confidence in their mathematics ability (Kloosterman & Emenaker, 1996; McLeod, 1992; Reyes, 1984; Schoenfeld, 1983;

Schoenfeld, 1985). These beliefs are formed within the context of individual academic experiences (Cobb, 1986; Garofalo, 1989a; Schoenfeld, 1989). Academic experiences are shaped by personal characteristics, such as gender, age, and ethnicity (Marsh & Shavelson, 1985; National Council of Teachers of Mathematics, 2000; Wilkins, 2003).

Personal Epistemological Beliefs

Personal epistemology refers to individuals' beliefs about what knowledge is, how it occurs, where it resides, and how it is constructed and evaluated (Hofer ed, 2004). Models of personal epistemology address the nature of knowledge and the nature of knowing (Hofer & Pintrich, 1997). The nature of knowledge refers to what individuals believe knowledge is and includes beliefs about the certainty and simplicity of knowledge. For example, perspectives about mathematics may range from views that mathematics consists of a discrete set of pre-existing rules and procedures to views that mathematics is a complex discipline involving interrelations, generalizations, and abstractions. The nature of knowing is how it is individuals know and includes beliefs about the source of knowledge and the justification for knowing. For instance, students may determine their level of understanding by grades on homework and tests or they may determine understanding by the ability to work independently and make connections to other tasks and disciplines.

Developmental models of personal epistemology reveal a progression along a continuum from an objective, dualistic view of knowledge to viewing knowledge as less certain and, finally, to a view of knowledge that is contextual and actively constructed (Baxter Magolda, 1992; Belenky, Clinchy, Goldberger, & Tarule, 1986; King & Kitchener, 1994; Perry, 1970). Views of the four aspects of the nature of knowledge and the nature of knowing vary on a continuum that range from simplistic views of

knowledge to more complex views. Hofer and Pintrich's (1997) description of the variation of views for each of the four aspects is depicted Table 1.

Table 1
Epistemological Beliefs and Corresponding Levels of Belief (Hofer & Pintrich, 1997)

Epistemological Beliefs	Perceptions of Knowledge	
	Low End	High End
<i>Nature of Knowledge</i>		
Certainty of Knowledge	Knowledge is unchanging.	Knowledge is evolving.
Simplicity of Knowledge	Knowledge is an accumulation of discrete pieces of information.	Knowledge consists of highly interrelated concepts.
<i>Nature of Knowing</i>		
Justification of Knowledge	Knowledge is justified by what feels right.	Knowledge is justified through evidence, logic, and reason.
Source of Knowledge	Knowledge is handed down through teachers.	Knowledge is constructed and developed through the learning experience.

Perceptions of knowledge vary by academic discipline (Mason & Boscolo, 2004; Muis, 2004; Schraw & Sinatra, 2004). Students' beliefs about mathematics are less likely to be advantageous to learning than their beliefs about other fields of study. Hofer and Pintrich (1997) discussed that academic disciplines have different knowledge structures and epistemological assumptions which need to be considered.

Epistemological Beliefs about Mathematics

Epistemological beliefs that have implications for mathematical learning include beliefs about the nature of mathematics as a discipline, the nature of knowing mathematics, as well as the acquisition of mathematics knowledge and the usefulness of

mathematics (Muis, 2004). Schommer-Aikins (2002) referred to the acquisition of knowledge specifically as the ability to learn and the speed of acquisition. Hofer and Pintrich (1997) discussed that beliefs about the ability to learn and beliefs about the speed of acquisition are separate constructs. For purposes of this study, an effort was made to more clearly distinguish beliefs about the ability to learn mathematics as beliefs about self as a learner of mathematics, and speed of acquisition as epistemological beliefs. Although speed of acquisition has not been a topic of interest in early discussions of general personal epistemology, it has consistently been discussed throughout the literature on the beliefs about mathematics as an important component to mathematical learning (Frank, 1988; Kloosterman & Stage, 1992; Mason, 2003; Schoenfeld, 1988; Spangler, 2002). Beliefs about the speed of acquisition range from the perception that knowledge is acquired quickly to the perception that acquiring knowledge takes time (Schommer-Aikins, Duell, & Hutter, 2005).

Beliefs about the usefulness of mathematics knowledge have also been a topic of interest in the literature as an important component to mathematical learning (Fennema & Sherman, 1978; Fennema & Sherman, 1977; Kloosterman & Stage, 1992; Schommer-Aikins et al., 2005; The National Council for Teachers of Mathematics, 1989). Students' beliefs about the usefulness of mathematics refer to perceptions about the value of mathematics in their current educational or vocational activities, and in relationship to their future goals (Fennema & Sherman, 1976). Views about the usefulness of mathematics may range from "mathematics is of no relevance to my life" at the low end of the continuum to "mathematics is a necessary and worthwhile subject" at the high end.

Nonavailing Beliefs

Recent and classical works have addressed the effect of epistemological beliefs on behavior, specifically as it relates to mathematical learning (Muis, 2004; Schoenfeld,

1983). Beliefs can limit expectations and cognitive resources and, therefore, affect the goals and strategies individuals use when engaging in mathematical activity and, ultimately, their understanding of mathematics (De Corte, Op 't Eynde, Peter, & Verschaffel, 2002; Mason, 2003; Schoenfeld, 1983). Beliefs that either hinder motivation or have a negative or no effect on students' understanding are considered non-advantageous to learning (Kloosterman & Stage, 1992; Muis, 2004). Muis (2004) adopted the labels “availing” for beliefs that contribute to learning and “nonavailing” for beliefs that have no influence or negatively affect learning. These labels were adopted for this study as well.

Students at all levels hold nonavailing beliefs about mathematics (Kloosterman & Stage, 1992; Muis, 2004; Schoenfeld, 1988). Nonavailing beliefs may include such beliefs as mathematics is based on facts, rules, formulas, and procedures; the learning of mathematics should occur quickly; mathematics is about getting the right answer; mathematical knowledge is passively handed down by some authority figure; and mathematics is not useful in daily life (Cobb, 1986; Frank, 1988; Garofalo, 1989a; Kloosterman & Stage, 1992; Mason, 2003; McLeod, 1992; Mtetwa & Garofalo, 1989; Schoenfeld, 1988; Schoenfeld, 1989; Schommer-Aikins et al., 2005). The National Council of Teachers of Mathematics (NCTM) reported, “These beliefs exert a powerful influence on students' evaluation of their own ability, on their willingness to engage in mathematical tasks, and on their ultimate mathematical disposition” (1989, p. 233).

Nonavailing beliefs about mathematics have been shown to negatively affect mathematical performance, either directly or indirectly (Buehl & Alexander, 2005; Garofalo, 1989a; Mason & Boscolo, 2004; Schoenfeld, 1989; Szydlik, 2000). For example, students who are more likely to believe that mathematics is mostly memorizing or learned mostly through step-by-step procedures tend to have lower grades as compared

to those who conceptualize mathematics as more than a discrete set of rules and procedures (Schoenfeld, 1989; Szydlik, 2000). Students who believe that almost all mathematics problems can be solved by the application of facts, rules, formulas, and procedures tend to approach mathematical tasks in a mechanical manner or by relying on memorization (Garofalo, 1989a). Students who hold nonavailing beliefs may also have lower levels of motivation and task performance (Buehl & Alexander, 2005).

The Relationship between Epistemological Beliefs, Gender, Ethnicity, and Age

Epistemological beliefs about mathematics are formed within the context of classroom experiences and, thus, are shaped by the expectations of teachers, peers, and parents (Cobb, 1986; Garofalo, 1989a; Schoenfeld, 1989). Expectations are low for certain demographic groups within the population, including women and nonwhites (National Council of Teachers of Mathematics, 2000). There is extensive research investigating the relationship between gender or ethnicity and mathematical learning (Fennema and Sherman, 1978; Kilpatrick & Silver, 2000; Leder, 1992; Mason, 2003; Muralidhar, 2003; Secada, 1992; Stage and Kloosterman, 1995; Wilkins, 2003). However, research investigating epistemological beliefs and mathematical learning with respect to gender or ethnicity, particularly at the college level, has been limited. Schraw and Sinatra (2004) noted that research needs to explore the effect personal characteristics have on beliefs and learning.

Investigations exploring the relationship between gender and epistemological beliefs with respect to mathematics achievement indicated that both genders hold nonavailing beliefs, but these beliefs influence mathematics achievement more so for women than for men (Mason, 2003; Stage & Kloosterman, 1995). Additionally, women tend to have more negative attitudes about the usefulness of mathematics than men (Fennema & Sherman, 1977; Wilkins, 2003).

Research exploring the relationship between race/ethnicity and epistemological beliefs about mathematics is practically nonexistent. Students who are poor and an ethnic minority have been characterized as having low mathematics achievement, unwilling to take more advanced secondary school mathematics courses, and disengaged from tasks within the mathematics classroom (Penny & White, 1998; Secada, 1992; The National Center for Education Statistics, 2001; Walker & Plata, 2000; Wilkins, 2003). Secada (1992) concluded that these outcomes are the results of classroom experiences that perpetuate nonavailing beliefs about mathematics.

As with gender and ethnicity, research exploring the influence of age on epistemological beliefs with respect to mathematics achievement has been limited, particularly between traditional age students and adult learners at the college level. Upon entry into college, a significant number of adult learners place into a developmental mathematics course (Fredrick, Mishler, & Hogan, 1984; Johnson, 1996; Walker & Plata, 2000). Adult learners' low level placement is specific to mathematics but not to other subject areas (Fredrick et al., 1984). However, adult learners seem to have greater satisfaction and appreciation for mathematics education than younger students (Miglietti & Strange, 1998; Stage & McCafferty, 1992) and tend to be successful in developmental as well as entry level mathematics courses (Johnson, 1996; Walker & Plata, 2000).

The personal characteristics of gender, ethnicity, and age influence academic experiences which form the context for epistemological beliefs (Cobb, 1986; Garofalo, 1989a; Marsh & Shavelson, 1985; National Council of Teachers of Mathematics, 2000; Schoenfeld, 1989; Wilkins, 2003). Epistemological beliefs are part of a more complete belief system which includes beliefs about mathematics, self, mathematics teaching, and social context (De Corte et al., 2002; Kloosterman et al., 1996; McLeod, 1985; McLeod, 1992; Schoenfeld, 1983; Schoenfeld, 1989; Silver, 1985). Several researchers have

discussed the need for exploring the relationship between epistemological beliefs about mathematics and beliefs about self as learners of mathematics (De Corte et al., 2002; McLeod, 1992; Schommer-Aikins et al., 2005).

Self-Concept

Measures of confidence have been consistently shown to be directly related to academic performance in mathematics (Kloosterman et al., 1996; McLeod, 1992; Reyes, 1984; Schoenfeld, 1983; Schoenfeld, 1985). Confidence has been studied under various constructs, such as self-efficacy, self-concept, and attribution style (Mone, Baker, & Jeffries, 1995; Pajares & Kranzler, 1995; Stevens, Olivarez, & Lan, 2004). Self-efficacy refers to belief in one's ability to reach given levels of attainment within a specific situation and, therefore, is task specific (Pajares & Miller, 1995). Self-concept is defined as an individual's perceptions of self (Marsh & Shavelson, 1985). Attribution style refers to perceived causation of success or failure and is a strong predictor of self-concept (Powers, Douglas, Lopez, & Rossman, 1985). As such, and for purposes of this study, self-concept more adequately defined beliefs about self as a learner of mathematics.

Shavelson, Hubner, and Stanton (1976) posited a model of self-concept that is multi-faceted and hierarchical. The facets of this hierarchy include facets which are academic and nonacademic. Academic self-concept is distinct from the nonacademic facets of social, emotional, and physical self-concepts. Academic self-concept includes the subject areas of self-concept, such as English, history, mathematics, and science. As individuals age, the hierarchical structure diminishes and the facets of self-concept become even more distinct (Marsh & Shavelson, 1985). In particular, self-concept with respect to mathematics is distinct from English as well as other academic and non-academic areas. Unlike self-efficacy, academic self-concept is measured at the domain-specific level (academic subject or discipline) (Seegers & Boekaerts, 1996). In a

discussion of self-concept as it relates to competence and motivation, Schunk and Pajares (2005) stated that academic self-concept can be domain specific. As individuals age, their increased awareness of subject-specific self-concepts guides their behavior within the subject area.

The predictive relationship between mathematics self-concept and mathematics achievement is well documented (Guay et al., 2003; House, 2000; P. Kloosterman et al., 1996; Silver, 1985; Wilkins, 2004). There is also strong support for the content specificity of mathematics self-concept (Marsh, Byrne, & Shavelson, 1988; Wilkins, 2004). Only mathematics achievement correlates with mathematics self-concept as opposed to general self-concept or verbal self-concept, and students with a more positive math self-concept have greater achievement in mathematics. Similar to epistemological beliefs about mathematics, mathematics self-concept has a reciprocal effect with achievement (Guay et al., 2003). Prior self-concept influences subsequent achievement and prior achievement influences subsequent self-concept.

Investigations exploring beliefs have not always clearly distinguished between beliefs about self and epistemological beliefs (Kloosterman & Stage, 1992; Mason, 2003; Schommer-Aikins et al., 2005; Stage & Kloosterman, 1995). Due to the ambiguous distinction between beliefs about mathematics as a discipline and beliefs about self as a learner of mathematics, the relationship between the two constructs and their shared effect on student behavior or performance is unclear. Several researchers have discussed the need for exploring the relationship between epistemological beliefs about mathematics and beliefs about self (De Corte et al., 2002; McLeod, 1992; Schommer-Aikins et al., 2005).

The Relationship between Self-Concept, Gender, Age, and Ethnicity

Personal characteristics, such as gender, age, and ethnicity, may also be important to mathematics self-concept and mathematics achievement. Most research that has explored gender differences in self-concept on mathematical learning has been at the elementary or secondary level. Students' beliefs in their ability to perform tend to decline as they move through school for boys and girls; however, boys tend to be more confident in their ability than girls (Fennema, Carpenter, & Jacobs, 1998; Wilkins, 2004). Also, girls tend to take fewer advanced courses than boys. Girls, more than boys, attribute success to a more variable attribute, such as effort, and failure to a more stable attribute, such as ability (Tapasak, 1990). In remedial college courses, men and women do not differ significantly in self-beliefs, but women relate their beliefs more strongly to course grade than do men (Walker & Plata, 2000).

There is little research exploring the relationship between race/ethnicity and competence beliefs about mathematics. Hispanic secondary students have reported low confidence in their ability to successfully complete mathematics problems as compared to Caucasian students (Stevens et al., 2004). More generally, African-American girls tend to experience a drop in positive feelings about teachers and school work from elementary school through secondary school (American Association of University Women, 1991).

The effect of age on self-concept, particularly for preadolescents, has been well documented (Guay et al., 2003; Marsh, Barnes, Cairns, & Tidman, 1984). As children grow older their academic self-concept becomes more reliable, more stable, and more strongly correlated with academic achievement. More research is needed at the college level to explore the differences in self-concept between traditional age students and adult learners. The "traditional" student is no longer typical (National Center for Education Statistics, 2002). Undergraduate students tend to work, tend to have more family

responsibilities, and are financially independent. As of 1999, more than a third of all postsecondary students are 25 years or older. Also, the enrollment rate for those age 25 to 29 between 1970 and 2004 increased from 8% to 13% (National Center for Education Statistics, 2006). Adult learners, age 25 or older, who enter postsecondary education seeking a degree are less likely than younger students to attain a degree (National Center for Education Statistics, 2002). Although there are very few studies that have explored adult learning and mathematics, some studies have shown that adults are at a disadvantage. Lower achievement scores for adult learners have been attributed to a prolonged absence from education or a lack of self-confidence (Evans, 2000; Fredrick et al., 1984; Miglietti & Strange, 1998). Adults may also have the tendency to make problems more complex due to their wider experiences (Evans, 2000). Many, if not most, of these adult learners begin their college experiences with a developmental mathematics class.

Developmental Mathematics

The primary goal of developmental mathematics education is to sufficiently improve the mathematics skills of underprepared students and, in so doing, provide opportunity for success in entry-level college mathematics (Penny & White, 1998). As colleges and universities have become more accessible over the last two decades, enrollment in remedial mathematics has steadily increased (National Science Board, 2006). For students who have had developmental mathematics, the strongest predictor of success in a subsequent mathematics course is the performance level achieved in the developmental class (Penny & White, 1998). A significant number of students placed into developmental mathematics courses are older, African-American, and female (American Mathematical Association of Two-Year Colleges, 1995). They enter with experiences that have affected their epistemological beliefs and self-concept about mathematics.

In summary, students at all levels hold beliefs about mathematics that are nonadvantageous to learning. These nonavailing beliefs include epistemological beliefs about mathematics as a discipline and beliefs about self as learners of mathematics. Furthermore, these beliefs are formed within the context of academic experiences that are influenced by personal characteristics, such as gender, ethnicity, and age.

Statement of Purpose

Although studies have shown that individually epistemological beliefs and self-concept influence mathematical performance, rarely has research explored the role that epistemological beliefs and self-concept share in predicting performance. Furthermore, there is very little research exploring the effects of personal characteristics on epistemological beliefs, self-concept, and mathematics achievement at the college level, particularly with respect to age. The primary purpose of this study was to determine a relationship between nonavailing epistemological beliefs, self-concept, and mathematical performance among college mathematics students taking an Intermediate Algebra course. Furthermore, this study explored the effects of the personal characteristics of gender, age, and ethnicity on epistemological beliefs and self-concept.

For purposes of this study, it was assumed that students' epistemological beliefs range on a continuum from nonavailing to availing. Likewise, it was assumed students' self-concepts about mathematics range on a continuum from low to high. Recognizing that both constructs are on a continuum, the extreme ends of both were explored for effects on mathematics performance.

Research Questions

The following research questions were used to guide this study:

1. What are the effects of epistemological beliefs about mathematics and mathematics self-concept on mathematics performance?

2. Are there significant differences in the effects of epistemological beliefs and self-concept on mathematics performance between men and women?
3. Are there significant differences in the effects of epistemological beliefs and self-concept on mathematics performance between adult learners and younger students?
4. Are there significant differences in the effects of epistemological beliefs and self-concept on mathematics performance between ethnic groups?
5. Are there significant interaction effects on mathematics performance between epistemological beliefs, self-concept, and the personal characteristics of gender, age, and ethnicity?

Research Design

Survey methodology was used to measure students' epistemological beliefs about mathematics and mathematics self-concept. The Mathematics Belief Scales (MBS) was modified from three existing scales: The Indiana Mathematics Belief Scales as proposed by Kloosterman and Stage (1992), Fennema-Sherman's (1976) Usefulness of Mathematics scale, and the Mathematics Self-Concept subscale from Herbert Marsh's (1989b) Self-Description Questionnaire III. MBS was designed to specifically measure beliefs about the time it takes to solve mathematics problems, the importance of conceptual understanding in mathematics, the procedural emphasis in mathematics, the usefulness of mathematics, and self-concept about mathematics.

The population consisted of all students enrolled in Intermediate Algebra in April 2006 and November 2006 at Wichita State University, Friends University, and Newman University (N=377). A total of 159 students participated. Of the students who participated, 60% were women (n=95), 30% were adult learners (n=47), and 37% were non-Caucasian (n=58).

The dependent variable, mathematics performance, was measured by the percent correct on the final examination for Intermediate Algebra during the semester of enrollment. The independent variables were epistemological beliefs about mathematics, mathematics self-concept, and the demographic variables of gender, age, and ethnicity. The variables, epistemological beliefs about mathematics and mathematics self-concept, were measured by the responses to the survey instrument, MBS. The demographic variables were self-reported by participants through a Personal Data Inventory sheet attached to the MBS questionnaire.

The surveys were distributed during class time within two weeks of the final exam date. Students signed an informed consent sheet prior to completing the Personal Data Inventory sheet and the survey. Instructors provided the percent correct on the final exam for each student. Appropriate quantitative methods were used to analyze the responses, including descriptive statistics, correlation analysis, analysis of variance techniques, and hierarchical regression analysis.

Significance of the Study

Increasingly, students entering college have diversity in demographic characteristics, academic preparedness levels, financial ability and socioeconomic levels (American Mathematical Association of Two-Year Colleges, 1995). Colleges and universities bear an ethical responsibility to provide students with opportunities for success. Developmental mathematics courses are offered for students who are underprepared in mathematics. For many, the success at this level will be a primary determinant of persistence in college.

The results of this study contributed to the literature on the relationship between nonavailing epistemological beliefs and poor self-concept, the personal characteristics of students who hold these beliefs, and success in developmental mathematics. As this

relationship continues to be explored, questions can be asked about how educators can affect change. Studies have found positive results that students' beliefs can change as a result of specific changes in classroom instruction (Muis, 2004). Educators who provide opportunities for development, exploration, and reflection of mathematical concepts provide a context in which students' beliefs can become more availing and, as students experience successes in understanding mathematics, their self-concept about mathematics improves.

Furthermore, educators need to have an understanding of the personal characteristics of students who have nonavailing epistemological beliefs and poor self-concept about mathematics. As we become more aware of the social barriers that exist for groups of individuals, researchers and educators can work to break down these barriers through awareness and changes in educational practices.

Limitations/Delimitations of the Study

Pursuant to the research questions, this study investigated the beliefs of participants enrolled in Intermediate Algebra at a mid-western state university that serves a diverse student population, as well as two small private universities. The sample was relatively small and, therefore, the ages and ethnic groups represented were limited. Because this study was directed at students in developmental mathematics, it will not generalize to students taking more advanced mathematics classes in college or to students in elementary or secondary school. It may not generalize to other developmental courses, such as Arithmetic, Pre-Algebra, or Basic Algebra.

The results of this study were limited by the features of the survey instrument used. Survey data do not capture the decision processes that produce observed outcomes. Also, statistical associations of survey data do not provide an understanding of complex relationships.

It was beyond the scope of this study to predict all factors that contribute to mathematics achievement. Although other factors, such as math anxiety, students' situational circumstances, classroom experiences, and institutional practices may influence mathematics achievement, this study was concerned primarily with the contributory value of self-concept and epistemological beliefs. Likewise, the correlation of these two constructs with personal characteristics was limited to the personal characteristics of gender, age, and ethnicity.

Definition of Terms

The following definitions will be used for purposes of this study.

Adult learner – a college or university student at least 25 years of age (National Center for Education Statistics, 2002).

Availing epistemological beliefs - an individual's beliefs about the nature, justification, sources, and acquisition of knowledge that are positively correlated with better learning outcomes (Muis, 2004).

Attribution theory – the study of perceived causation. Three dimensions of attributional patterns are locus (internal/external), stability (stable/unstable), and controllability (controllable/uncontrollable) (Kelley & Michaela, 1980; Weiner, 1980).

Developmental mathematics – “any course taught on the college level (2-year, 4-year, or university) below the level of “college algebra” or “precalculus”: arithmetic, pre-algebra, beginning or intermediate algebra, and (high-school level) geometry” (MAA Online, 2005, http://www.maa.org/t_and_l/developmental/dm.html).

Epistemology – a branch of philosophy concerned with the nature of knowledge and justification of belief (Muis, 2004).

Nonavailing beliefs - an individual's beliefs about the nature, justification, sources, and acquisition of knowledge that either don't correlate or negatively correlate with better learning outcomes (Muis, 2004).

Personal epistemology – the beliefs and theories that individuals come to hold about knowledge and knowing (Hofer, 2004).

Self-concept – an individual's perceptions formed through experiences with and interpretations of the environment, and influenced by reinforcements and evaluations of significant others (Marsh & Shavelson, 1985).

Self-efficacy – personal belief in the capability to organize and execute actions to produce outcomes. Perceptions of self-efficacy are derived from four sources of information: personal accomplishments, verbal persuasion, vicarious learning experiences, and physiological and affective reactions (Bandura, 1997).

Traditional age student – a college or university student 24 years of age or less (National Center for Education Statistics, 2002).

Summary

Success in a college level developmental mathematics class is influenced by epistemological beliefs and self-concept. Availing epistemological beliefs about mathematics influence more positive learning outcomes (Buehl & Alexander, 2005; Mason & Boscolo, 2004; Schoenfeld, 1989; Szydlik, 2000). Likewise, students with a positive math self-concept have greater achievement in mathematics (Kloosterman, Raymond, & Emenaker, 1996; McLeod, 1992; Reyes, 1984; Schoenfeld, 1983; Schoenfeld, 1985). There is very little research that explores the shared relationship between epistemological beliefs and self-concept on mathematics achievement, particularly at the college level. There is also limited research at the college level that

explores the relationship between epistemological beliefs about mathematics, self-concept, and the personal characteristics of gender, age, and ethnicity that may be influencing personal beliefs about mathematics. This study explored that shared relationship as it relates to mathematics performance.

Chapter 2

Literature Review

Introduction

Through a review of the literature, this chapter explores personal epistemology and self-concept within the academic setting. The theoretical groundwork of these two constructs is discussed both generally and within the domain-specific context of mathematics education. The relationships between personal epistemology, self-concept, and mathematics achievement are explored as well as the demographic influences of gender, age, and ethnicity. Considerations for developmental mathematics are discussed as well.

Personal Epistemology

The branch of philosophy called epistemology addresses the nature, scope, and sources of knowledge (DeRose, 2005). Epistemologists ask the question: Under what conditions does a subject believe something is true? Knowledge, within this framework, is at the intersection of truth and belief. In Gettier's (1963) classic paper, "Is Justified True Belief Knowledge?", Gettier argued that belief and truth is not sufficient for knowledge. As a result of Gettier's argument, central points in the discussions of epistemology have been how true belief might be properly justified and what constitutes evidence for individual beliefs (DeRose, 2005). Epistemology in reference to the individual is simply labeled "Personal epistemology". Personal epistemology is defined as "...a field that examines what individuals believe about how knowing occurs, what counts as knowledge and where it resides, and how knowledge is constructed and evaluated" (Hofer, 2004, p.1).

Personal epistemology has been investigated from varying disciplines, including educational psychology, developmental and instructional psychology, science and math education, higher education, and reading and literacy (Muis, 2004). As a result, there is no unifying theoretical framework from which to approach the understanding of personal epistemology. However, there is general agreement that personal epistemology has important implications for teaching and learning (Bendixen & Rule, 2004; Hofer, 2004; Muis, 2004). Theories or models of epistemology address the nature of knowledge and the nature of knowing and, thus, provide a standard for our understanding of learning (Hofer & Pintrich, 1997). The nature of knowledge refers to what individuals believe knowledge is. The nature of knowing is how it is they know.

Within theoretical models, nature of knowledge is further defined as the certainty and simplicity of knowledge (Hofer & Pintrich, 1997). The nature of knowing is described as the source of knowledge and the justification for knowing. Individuals' views of these four aspects vary on a continuum from simplistic views to more complex views. Certainty of knowledge can range from individuals' view of knowledge as absolute to a view that knowledge is tentative and evolving. Simplicity of knowledge refers to the view that knowledge consists of discrete facts at the low level to the view that knowledge is relative and contextual at the high level. Justification for knowing includes beliefs about evaluation of knowledge claims, ranging from validation through authority to validation through more multiplistic perspectives of evidence. Source of knowledge refers to views of knowledge in relation to self. At lower levels, knowledge is viewed as originating outside of self, such as through authority. At higher levels, knowledge is constructed in interaction with others.

Early classical investigations of personal epistemology include the works of Piaget and Perry. Piaget (1970) addressed epistemology in terms of the formation and

meaning of knowledge. He described the acquisition of knowledge from a biological perspective as a process of continual change through construction and reorganization. Piaget further stated that the acquisition of knowledge is an intellectual construction and therefore cannot be considered separately from the development of intelligence. The acquisition of knowledge was also described as a system of transformations that is active, rather than passive, and that progresses developmentally. Piaget influenced other researchers who used a developmental model to describe epistemology, namely Perry, Belenky, et al., Kitchener and King, and Baxter Magolda.

Like Piaget, Perry (1970) recognized the individual as moving from a level of concrete functioning in early stages of development to more abstract functioning in later stages. While Piaget studied young children, Perry studied individuals beyond the age of 15. Perry was interested in differences in students' responses to diverse intellectual and social challenges of universities. Perry's developmental model consists of nine positions of ethical and intellectual development. The term "position" is described as an individual's world point of view. In the early position, students assume a dualistic structure of knowledge. Knowledge is perceived as either right or wrong and students tend to believe that authority figures have all the answers. As students develop, they begin to doubt absolutes and they recognize one point of view as being as good as another. Further in the progression, students begin to view knowledge as being relative to various contexts. In the last position, students realize that there are multiple possibilities for knowledge and that they may need to give credence to some ideas over others.

Other developmental models parallel Perry's scheme in that the developmental progression begins with a dualistic perspective of knowledge or knowing that graduates to a more relativistic view and ultimately to a contextual or constructivist view (Hofer, 2002). Since Perry's model was the result of research with men only, Belenky, et al.'s

“Women’s Ways of Knowing” (1986) extended Perry’s model by focusing on the epistemological perspectives of women. Different aspects of epistemology were emphasized between the two models. Perry was concerned more with the nature of knowledge, whereas Belenkey et al. emphasized the nature of knowing and, more specifically, the source of knowledge (Clinchy, 2002). Similar to Perry’s “positions”, women’s ways of knowing consist of five different perspectives of truth, knowledge, and authority. The first perspective is the Silence perspective which is described as the voicelessness of women. Within this perspective, women view themselves as “deaf and dumb”. Women who have been raised under demeaning circumstances have little confidence in their ability to find meaning in dialogue. Clinchy (2002) explained that the Silence perspective is a failure to develop rather than a step in normal epistemological development. The second perspective is Received Knowing. This perspective parallels Perry’s dualism in that truth is viewed as absolute. Within this perspective, authority is the only source of knowledge. Within the third perspective, Subjective Knowing, truth is viewed as personal and individual. Individuals’ opinions are equally valid. Knowledge from this perspective is not based on authority or inferences, but rather on the immediate interpretation of reality. As perspectives of knowledge progress, individuals begin to view knowledge as a process rather than the result of immediate apprehension. Individuals in the Procedural Knowing perspective rely on procedures for obtaining knowledge. Belenkey et al. (1986) described procedural knowing as being either separate or connected. Separate Knowers approach the acquisition of knowledge through an objective, critical approach that is primarily oriented towards validity. Because of this objective approach, Separate Knowing has implications for education of the hard sciences and, in particular, mathematics. Connected Knowers, on the other hand, are primarily interested in understanding concepts, often through other people’s ideas. Constructed

Knowing is the final perspective in which individuals view knowledge as complex and ambiguous. Knowledge is constructed and theories are viewed as models for approximating experiences. Of particular interest is that women's ways of knowing are connected to understandings of self (Belenky et al., 1986). A change in the understanding of self affects how women think about truth and knowledge.

Another developmental model which encompasses personal epistemology is Kitchener and King's Reflective Judgment Model (King & Kitchener, 2002). This model describes the development of reflective thinking in relationship to epistemic assumptions about the process of knowing and how knowing is acquired (King & Kitchener, 2002). The Reflective Judgment Model describes individuals' concepts of how to justify beliefs when faced with ill-structured problems. The model consists of seven stages within three periods: the prereflective period, the quasi-reflective period, and the reflective period. Similar to Perry and Belenky et al., King and Kitchener (2002) described individuals within the first period as believing that knowledge is gained through authority figures or firsthand observation rather than through evidence. Individuals within the prereflective period treat all problems as well-structured. Quasi-reflective thinkers view knowledge as containing elements of uncertainty and will use evidence to explain missing information. But they still view judgments as individualistic. Reflective thinkers believe that knowledge is actively constructed and evaluated in relationship to the context of the knowledge claims. King and Kitchener (2002) found that higher educational attainment correlated with higher stages of reflective judgment and that a strong linear relationship existed between age and stage from adolescence through adulthood.

Baxter Magolda's (2002) Epistemological Reflection Model also aligns with Perry's positions and Belenky et al.'s perspectives. This model, based on constructivism, describes individuals' views of knowledge within the context of their epistemic

assumptions and personal experiences. The model encompasses the nature, limits and certainty of knowledge. The role of gender is incorporated as well. The Epistemological Reflection Model is divided into two phases, the college phase and the postcollege phase, each with its own perspectives. The college phase has three perspectives: Absolute Knowing, Transitional Knowing and Independent Knowing. Similar to the early stage of Perry, Belenky, et al., and King and Kitchener, individuals from an Absolute Knowing perspective view knowledge as certain and rely on authorities to know the truth. Women tend to acquire knowledge through listening and recording information, whereas men are less passive and more actively involved in remembering material. Baxter Magolda (2002) associated this perspective with the first two years of college. In later college years, transitional Knowers begin to view knowledge as absolute in some areas but uncertain in other areas. Two patterns can emerge: interpersonal or impersonal. Women tend to use an interpersonal pattern by employing others as evidence to sort out uncertainty and by sharing their views with others. Men tend to use an impersonal pattern by using others to help them think and by focusing on the defense of their views. Within the third perspective, Independent Knowers view knowledge as uncertain. Primarily women use an interindividual pattern of recognizing others' views and, as a result, are more willing to change their own views. Independent Knowers using an individual pattern are more reluctant to change their own views. Baxter Magolda (2002) explained that this perspective does not become evident until after college as individuals become more independent. The postcollege phase is characterized by the Contextual Knowledge perspective. Contextual Knowers have multiple views and use criteria to determine choices. They use external cues to make these choices while searching for internal authority and developing an internal foundation for belief.

Primary developmental models show a progression from an objective, dualistic view of knowledge to viewing knowledge as less certain and, finally, to a view of knowledge that is contextual and actively constructed. Most developmental models apply to individuals within their first year of college and beyond. Some researchers find it unlikely that this progression actually begins at the first year of college (Chandler, Hallett, & Sokol, 2002; Hofer & Pintrich, 1997). It is more likely that individuals do have experiences beyond a dualistic perspective prior to college, suggesting that development occurs earlier in life. Hofer and Pintrich (1997) explained that this development may be a recursive process, possibly affected by new challenges or affective issues involving self, such as feelings of anxiety. Although education has been shown to be correlated with higher levels of epistemological development (King & Kitchener, 2002), it is possible that an authoritative environment which lacks opportunities for critical thinking may actually perpetuate dualistic thinking. As Baxter Magolda (2002) concluded, the development of epistemological assumptions is socially constructed and contextually bound.

Schommer-Aikins (2002) departed from the developmental approach to personal epistemology with the model the Epistemological Belief System. This model conceptualizes personal epistemology as a system of independent beliefs that include beliefs about the stability of knowledge, structure of knowledge, source of knowledge, speed of knowledge acquisition and the control of knowledge acquisition. Schommer-Aikins (2002) defined independent beliefs as individual beliefs that do not develop in synchrony. Beliefs were described as ranging on a continuum from naïve to sophisticated and are influenced by learning experiences from family, friends, formal education, and life. Furthermore, epistemological beliefs may relate to different aspects of comprehension and learning within the academic setting (Schommer, 1993). Schommer

(1990) argued that a naïve belief about the certainty of knowledge may lead an individual to make an absolute conclusion about something that is unresolved. Belief in fixed ability may be related to motivation and effort. That is, those who believe they do not have the innate ability to understand a concept will not put forth the effort to learn. Also, belief in simple knowledge is related to the interpretation and understanding of interrelated text. For example, Schommer's (1990) study of 86 junior college students revealed that students' belief in quick learning predicted oversimplified conclusions to previously read passages and poor performance on a mastery test. Students who believed in certain knowledge tended to write absolute conclusions to the passages. In another study, Schommer (1993) found that epistemological beliefs, particularly quick learning, predicted GPA among secondary school students.

In addition to Schommer's findings, there is a preponderance of research giving evidence that individuals' personal epistemology can affect comprehension and learning in the academic setting (Hofer & Pintrich, 1997; Muis, 2004; Schraw & Sinatra, 2004). Students with less sophisticated beliefs may affect academic performance indirectly by employing insufficient study strategies. For example, Braten and Stromso (2004) found that students who believed in quick learning were less likely to adopt mastery goals that pertain to an orientation towards learning. Kardash and Howell (2000) also found that belief in quick learning was related to the number of strategies used to develop awareness and recall of previously read text. Mason and Boscolo (2004) investigated a more direct effect of epistemological beliefs on academic performance. They found that students who believed in the legitimacy and evaluativity of different knowledge claims scored higher on open-ended questions than those with less advanced epistemological understanding.

Just as students' personal epistemology influences comprehension and learning, the academic setting and instructional contexts influence students' beliefs and the

strategies they use for learning (Muis, 2004). Academic settings and instructional contexts differ between disciplines. There is strong agreement among researchers that epistemological assumptions also differ between academic disciplines (Hofer, 2000; Kardash & Howell, 2000; Muis, 2004; Schommer-Aikins, 2002).

Domain Specificity

Much of the early work on the effects of personal epistemology on academic performance is domain general (Hofer, 2002). Domain within this context refers to an academic discipline. Hofer and Pintrich (1997) discussed that academic disciplines have different knowledge structures and epistemological assumptions which need to be considered. More recently, researchers have discussed and investigated the domain specificity of epistemological assumptions (Baxter Magolda, 2002; Clinchy, 2002; Hofer, 2000; Kardash & Howell, 2000; Schommer-Aikins, 2002). Clinchy (2002) discussed that students with an inclination towards the Received Knowing perspective gravitate towards the sciences and mathematics whereas students inclined towards Subjectivism gravitate towards the humanities. Within the Epistemological Reflection model, Transitional Knowers tend to view knowledge as certain in the areas of mathematics and science, but view knowledge as uncertain in areas such as humanities and social science (Baxter Magolda, 2002). Hofer (2000) also found that first year college students viewed knowledge in science as more certain than knowledge in psychology. Additionally, Hofer (2002) found that students used personal knowledge and firsthand experience to justify knowledge in psychology, whereas students used authority and expertise to justify knowledge and truth in science. Furthermore, Schommer-Aikins (2002) explained that independent beliefs may be a phenomenon occurring due to domain specificity.

Muis (2004) reviewed research of epistemological beliefs about mathematics including domain differences in epistemological beliefs, development of epistemological

beliefs, effects of epistemological beliefs on behavior, and changing epistemological beliefs. The majority of studies selected by Muis that examined differences in beliefs between students across domains supported a domain-specific hypothesis. For example, Schoenfeld (1989) found that students tended to believe firmly in native ability in mathematics as compared to English or social studies. Stodolsky and Glaessner (1991) also compared students' views about native ability between mathematics and social studies. More fifth grade students believed they could learn social studies on their own than those who believed they could learn math on their own. Similarly, Buehl and Alexander (2005) found that students tended to believe that knowledge in history is less certain than knowledge in mathematics. In general, Muis' (2004) literature assessment revealed that students' beliefs about mathematics were less likely to be advantageous to learning than their beliefs about other fields of study.

Beliefs about Mathematics

Personal epistemology with regard to mathematics education has historically been referred to as "beliefs" (Muis, 2004). Schoenfeld (1983) described mathematics beliefs as an individual's perspective towards approaching mathematics and mathematical tasks that transcend beyond the purely cognitive. Schoenfeld concluded, "... the tangible cognitive actions produced by our experimental subjects are often the result of consciously or unconsciously held beliefs about (a) the task at hand, (b) the social environment within which the task takes place, and (c) the individual problem-solver's perception of self and his or her relation to the task and the environment" (p. 330). McLeod (1992) also concluded that beliefs about mathematics as a discipline and individual beliefs about self as learners of mathematics extend beyond the domain of cognition. Furthermore, Cobb (1986) stated that beliefs are part of structures used to create meaning and establish goals, which shape "pure cognition".

Within the last ten years, researchers have often used the term, “epistemological beliefs” instead of “beliefs” (Braten & Stromso, 2004; Buehl & Alexander, 2005; Mason & Boscolo, 2004; Schommer-Aikins, 2004). The term, “epistemological beliefs” more readily associates beliefs with personal epistemology. Muis (2004) assessed the literature on epistemological beliefs about mathematics by reviewing studies that satisfied components of the definition of personal epistemology. These components include beliefs about the nature of knowledge in mathematics and the nature of knowing in mathematics as well as the acquisition of mathematics knowledge. To reiterate, the beliefs about the nature of knowledge in mathematics encompass beliefs about the certainty and simplicity of mathematical knowledge. Beliefs about the nature of knowing include the justification of mathematical knowledge and sources of knowledge in mathematics. Belief about the acquisition of mathematics knowledge refers specifically to the speed of acquisition of mathematical knowledge.

Included in a student’s view about mathematics is the perspective the individual holds about the usefulness of mathematics. The National Council of Teachers of Mathematics (NCTM, 1989) stated that the belief in the utility and value of mathematics is a goal teachers should have for students. Belief about the usefulness of mathematics is related to motivation and, consequently, mathematics achievement (Kloosterman & Stage, 1992; Schommer-Aikins et al., 2005).

Epistemological beliefs are formed within the context of the individual’s mathematical experiences (Cobb, 1986; Garofalo, 1989b). The National Council of Teachers of Mathematics (1989, p. 233) reported, “Teachers implicitly provide information and structure experiences that form the basis of students’ beliefs about mathematics”. If mathematics is taught in isolated pieces with a focus on memorization of facts, rules and mastery of algorithmic procedures, then an individual’s perspective of

mathematics will be that mathematics consists of a set of discrete facts, rules, and algorithmic procedures. Depending on the nature of the classroom environment, beliefs within the classroom may very well differ from beliefs about mathematics as applied to real-life situations or even as a discipline of creativity, problem solving and discovery (Schoenfeld, 1989). Beliefs can limit expectations and cognitive resources and, therefore, affect the goals and strategies individuals use when engaging in mathematical activity and, ultimately, their understanding of mathematics (De Corte et al., 2002; Mason, 2003; Schoenfeld, 1983). Beliefs that either hinder motivation or have a negative or no effect on students' understanding are considered non-advantageous to learning (Kloosterman & Stage, 1992; Muis, 2004).

Learning mathematics involves being able to understand mathematics as a complex subject with interrelated concepts that can be applied in a variety of meaningful situations. Beliefs that have a negative or no effect on students' understanding negate the assumptions about the nature of mathematics. Assumptions about the nature of mathematics extend beyond a set of distinct facts, rules, and procedures (Garofalo, 1989a; Schoenfeld, 1988). The ability to understand mathematics is akin to being able to "think mathematically". Schoenfeld (1988) stated, "...thinking mathematically consists not only of mastering various facts and procedures, but also in understanding connections among them; and thinking mathematically also consists of being able to apply one's formal mathematical knowledge flexibly and meaningfully in situations for which the mathematics is appropriate" (p. 164).

Beliefs have been described as ranging on a continuum, depending on the degree to which they influence learning outcomes (Muis, 2004; Schommer-Aikins, 2002). Various terminologies have been used to express beliefs on the low end or high end of the continuum as, accordingly, non-advantageous or advantageous to learning. For example,

Schommer-Aikins (2002) has described beliefs as ranging on a continuum from naïve to sophisticated. Schommer-Aikins described sophisticated beliefs as being associated with quality study strategies and better learning outcomes. Mtetwa and Garofalo(1989) used the term “healthy” to describe beliefs that promote conceptual understanding and “unhealthy” to describe beliefs that interfere with understanding. However, Mtetwa and Garofalo (1989) explained that all beliefs are valid within some context. Muis (2004) adopted the label “availing” for beliefs that contribute to learning and “nonavailing” for beliefs that have no influence or negatively affect learning. Muis (2004) specifically chose this label because it limits the interpretation of a value judgment and it more strongly associates beliefs with learning outcomes.

For purposes of this research, “availing” was used to describe beliefs about knowledge on the high end of the continuum. In alignment with the developmental models of Perry, Belenky et al., Kitchener and King, and Baxter Magolda, availing belief is belief in mathematical knowledge as evolving, complex, validated through multiple perspectives, or constructed in interaction with others. Availing beliefs also include belief that mathematical learning takes time or belief that mathematics is useful. The term, “nonavailing beliefs”, on the other hand, is used to express beliefs on the low end of the continuum. Nonavailing belief is belief that mathematical knowledge is absolute, an accumulation of discrete facts, validated through authority or oriented outside of self. Nonavailing beliefs also include belief in quick learning or the belief that mathematics is not useful.

Nonavailing Beliefs

Students at all levels hold beliefs that hinder understanding of mathematics (Kloosterman & Stage, 1992; Muis, 2004; Schoenfeld, 1988). Students who hold nonavailing beliefs about the nature of mathematical knowledge believe that mathematics

is based on facts, rules, formulas, and procedures (Frank, 1988; Garofalo, 1989a; McLeod, 1992; Mtetwa & Garofalo, 1989; Schoenfeld, 1989). Therefore, students believe that computation is the key rather than derivation, the form is as important as the content and word problems are irrelevant. They may also believe that mathematics is already known and unchanging and that the various components of mathematics are unrelated (Schoenfeld, 1989). Furthermore, students with nonavailing beliefs about the certainty and simplicity of mathematical knowledge believe that there is only one correct answer and that mathematics involves searching for that one answer (Frank, 1988; Mtetwa & Garofalo, 1989; Schoenfeld, 1988).

Nonavailing beliefs about the nature of knowing mathematics include beliefs in inherent ability and that only prodigious individuals are capable of discovering, creating, or understanding mathematics (Kloosterman & Stage, 1992; Mason, 2003; Schoenfeld, 1988). Additionally, the student is viewed as being passive and reliant on the teacher, and the teacher is viewed as active and telling; that is, telling in the sense that the teacher tells the student whether the answer is right or wrong (Cobb, 1986; Frank, 1988; McLeod, 1992; Spangler, 1992).

Belief in quick learning is also considered a nonavailing belief as opposed to the availing belief that problem solving and mathematical study takes time to understand. Students typically believe that mathematical problems should be solved within five to ten minutes (Kloosterman & Stage, 1992; Mason, 2003; Schoenfeld, 1988; Spangler, 1992). Moreover, nonavailing beliefs include the belief that formal mathematics is not useful to the task at hand or mathematics in general is not useful in daily life as a tool or as a skill to enter other fields (Schoenfeld, 1985; Schommer-Aikins et al., 2005). Specifically, Schoenfeld (1985) found that students believed formal mathematics, such as theorem proofs, had little to do with real thinking or problem solving.

Relationship between Epistemological Beliefs and Achievement

As stated previously, individuals' epistemological beliefs about mathematics within the context of their own academic experiences may indirectly or directly affect their mathematical performance. Nonavailing beliefs may limit cognitive resources and shape the ways individuals engage in mathematical activity which ultimately affects their achievement (Cobb, 1986). Silver (1985) discussed that cultural belief systems can influence memory, perception, and cognition. NCTM reported, "These beliefs exert a powerful influence on students' evaluation of their own ability, on their willingness to engage in mathematical tasks, and on their ultimate mathematical disposition" (1989, p. 233).

Ample research has revealed a negative relationship between nonavailing beliefs and mathematical performance (Muis, 2004). With respect to nonavailing beliefs about the nature of mathematical knowledge, Schoenfeld (1989) found that 10th grade geometry students tended to have higher grades if they were less likely to emphasize memorization. Additionally, students tended to have higher grades if they were less likely to believe that success depends on memorization or through step-by-step procedures. Szydlik's (2000) study of calculus students also revealed that those students who viewed calculus as a set of facts and procedures to be memorized tended to have an incomplete or contradictory understanding of the concept of limits. Garofalo (1989a) found that secondary school students who believed that almost all mathematics problems can be solved by the application of facts, rules, formulas, and procedures tended to approach mathematical tasks in a mechanical manner or by relying on memorization. Buehl and Alexander (2005) also found that undergraduate students who believed in the isolation and certainty of knowledge had lower levels of motivation and task performance. Additionally, Mason's (2003) study of secondary school students' beliefs about mathematics revealed

that those who believed in the importance of understanding concepts had higher achievement than those who did not believe in the importance of conceptual understanding.

Students' nonavailing beliefs about the nature of knowing might also affect mathematical performance. Szydlik (2000) discussed that students with external sources of conviction will not make sense of mathematical concepts. Garofalo's (1989a) study of secondary school students revealed that students who relied on authority for their mathematical knowledge never questioned what was taught to them and were reluctant to derive mathematical knowledge on their own. Buehl and Alexander (2005) also found that students who relied on authority as the main source of mathematical knowledge did not perform as well on mathematical tasks as those who were more self-reliant. Schommer-Aikins, et al. (2000) investigated middle school students' beliefs about mathematics and found a positive, predictive relationship between students' belief in gradual learning and GPA scores.

Similarly, belief in quick learning and belief that mathematics is not useful have been shown to have a negative relationship with achievement. Belief in the speed of knowledge acquisition influences the time students engage in problem solving and thus affects their performance (Schommer, 1990). The perception of mathematics' usefulness also affects student effort to learn math (Kloosterman & Cougan, 1994). Schommer-Aikins' et al., (2005) study of middle school students' beliefs about mathematics revealed a relationship between the two nonavailing beliefs of belief in quick learning and belief that mathematics is not useful. That is, students who believed in quick learning tended to believe that mathematics is not useful. Results also indicated that belief in quick learning was related to less time trying to solve problems, and students who believed that mathematics is not useful tended to be unsuccessful at problem solving.

Epistemological Beliefs, Gender, Age, and Ethnicity

Epistemological beliefs about mathematics are formed within the context of classroom experiences (Cobb, 1986; Garofalo, 1989a; Schoenfeld, 1989). Classroom experiences are shaped by the expectations of teachers, peers, and parents. For example, Wilkins (2003) found that secondary school students who believed their teachers and parents had high expectations for their success tended to have more positive attitudes toward mathematics and more positive beliefs about the usefulness of mathematics than do other students. There is a commonly held belief in North America that not everyone is capable of understanding mathematics (National Council of Teachers of Mathematics, 2000). Additionally, expectations are low for certain demographic groups within the population. Specifically, “Students who live in poverty, students who are not native speakers of English, students with disabilities, women, and many nonwhite students have traditionally been far more likely than their counterparts in other demographic groups to be the victims of low expectations” (NCTM, 2000, p. 12). Leedy’s et al. (2003) study of 4th, 6th, and 8th grade students with interest and aptitude in mathematics provides evidence of women experiencing low expectations in mathematics. Even within this select group, female students tended to view their mothers as having lower expectations for their success in mathematics.

Gender

Although there is extensive research investigating the relationship between gender and mathematical learning (Leder, 1992), research investigating epistemological beliefs, gender, and mathematical learning, particularly at the college level, is limited. As stated previously, Belenky et al. (1986) and Baxter Magolda’s (2002) epistemological models recognize that beliefs about knowledge and knowing may have aspects that differ

between men and women. Baxter Magolda's (1992) longitudinal study of approximately 100 college students revealed gender patterns in views of knowledge. Specifically, more women than men were relationship oriented in their views of knowledge. For example, within the transitional knowing phase, women tended to rely on a connection with others and the subject to help sort out opinions and they tended to focus on sharing views. In contrast, men were more inclined to defend their views rather than share their views.

With respect to mathematics, men and women both hold nonavailing beliefs about the nature of knowledge and the nature of knowing (Stage & Kloosterman, 1995). However, Stage and Kloosterman (1995) found that even though men and women in remedial college mathematics both hold nonavailing beliefs, beliefs influenced mathematics achievement more so for women than for men. Specifically, there was a stronger relationship for women than for men between final grade and belief in mathematics as more than a series of steps. On the other hand, the relationship between the level of secondary school mathematics and beliefs was stronger for men than for women as well as the relationship between the level of secondary school mathematics and achievement.

Mason's (2003) study of elementary grade children is another example of the correlation between beliefs and gender. Mason (2003) found that girls in the lower elementary grades were more likely to believe in the importance of understanding concepts than boys. Muralidhar's (2003) study of first year university students revealed that significantly more men than women viewed mathematics as a practical subject important to critical thinking and requiring perseverance. Muralidhar's study also revealed that more men than women wanted a "tough" teaching style. Several men specifically mentioned the need for male teachers. On the other hand, more women than men viewed mathematics as a challenging subject requiring familiarization with formulas

and symbols and dependent on good teaching. Also, more women than men wanted a teaching style that encourages understanding through support.

Fennema and Sherman (1977) investigated secondary school students' attitudes about mathematics and found that girls viewed mathematics as less useful than boys. Fennema and Sherman's (1978) study of middle school students' attitudes about mathematics had similar results. When gender differences were found in mathematics learning, both studies revealed significant differences between boys' and girls' attitudes about the usefulness of mathematics as well as other affective variables, such as mathematics confidence and attitude toward success. Wilkin's (2003) more recent study indicated that middle school girls still develop negative beliefs about the importance of mathematics at a faster rate than boys. However, by secondary school, boys develop increasingly more negative beliefs about the importance of mathematics.

As investigations continue into the differences between men's and women's ways of knowing and learning, it becomes clear that women's learning is complex, dynamic, and not easily understood (Hayes, 2001). Fennema (2000) and Hayes (2001) expressed in separate discussions the need to continue the study of women's learning. With respect to mathematical learning, Fennema stated, "... we need to develop new paradigms of research that will provide insight into why gender differences occur. In other words, gender as a critical variable must enter the mainstream of mathematics education research" (2000, p.16).

Age

Age also seems to be an important factor in epistemological development. King and Kitchener (1994) traced the epistemological development of eighty individuals ranging in age from 16 to 28 over a span of ten years. In this longitudinal study, the authors discovered a strong linear relationship between age and stage of development.

Most participants over the age of 25 and almost all of the participants by the time they are 36 years old were at stages 6 and 7, the stages of reflective thinking. Reflective thinkers believe that knowledge is actively constructed and situated within the context of the knowledge claims. In contrast, individuals at the age of 16 to 20 were predominantly in Stage 3, the pre-reflective period. At Stage 3, individuals begin to recognize knowledge as uncertain in some areas but do not recognize that uncertainty is an inherent part of the process of knowing. They still rely on authority or first hand observation as sources of evidence. Individuals age 21 to 25 were predominantly in Stages 4 and 5, labeled quasi-reflective thinking. In these stages, individuals recognize that in some areas knowledge will never be certain and that what is known is limited by the perspective of the knower, but they still view judgments as individualistic. King and Kitchener cautioned that individuals' progression through stages may be due to education rather than age. Baxter Magolda (1992) also concluded that a view of contextual knowledge is more apparent in the post-college years. Less clear is whether or not progression to the more advanced stages of epistemological development is due to educational attainment or maturity as a result of age and the accumulation of life experiences or a combination of both.

Schommer (1998) tested the relationship between age and beliefs with a sample of 400 adults. After controlling for educational level, age still predicted more availing beliefs about learning. When controlling for age, education level predicted more availing beliefs about knowledge. Schommer (1998) concluded age alone is insufficient for beliefs about knowledge to become more availing over time. Furthermore, beliefs about knowledge are less likely to advance without formal education.

With respect to epistemological beliefs and mathematics at the college level, most research does not differentiate between ages or between nontraditional age students and traditional age students. Yet, as of 1999, 39% of all postsecondary students were age 25

or older (National Center for Education Statistics, 2002). Also, the enrollment rate for those age 25 to 29 between 1970 and 2004 increased from 8% to 13% (National Center for Education Statistics, 2006). Adult learners, age 25 or older, who enter postsecondary education seeking a degree are less likely than younger students to attain a degree (National Center for Education Statistics, 2002). These students are most at risk of dropping out in their first year of study. The National Center for Education Statistics makes the point that adult learners may be at a disadvantage because they are of the same population that did not pursue a degree when they were younger, often times because they were underprepared academically. Adult learners may also be at a disadvantage due to a gap in time since last attending school or due to competing responsibilities of family and work.

Upon entry into college, a significant number of adult learners place into a developmental mathematics course (Fredrick et al., 1984; Johnson, 1996; Walker & Plata, 2000). Adult learners' low level placement is specific to mathematics but not to other subject areas. Fredrick, et al. (1984) discovered that while adult learners' scores were low for mathematics placement, adults scored significantly higher than younger students for the humanities. Adult learners tended to miss questions on the mathematics placement test associated with secondary school courses, such as geometry, advanced algebra or trigonometry. However, adult learners did well on questions related to basic operations. Frederick, et al. (1984) attributed the poor performance on secondary school related questions to lack of practice.

Developmental mathematics courses prepare students for entry level college mathematics. Poor performance in the developmental mathematics courses will increase the risk of failure for subsequent courses that are necessary to attain a degree (Johnson, 1996). Although adult learners appear to be at an initial disadvantage in college

mathematics, they tend to be successful in developmental as well as entry level mathematics courses (Johnson, 1996; Walker & Plata, 2000). Adult learners also seem to have greater satisfaction and appreciation for mathematics education than younger students (Miglietti & Strange, 1998; Stage & McCafferty, 1992). Miglietti and Strange (1998) compared underprepared adults, age 25 and older, with underprepared younger students. Results indicated that adult learners expressed a greater sense of accomplishment. Stage and McCafferty (1992) also determined that adult learners were significantly more likely than younger students to describe students in class as involved in the subject matter and to view the teacher as innovative.

Ethnicity

Similar to women, nonwhite students have also been victims of low expectations in mathematics education by teachers, peers, and parents (National Council of Teachers of Mathematics, 2000). Research exploring the relationship between race/ethnicity and epistemological beliefs about mathematics is basically nonexistent. There is ample research of the relationship between race/ethnicity and mathematics achievement (Secada, 1992). However, this relationship is often complicated by other variables correlated with ethnicity, such as poverty and family structure. Secada (1992) discussed that race and ethnicity have conceptual cores, but they are socially constructed. Achievement should be viewed as a function of social demographic characteristics. Achievement disparities based on race/ethnicity group membership are apparent across mathematical content areas and skill levels, and achievement disparities increase over time.

The concept of ability is frequently operationalized as achievement (Kilpatrick & Silver, 2000; Secada, 1992). As a result of achievement disparities, students have often been sorted into groups according to ability in elementary and secondary school. Low

ability groups have a significantly high number of African-Americans, Hispanics, and students with low socio-economic status (SES) compared to Whites, Asian Americans, and students from middle to upper-SES backgrounds. Kilpatrick and Silver (2000) questioned the concept of ability. “As research over the last half century has shown, children said to lack ability may instead lack appropriate opportunities to learn or the support necessary to assist them in meeting learning expectations” (p. 224). Kilpatrick and Silver (2000) also criticized sorting students into groups according to ability, stating that the assessment of ability is difficult and subject to error. For example, assessment of ability based on the achievement or accuracy of problem solving in ten minutes or less will yield different results than when problems are made meaningful and the solutions matter. Secada (1992) criticized ability-based grouping as well, stating that low ability groups receive lower quality education. Students in low ability groups tend to have less content coverage and more often engage in small, repetitive, meaningless tasks. Teachers of low ability groups focus more on classroom management than on academic tasks.

Students grouped as low ability are often placed in a nonacademic track in secondary school (Secada, 1992). These students are not encouraged to take advanced mathematics. One powerful predictor of enrollment in a four year institution and student achievement in mathematics at the college level is the taking of advanced coursework at the secondary school level (Secada, 1992; The National Center for Education Statistics, 2001). The statistics reported by NCES for 1992 high school graduates is enlightening (The National Center for Education Statistics, 2001). Seventy-six percent of high school graduates who had taken a mathematics course beyond algebra II enrolled in a four- year institution by 1994. This is compared to only 44% for students who did not go beyond algebra II and to 16% for those who only took algebra and geometry. For those students with no math or low-level or nonacademic math, only 6% enrolled in a four-year

institution by 1994. High school mathematics course-taking is also strongly related to parents' education (The National Center for Education Statistics, 2001). Parents who are more educated are more likely to have taken more mathematics and are more likely to recognize the importance of mathematics for future success (Wilkins, 2003). Wilkins' (2003) study of students in grades 7 through 11 revealed students had more positive feelings about the usefulness of mathematics throughout secondary school if they perceived their parents to also have positive feelings about the usefulness of mathematics. High school graduates whose parents did not go to college were less likely to be academically prepared for admission to a four-year college. These graduates were more likely to be African-American or Hispanic and to be from families in the lowest income quartiles.

Analyses of students' initial years of college reveal a relationship between students' ethnicity and their performance in entry level mathematics (Penny & White, 1998; Walker & Plata, 2000). Within a large sample of 1,475 students who had completed a developmental mathematics course and went on to take College Algebra, being African-American or Hispanic predicted poorer performance (Penny & White, 1998). Penny and White (1998) acknowledged that these results could have been due to lower teacher expectations and enrollment in lower-level mathematics courses in high school. Walker and Plata (2000) also found a significant relationship between ethnicity and achievement. The sample consisted of 500 students enrolled in an accredited four-year university and lacking basic algebra skills. A significantly higher number of African-American students than Anglo students chose to take the basic algebra placement test, but due to poor performance, were required to take the computation mathematics test. Walker and Plata (2000) concluded that African-American students may have overestimated their mathematics skills. Within the same study, African-Americans earned

fewer As and more Cs and Ds than expected in fundamental mathematics and intermediate algebra and more than the expected number of African-Americans failed elementary Algebra.

Students who are poor and an ethnic minority have been characterized as having low mathematics achievement, unwilling to take more advanced secondary school mathematics courses, and disengaged from tasks within the mathematics classroom. Secada (1992) concluded that these characteristics are logical outcomes of a mathematics education that is “full of trivial facts, structured in ways that have little to do with how real people actually learn and perform mathematics, and out of touch with the mathematics people will need to live and function in our society” (p. 654). Assuming that epistemological beliefs are developed and situated within the context of school experiences, than the existence of a relationship between ethnicity and beliefs about mathematical knowledge seems likely. Hofer and Pintrich (1997) discussed that existing theory is based on findings from a mainly White, well-educated U.S. population. They further concluded, “It may be that thinking of gender and ethnicity as different contexts of development, just as different cultures provide different contexts, would be more beneficial for recent efforts” (p. 129).

The personal characteristics of gender, ethnicity, and age influence academic experiences which form the context for epistemological beliefs (Cobb, 1986; Garofalo, 1989a; Marsh & Shavelson, 1985; National Council of Teachers of Mathematics, 2000; Schoenfeld, 1989; Wilkins, 2003). The effect is recursive since the epistemological beliefs held by students will influence their academic experiences (Buehl & Alexander, 2005; Garofalo, 1989a; Mason & Boscolo, 2004; Schoenfeld, 1989; Szydlik, 2000). Students’ academic experiences are further influenced by beliefs about themselves as learners of mathematics.

Beliefs about Self as Part of the Belief System

A complete belief system about mathematics includes beliefs about the nature of knowledge in mathematics and the nature of knowing in mathematics as well as beliefs about self (Kloosterman et al., 1996; McLeod, 1985; McLeod, 1992; Schoenfeld, 1983; Schoenfeld, 1989; Silver, 1985). McLeod (1992) described beliefs as a subset of the affective domain in mathematics education. Other subsets in the affective domain are attitudes and emotions. Beliefs are more cognitive in nature than attitudes and emotions and develop over a longer period of time. Beliefs, according to McLeod, include beliefs about mathematics, self, mathematics teaching, and social context. Similarly, Schoenfeld (1983) described knowledge, belief, and value systems (KBS) as a meta-cognitive construct that includes beliefs about self, facts and procedures, task, and the environment. De Corte et al. (2002) also discussed a categorization of mathematical beliefs that include beliefs about mathematics education, self in relation to mathematics, and the social context in relation to mathematical learning.

Beliefs about mathematics, mathematics teaching, and the social context have already been discussed in previous paragraphs as epistemological beliefs. For instance, “mathematics is based on rules” is an example of beliefs about mathematics (McLeod, 1992). “Teaching is telling” is an example of beliefs about mathematics teaching. Finally, “mathematics learning is memorizing” is an example of beliefs about the social context (De Corte et al., 2002). Beliefs about self are the beliefs individuals hold about their own competence (Schunk & Pajares, 2005). As part of the same belief system, beliefs about self are characteristically similar to other beliefs in that they are slow to change and more cognitive in nature than attitudes and emotions. However, beliefs about self are also characteristically distinct from the epistemological beliefs of mathematics as a discipline. In contrast to beliefs about mathematics as a discipline, examples of beliefs about self are

written in the first-person, such as “I am able to solve problems” (McLeod, 1992).

Individuals’ views of their own competence directly determine their emotions during problem solving. As such, beliefs about self are more strongly associated with achievement motivation and have been specifically labeled as motivational beliefs (De Corte et al., 2002).

Investigations exploring beliefs have not always clearly distinguished between beliefs about self and other types of beliefs (Kloosterman & Stage, 1992; Mason, 2003; Schommer-Aikins et al., 2005; Stage & Kloosterman, 1995). For example, Kloosterman and Stage (1992) developed the Indiana Mathematics Belief Scales, which consisted of five subscales that measured individuals’ beliefs about mathematics problem solving. One subscale, labeled “Difficult Problems”, measured an individual’s perceived ability to solve time-consuming mathematics problems. According to Kloosterman and Stage, this subscale measured beliefs about the individual as a learner of mathematics. It appeared to incorporate both a belief about self and an epistemological belief about the nature of mathematics. To further clarify, some students believe that mathematics problems should not take a long time to solve (Schoenfeld, 1989). This is an epistemological belief about the nature of mathematics problems. A belief about one’s own ability to solve mathematical problems is clearly a belief about self. Stage and Kloosterman (1995) stated that the belief identified by the “Difficult Problems” subscale “...involves confidence in solving time-consuming mathematics problems. This belief is similar to mathematics self-confidence and perception of one’s ability in mathematics” (p. 296).

Similarly, Schommer (1990, 2005) developed a subscale for students’ belief in quick/fixed learning within the Epistemological Belief questionnaire (EB). One item of the middle-school version of the EB is, “If I cannot understand something quickly, it usually means I will never understand it” (Schommer-Aikins et al., 2005). Belief in quick

learning and belief in ability both seem to be integrated within this subscale. Hofer and Pintrich (1997) discussed that belief about quick learning, as defined by Schommer's questionnaire, may be related to ability and, as such, is a separate construct from the epistemological beliefs about the nature of knowledge. They further discussed that, although these beliefs may be correlated with each other, it is useful to keep them separate.

Due to the ambiguous distinction between beliefs about mathematics as a discipline and beliefs about self, the relationship between the two constructs and their shared effect on student behavior or performance is unclear. With respect to epistemological development in general, Belenkey et al. (1986) discussed beliefs about self as intrinsically linked to epistemological development. Belenkey et al. stated, "All knowledge is constructed, and the knower is an intimate part of the known" (p. 137). In other words, an understanding of self affects how individuals think about knowledge. As for the domain-specificity of mathematics, several researchers have discussed the need for exploring the relationship between epistemological beliefs about mathematics and beliefs about self (De Corte et al., 2002; McLeod, 1992; Schommer-Aikins et al., 2005). McLeod (1992) stated, "Future research on confidence needs to take into account the complete mosaic of mathematical beliefs, rather than just studying one such belief in isolation...Making sense of confidence as a variable in mathematics education will require a more complete picture of the affective domain than is presently found in most studies" (p. 584).

Researchers have consistently shown a direct relationship between measures of confidence and motivation and academic performance in mathematics (Kloosterman et al., 1996; McLeod, 1992; Reyes, 1984; Schoenfeld, 1983; Schoenfeld, 1985). Reyes (1984) discussed confidence in learning mathematics as one of the most important

affective variables. Confident students are more interested in pursuing mathematical ideas and learn more than students with less confidence. Schoenfeld (1983) also discussed that when students are confident in their ability to solve mathematical problems, their procedural knowledge is more accurate. In addition, there is a strong positive correlation between confidence in mathematical ability and expected mathematical performance (Schoenfeld, 1989).

Self-Efficacy and Self-Concept

Confidence has been studied under various constructs, such as self-efficacy, self-concept, and attribution theory. Each construct provided a different perspective from which to approach understanding of beliefs about self. Bandura (1997) defined perceived self-efficacy as "... a judgment of one's ability to organize and execute given types of performances" (p. 21). Self-efficacy refers to belief in one's ability to reach given levels of attainment within a specific situation and, therefore, is task specific (Pajares & Miller, 1995). Measures of self-efficacy are tailored to the task being assessed within a domain of functioning. For example, a self-efficacy judgment within an Algebra class might be one's expectation of doing well on an examination over the quadratic formula. It is not a personal judgment in one's competence of Algebra in general, but rather a judgment more specific to a task under a given circumstance.

Self-efficacy has strong predictive validity with academic performance and motivational goals (Mone et al., 1995; Pajares & Kranzler, 1995; Stevens et al., 2004). Mone et al. (1995) found that self-efficacy predicted personal goals and academic performance among students enrolled in an introductory mathematics class. Pajares and Kranzler (1995) analyzed responses from undergraduate students who completed the Mathematics Self-Efficacy Scale and concluded that measures of self-efficacy strongly predicted problem-solving performance. Students who were confident about being able to

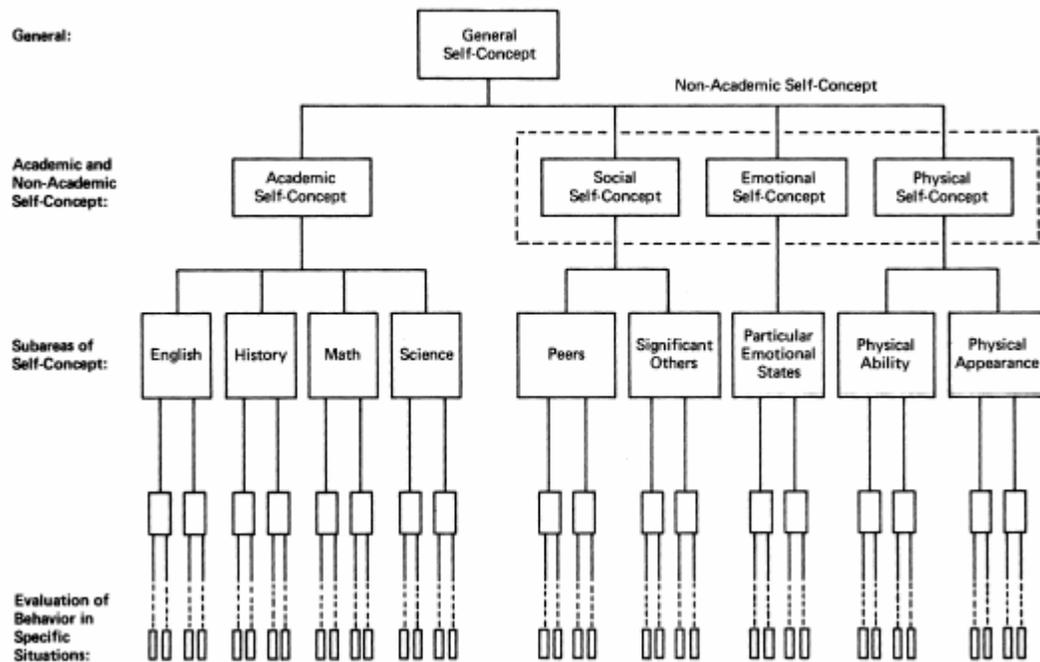
solve specific problems were more likely to solve the same or similar problems correctly than students who were less confident. Among secondary school Algebra students, Stevens et al. (2004) concluded mathematics self-efficacy predicted motivational orientation and mathematics achievement. Students' beliefs about their ability to successfully complete mathematics problems predicted their problem-solving performance even when beliefs did not match with actual ability or prior levels of achievement.

When discussing competence beliefs, authors have sometimes interchanged the terms, "self-efficacy" and "self-concept" (Seegers, Putten, & Vermeer, 2004). However, there are subtle conceptual distinctions between self-efficacy and self-concept (Bong, 2004). Academic self-concept is measured at the domain-specific level (academic subject or discipline), whereas self-efficacy is task-specific within a domain (Seegers & Boekaerts, 1996). Like self-efficacy, academic self-concept of ability is related to motivation and persistence as well as academic performance. Bong and Skaalvik (2003) suggested that self-concepts are created from individuals' past experiences in a particular domain and thus are past-oriented. On the other hand, self-efficacy beliefs represent individuals' views about completing forthcoming tasks and therefore are future-oriented. Bong and Skaalvik further stated that self-efficacy is a component of academic self-concept. Belief about academic ability is a common denominator between self-efficacy and self-concept.

Self-concept is defined as an individual's perceptions of self (Marsh & Shavelson, 1985). These perceptions are formed through experiences with the environment and are influenced by significant others. Shavelson, Hubner, and Stanton (1976) posited a model of self-concept that is multi-faceted and hierarchical (Figure 1). General self-concept, a global perception of self, is at the top of the hierarchy. Below general self-concept are the

discrete facets of academic self-concept and non-academic self-concept. Non-academic self-concept is comprised of the social, emotional and physical aspects of self-concept. Below academic self-concept are the domain-specific areas of self-concept, including English, history, mathematics, and science.

Figure 1
Hierarchical Structure of Self-Concept (Shavelson, Hubner, & Stanton, 1976)



Shavelson and Bolus (1982) found support for a multi-faceted and hierarchical structure of self-concept with a sample of 7th and 8th grade students. They concluded that a general, academic, and subject-matter model fit measures of self-concept better than competing models with fewer facets. Furthermore, math and science facets were correlated higher with each other than the English facet, suggesting that academic self-concept could be subdivided according to subject areas. Further support of the multi-faceted nature of self-concept is found in Marsh et al.'s (1984) study. Elementary students took the Self-Description Questionnaire (SDQ). An academic factor correlated

with reading and mathematics. The nonacademic factors of physical ability, appearance, peers, and parents correlated with each other. Marsh and O’Niell (1984) also found that self-concept was multi-faceted among secondary school girls. Results indicated that achievement measures were correlated with academic self-concepts, but not with nonacademic factors. The relationships were particularly strong for Math and Verbal self-concepts and specific to the subject area. The general self-concept factor was not correlated with any other factors, indicating that as individuals get older, facets become more distinct and the hierarchical structure begins to diminish. Marsh, Byrne, and Shavelson (1988) explored the relationship between two academic facets, verbal and math. Math self-concept was positively related to math achievement but negatively related to verbal achievement and unrelated to general school achievement. Verbal self-concept was positively related to verbal achievement, negatively related to math achievement, and also unrelated to general school achievement. General self-concept was unaffected by verbal, math, or school achievements.

Self-Concept and Mathematics Achievement

Reyes (1984) defined self-concept specific to mathematics as how sure an individual is of being able to learn new topics in mathematics and perform well in a mathematics class. “For each individual, mathematical power involves the development of personal self-confidence” (The National Council for Teachers of Mathematics, 1989, p. 7). NCTM (1989) discussed the goal to help students become confident in their personal ability so that they can trust in their own mathematical thinking. Silver (1985) also stated that an individual’s feelings of self-esteem have a powerful influence on the quality of engagement with mathematical tasks. Self-esteem is analogous to general self-concept (Schunk & Pajares, 2005). Researchers have frequently interchanged the terms “self-esteem” and “self-concept”.

Mathematics self-concept has a reciprocal effect with achievement (Guay et al., 2003). Prior self-concept influences subsequent achievement and prior achievement influences subsequent self-concept. The reciprocal effect of mathematics self-concept with performance is strongly supported in the literature. For example, House (2000) found that freshmen declaring a major in science, engineering, or mathematics with high self-concepts about mathematics achievement earned higher grades than those with lower self-concepts. Kloosterman et al. (1996) concluded that average or above average elementary students were confident in their abilities, whereas low achievers had low self-confidence. Wilkins (2004) analyzed data from the 2003 Trends in International Mathematics and Science Study (TIMSS). The sample consisted of 290,000 students from two adjacent grade levels containing the largest population of 13 year olds from 41 countries. Wilkins concluded that students with more positive self-concept had greater achievement and vice versa. Also, students' belief in their abilities to perform in mathematics and science declined as they moved from one grade level to the next. This decline was evident in most countries; however, the magnitude of the effect differed between the countries. Guay et al. (2003) studied the responses of Canadian children from ten elementary schools. Results supported the reciprocal-effects model. Prior self-concept affected subsequent achievement and prior achievement affected subsequent self-concept.

In addition to prior achievement, attribution style is a strong predictor of self-concept (Kloosterman, 1988). Attribution style refers to perceived causation of success or failure (Weiner, 2005). In a study with over 400 7th grade students, Kloosterman (1988) found that attribution style partly explained self-confidence in learning mathematics. Students with high self-confidence tended to attribute success to ability and failure to effort. Research on causal attributions related to mathematics learning has been quite

extensive within the last fifteen years (Lebedina-Manzoni, 2004; McLeod, 1992; Seegers et al., 2004; Weiner, 2005).

Attribution theory is the study of perceived causation (Powers et al., 1985). Weiner (1986) proposed a model that identified three dimensions of attributional patterns: locus (internal/external), stability (stable/unstable), and controllability (controllable/uncontrollable). Locus refers to the location of a cause (Weiner, 2005). Ability and effort are examples of internal causes of success. Chance and help from others are examples of external causes of success. Stability refers to the perceived duration of a cause. For example, math aptitude as a cause for success is perceived as constant. Chance, on the other hand, is unstable and temporary. Controllability is the degree to which a cause can be personally altered. Effort can be willfully changed, but luck and aptitude cannot. Locus and controllability influence the affective domain, including self-concept. Stability influences expectations for success. An individual has more positive self-concept when the outcomes are attributed to internal, stable, and controllable causes rather than external, unstable, and uncontrollable causes.

Attribution style is related to achievement. Successful students tend to attribute success or failure to self-characteristics, whereas unsuccessful students attribute success or failure to external characteristics (Lebedina-Manzoni, 2004). Lebedina-Manzoni (2004) found that 4th and 5th year successful students from the University of Zagreb attributed success to persistence, a will to gain knowledge, and being well-organized. They attributed failure to bad organization, tension and fear, giving up, lack of interest, or low self-confidence. Unsuccessful students attributed success to general knowledge, luck, current mood on the exam, determination, learning with interest, and parents. They attributed failure to uncertainty at choosing the subject of studying, fear, fantasy and

dreaming, boredom, current mood of professors, disorganization of faculty, overload with obligations, and boring lectures.

As stated previously, attribution style is related to self-concept. For example, Seegers et al. (2004) sampled students ages 11 and 12 from 27 primary schools in the Netherlands. Results indicated that attributing success to individual ability and failure to lack of effort promoted achievement motivation and estimated competence for the task. Attributing failure to lack of ability had the reverse effect. High correlation existed between self-concept of mathematics ability and subjective competence. Seegers et al. concluded that attributing failure to lack of ability would lead to a negative attitude toward learning and avoidance of effort. In Kloosterman's (1988) study of 7th graders, results indicated students high in confidence were likely to attribute success to ability and failure to effort.

Measures of Self-Confidence and Gender, Ethnicity, and Age

Perceptions of self are formed through experiences with the environment and are influenced by significant others (Marsh & Shavelson, 1985). Hyde and Durik (2005) stated, "Competence beliefs are shaped by not only people's past achievement experiences but also a variety of social and cultural factors, including (1) the behaviors and beliefs of important socializers, such as parents and teachers; and (2) cultural gender roles that prescribe certain qualities as appropriate or inappropriate for men or women, and gender stereotypes about particular activities" (p. 376). Similar to epistemological beliefs, beliefs about self are influenced by low expectations of others. Therefore, individuals who experience low expectations by teachers, parents, and peers are at greater risk for developing low self-concepts than individuals who do not experience these low expectations. Expectations for success in mathematics are often low for certain

demographic groups over other groups, including women and African-American and Hispanic minorities (National Council of Teachers of Mathematics, 2000).

Gender

A significant amount of research exploring the relationship between self-concept and gender indicates substantial differences in self-concept between men and women (Carmichael and Taylor, 2005; Fennema and Sherman, 1977; House, 2000; Leedy et al. 2003; Marsh et al., 1988; McLeod, 1992; Stage and Kloosterman, 1995). Women tend to be less confident in learning mathematics than men. Furthermore, competence beliefs affect mathematics achievement more so for women than for men. (Previous discussion indicated that epistemological beliefs also affect mathematics achievement more so for women than for men.) For example, Stage and Kloosterman (1995) sampled undergraduates enrolled in remedial algebra. Women who had more positive beliefs about their own ability were more likely to succeed than men holding similar beliefs. House (2000) also found that achievement expectancies for students majoring in science, engineering, or mathematics predicted grades for women, but not for men. Female students with high achievement expectancies tended to earn higher grades than those with lower achievement expectancies.

A gender gap in self-concept exists irrespective of ability. Carmichael and Taylor (2005) investigated confidence of university students enrolled in a preparatory mathematics program. Women reported lower levels of confidence even though their actual performance did not differ significantly from men's performance. Fennema and Sherman (1977) sampled secondary school students from four schools. They found that mathematics confidence was significantly higher in men than in women. Fennema and Sherman concluded that it is unlikely girls are less confident because of poorer achievement since there were more instances of gender-related differences in confidence

than in mathematics achievement. When there was a gender-related difference in achievement, there was always an associated gender-related difference in confidence, but not always vice versa. In a study with 11th and 12th grade Canadian students, Marsh et al. (1988) found that boys had higher math self-concepts than did girls but lower math achievements. Correcting math self-concepts for math achievements actually increased the gender differences in math self-concepts. Leedy, et al. (2003) found that even girls who were motivated and talented in mathematics had less confidence in their mathematics abilities than boys. Girls in grades 4 and 8 also viewed their mothers as having lower expectations for their success in mathematics. Additionally, Leedy et al. made an indirect connection between self-concept and epistemological beliefs. Mothers more frequently focused on the use of mathematics for computational tasks, whereas fathers more frequently discussed mathematics as being connected to problem solving and symbol manipulation.

Although research is limited, the gender gap in self-concept seems to increase with age (American Association of University Women, 1991). A survey of 300 children in grades 4 and 10 revealed that 60% of elementary girls and 67% of elementary boys are happy with themselves. This is compared to 29% of secondary school girls and 46% of secondary school boys. The influence of teachers on young women and their self-esteem is stronger for women than for men. This study also revealed that the percentage of students who like mathematics drops between elementary and secondary school, but the drop is more significant for girls. Students who like mathematics and science are more likely to aim for professional careers, and this impact is stronger for girls than for boys.

Research also indicates gender differences in self-concept at the college level (Carmichael and Taylor, 2005; Ramos, 1996; Royster et al., 1999). Carmichael and Taylor (2005) found that university women enrolled in a preparatory mathematics

program had lower levels of confidence than men also enrolled in the program. Ramos (1996) investigated responses of students from two private urban colleges. There were significantly fewer women who believed they were good in mathematics than men who held a similar belief. Royster et al. (1999) found that men enrolled in a college mathematics class had a significantly more positive disposition towards mathematics than women.

Gender differences in mathematics self-concept exist at the domain level as well as at the task-specific level (Bong, 1999; Marsh, 1989a; Meece et al., 2006; Seegers and Boekaerts, 1996). Meece et al. (2006) reviewed the research examining the role of motivation-related beliefs in mathematics and science. The authors concluded that girls had more confidence and interest in language arts and writing and boys had more confidence and interest in mathematics and science. Seegers and Boekaerts (1996) found that 8th grade boys in the Netherlands had more positive learning experiences than girls when they were confronted with a mathematics test. Boys had higher estimates of their capacity to do mathematics than girls. Differences remained after accounting for differences in performance. In a study exploring gender differences in self-concept across age groups, Marsh (1989a) found that boys had higher physical ability, appearance, and math self-concepts and girls tended to have higher verbal/reading and school self-concepts. This trend was consistent from preadolescence to young adulthood. Bong (1999) sampled students ranging in age from 15 to 21 from four Los Angeles high schools. Results indicated that both genders possessed strong subject-specific components in academic efficacy. Girls more clearly distinguished between their verbal and mathematics self-efficacy. Boys provided stronger self-efficacy judgments in U.S. history than did girls.

Men and women tend to interpret their own mathematics successes and failures differently (Assouline et al., 2006; McLeod, 1992; Tapasak, 1990). Assouline et al. (2006) investigated the attributional choices of over 4900 gifted students in grades 3 through 11. They found that for math and science, more girls than boys attributed success to effort and more boys than girls attributed success to ability. In a review of the literature, McLeod (1992) reported men were more likely to attribute their success to ability than women. Women were more likely to attribute their failure to lack of ability than men. In a study of 8th grade mathematics students, Tapasak (1990) found that girls tended to attribute effort rather than ability to success. Girls, more than boys, viewed their ability as the main cause of their mathematics failures. Similarly, Turner et al. (1998) found that female college students enrolled in introductory psychology classes attributed failure to uncontrollable factors, such as ability. Moreover, self-esteem was negatively correlated to reporting ability as important to success for women but not for men.

Ethnicity

Similar to women, nonwhite students are victims of low expectations in mathematics education by teachers, peers, and parents (National Council of Teachers of Mathematics, 2000). There is little research exploring the relationship between race/ethnicity and competence beliefs about mathematics. As stated in earlier discussion, ethnicity is a social construct. The study of ethnicity in relationship to achievement, or self-concept for that matter, is complicated since it is correlated with other variables, such as poverty and family structure (Secada, 1992).

Some research does indicate that ethnic identity is related to self-concept. A survey of 200 children in grades 4 and 10 revealed that African-American girls expressed higher levels of self-esteem from elementary school through secondary school than

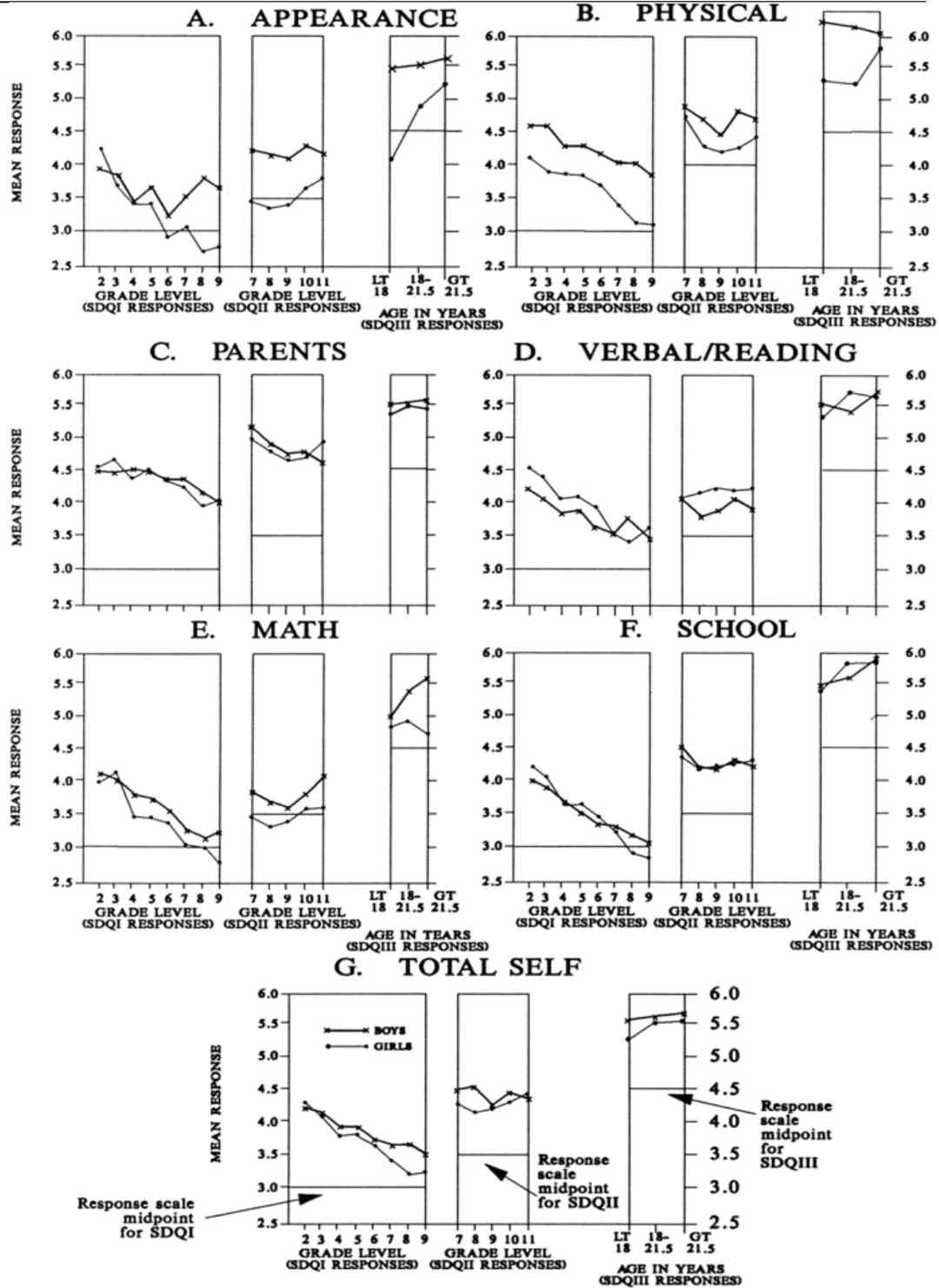
Caucasian girls (American Association of University Women, 1991). However, they experienced a significant drop in positive feelings about their teachers and their school work. Hispanic girls' personal self-esteem dropped more significantly than either Caucasian or African-American girls' self-esteem. O'Brien et al. (1999) sampled 11th grade parochial school students. Results indicated that ethnic identity significantly predicted mathematics self-efficacy. Ethnic identity was measured by the Multigroup Ethnic Identity Measure (MEIM), which consisted of statements related to positive ethnic attitudes and sense of belonging, ethnic identity achievement, and ethnic practices. MEIM was positively correlated with self-efficacy. In another study, Stevens et al. (2004) found that Hispanic 9th and 10th grade students reported significantly less confidence in their ability to successfully complete mathematics problems than Caucasian students. Bempechat et al. (1996) found a positive relationship across ethnic groups between achievement with attributing success to ability and not attributing failure to lack of ability. Indochinese students, however, attributed failure to lack of ability significantly more often than did Caucasians even though they outperformed Caucasian students. Bempechat et al. (1996) concluded that regardless of ethnicity, a positive self-concept is helpful in fostering achievement.

Age

The effect of age on self-concept, particularly for preadolescents, is well documented (AAUW, 1991; Guay et al., 2003; Marsh et al., 1984; Marsh and Shavelson, 1985). Marsh et al. (1984) surveyed students in grades two through five using the Self Description Questionnaire (SDQ). Results indicated facets become more distinct with age. The correlations among the facets differed significantly with grade. Marsh and Shavelson (1985) also discussed that as subjects grow older, levels of self-concept vary and facets of self-concept become more distinct. Furthermore, the hierarchical structure

of self-concept becomes weaker. Guay et al. (2003) analyzed responses of children in grades two through four. Results showed that as children grow older their academic self-concept becomes more reliable, more stable, and more strongly correlated with academic achievement. Research on the responses of three SDQ instruments from over 1,000 participants ranging in age from 13 to 48 revealed that there was a linear decline in self-concept during preadolescent years that continued into early adolescent years (Marsh, 1989a). Marsh (1989a) found that self-concept declined between grades seven and nine, leveled out, and then increased in secondary school years. These results were consistent for boys and girls and across different dimensions of self-concept. Figure 2 below displays the age and sex effects from this study for six self-concept scales and for total scores. With the exception of the Appearance self-concept, results did not indicate significant gender and age interactions. These results do not support the AAUW (1991) study which found that the gender gap in self-concept increased in age from elementary school to secondary school. Marsh (1989a) did not discuss gender and age interaction beyond young adulthood. It appears from Figure 2 that the gender gap for Math self-concept increases dramatically from young adulthood to adults age 21 and older.

Figure 2
 Age and Sex Effects for the Six Self-Concept Scales Common to the three SDQ
 Instruments (H. W. Marsh, 1989a)



The gender gap for math self-concept in adult learners may be related to differences in attribution styles. Elliott (1990) investigated the attribution styles of traditional and nontraditional age students enrolled in basic algebra classes from seven universities in Maine. Nontraditional female students tended to attribute success to luck. Attribution of success to luck negatively predicted future mathematics learning. Nontraditional men tended to attribute failure to effort, which was a significant positive predictor for mathematics learning. There were no significant affective predictors for traditional female or male students. Schunk and Pajares (2005) stated, “People become increasingly aware of their differing domain-specific self-concepts as they grow older, and it is the self-views in discrete and specific areas of one’s life that are most likely to guide and inform behavior in those areas” (p. 88).

Considerations for Developmental Mathematics

Students enrolling in developmental mathematics courses are diverse with respect to gender, age, and ethnicity (American Mathematical Association of Two-Year Colleges, 1995). They include traditional full-time students who are recent high school graduates, but they may also fall into one or more of the following categories.

They:

- Are older,
- Work a full- or part-time job while attending college,
- Manage a household,
- Are returning to college after an interruption in their education of several years,
- Intend to enter the work force after obtaining an associate degree,

- Intend to work towards bachelor's degree either at a transfer institution or in the upper division of their present four-year college or university,
- Are studying for a degree as a part-time student,
- Have English as a second language,
- Need formal developmental work in a variety of disciplines and in study skills,
- Have no family history in postsecondary education, or
- Have disabilities that require special accommodations.

All of these characteristics dramatically affect introductory college mathematics instruction (American Mathematical Association of Two-Year Colleges, 1995, p. 4).

The need for courses in developmental mathematics has increased. The Mathematical Association of America reports:

Higher education is situated at the intersection of two major crossroads: A growing societal need exists for a well-educated citizenry and for a workforce adequately prepared in the areas of mathematics, science, engineering, and technology while, at the same time, increasing numbers of academically underprepared students are seeking entrance to postsecondary education (American Mathematical Association of Two-Year Colleges, 1995, p. 3).

The primary goal of developmental mathematics education is to sufficiently improve the mathematics skills of underprepared students and, in so doing, provide opportunity for success in entry-level college mathematics (Penny & White, 1998).

Enrollment in remedial mathematics has steadily increased over the last two decades (National Science Board, 2006). In 2000, enrollment in remedial mathematics courses accounted for 60% of all mathematics enrollment in 2-year institutions, compared to 48% in 1980, and 14% of total mathematics enrollment at 4-year institutions. The 2002 annual freshmen norms survey, administered by the Higher Education Research Institute (HERI), indicated almost 25% of freshmen declaring a non- science and engineering

major reported a need for remediation in mathematics (National Science Board, 2004). Despite the rising participation in advanced course taking at the secondary school level, many college freshmen are still not ready for entry-level college mathematics and are in need of remedial assistance (National Science Board, 2006).

The Education Longitudinal Study of 2002 (ELS: 2002) provided national data on high school seniors' achievement in mathematics and expected educational attainment (Ingels, Planty, & Bozick, 2005). The longitudinal study assessed students at five levels: (1) simple arithmetical operations with whole numbers; (2) simple operations with decimals, fractions, powers, and roots; (3) simple problem solving requiring the understanding of low-level mathematical concepts; (4) understanding of intermediate-level mathematics concepts; and (5) complex multi-step word problems and/or advanced mathematics material. Summary of results are shown in Table 2. Almost two-thirds of seniors who expected to earn a four year college degree did not exhibit a mastery of level 4, understanding of intermediate-level mathematics concepts. One-third had not mastered level 3, simple problem solving requiring the understanding of low-level mathematical concepts. The longitudinal study revealed relationships between mathematics level and gender as well as between mathematics level and ethnicity. The gap between men and women demonstrating mastery of specific mathematics knowledge and skills widened, in favor of men, as mathematics levels increased. Similarly, the gap between Whites and minorities, including African Americans and Hispanics, widened, in favor of Whites, as mathematics levels increased.

Table 2
Percentage of High School Seniors Demonstrating Mastery of Specific Mathematics Knowledge and Skills, by Selected Student Characteristics: 2004 (National Science Board, 2004)

Characteristic	Level 1	Level 2	Level 3	Level 4	Level 5
Total	96.0	78.5	62.4	35.1	3.9
Sex					
Male	96.0	79.6	64.0	38.0	5.1
Female	96.1	77.5	60.74	32.3	2.7
Race/ethnicity					
American Indian or Alaska Native	94.5	66.8	42.9	16.1	1.0
Asian or Pacific Islander	97.7	86.1	73.5	49.6	10.9
Black or African American	92.3	59.1	35.8	12.0	0.5
Hispanic or Latino	92.8	64.7	42.7	18.3	1.1
More than one race	95.1	77.7	61.1	31.8	2.6
White	97.6	85.7	72.4	43.6	4.9

Developmental mathematics education at the college level can overcome a weak high school mathematics background (Stage & Kloosterman, 1995). Successful participation in developmental mathematics courses has a positive, direct effect on persistence and success in subsequent mathematics courses (Penny & White, 1998). Penny and White (1998) found that students' performance in their last developmental mathematics course was a strong predictor of their performance in college algebra. Similarly, Johnson (1996) found a positive relationship between a student's grade in developmental mathematics and performance in a subsequent entry-level mathematics course. Students' poor performance in exit-level developmental mathematics significantly increased the risk of failure or attrition in entry-level college mathematics (Johnson, 1996).

As previously discussed, affective considerations have a substantial influence on student performance in mathematics and, in particular, developmental mathematics. Smittle (2003) stated, "...successful developmental education programs for

underprepared students must deal with affective as well as cognitive needs” (p. 12). As evidence, Wheland et al. (2003) sampled over 2000 students enrolled in intermediate algebra at a metropolitan university. Students who performed poorly tended to have the following perceptions about their performance: (a) the non-native English speaking status of their instructor negatively affects performance, (b) instruction by teaching assistants over adjunct faculty negatively affects performance, (c) performance in intermediate algebra is not representative of performance in non-mathematics courses, (d) success in intermediate algebra is irrelevant to subsequent mathematics courses, and (e) attendance has no significant impact on course performance. In this study, these perceptions all proved false. Final exam performances were not significantly different between non-native English speaking instructors and native instructors. Teaching assistants gave more As and Bs than adjunct faculty. Students struggling in mathematics were having academic difficulties overall. Students who received a low grade in intermediate algebra stopped out of the subsequent mathematics course at a high rate. Finally, there was a significant positive relationship between attendance and grade earned. Beliefs about mathematics as a discipline and self as a learner of mathematics may very well have contributed to poor performance.

Summary

A review of the literature has included discussions of the theoretical understandings of personal epistemology and self-concept, both in general and within the domain-specific discipline of mathematics. Further discussion explored the relationships between epistemological beliefs and self-concept with mathematics performance. The influences of gender, age, and ethnicity on epistemological beliefs, self-concept, and mathematics performance were also explored. Points of the discussion are highlighted below.

Personal epistemology refers to the nature of knowledge and the nature of knowing (Hofer, 2004). Developmental models show a progression along a continuum from an objective, dualistic view of knowledge to viewing knowledge as less certain and, finally, to a view of knowledge that is contextual and actively constructed (Baxter Magolda, 1992; Belenky et al., 1986; King & Kitchener, 1994; Perry, 1970). Perspectives of knowledge and knowing may differ between men and women, and may be influenced by age. Individuals' personal epistemology can affect comprehension and learning in the academic setting and can be domain-specific (Hofer, 2000).

Personal epistemology with respect to mathematics is often referred to as "beliefs" or "epistemological beliefs" (Muis, 2004). Epistemological beliefs that have implications for mathematical learning include beliefs about the nature of mathematics as a discipline, the nature of knowing mathematics, the acquisition of mathematics knowledge, and the usefulness of mathematics. Epistemological beliefs are formed within the context of individuals' mathematical experiences (Cobb, 1986; Garofalo, 1989a; Schoenfeld, 1989). Nonavailing beliefs are beliefs that are nonadvantageous to mathematical learning (Muis, 2004). Nonavailing beliefs about mathematics include the following beliefs:

- Mathematics is based on facts, rules, and procedures.
- Mathematics is already known and unchanging and that the various components of mathematics are unrelated.
- There is only one correct answer and that mathematics involves searching for that one answer.
- Only prodigious individuals are capable of discovering, creating, or understanding mathematics.

- Mathematical problems should be solved within five to ten minutes.
- Formal mathematics is not useful to the task at hand or in daily life as a tool or as a skill to enter other fields.

Nonavailing beliefs about mathematics have been shown to negatively affect mathematical performance, either directly or indirectly (Buehl & Alexander, 2005; Mason & Boscolo, 2004; Schoenfeld, 1989; Szydlik, 2000). Furthermore, epistemological beliefs about mathematics are formed within the context of individual academic experiences. Academic experiences are shaped by characteristics of gender, age, and ethnicity (National Council of Teachers of Mathematics, 2000; Wilkins, 2003). Research exploring the relationship between epistemological beliefs about mathematics and mathematics achievement at the college level is limited, especially with respect to the influences of gender, age, and ethnicity.

Epistemological beliefs are part of a wider belief system, which includes beliefs about self (Kloosterman et al., 1996; McLeod, 1985; McLeod, 1992; Schoenfeld, 1983; Schoenfeld, 1989; Silver, 1985). Beliefs about self are characteristically similar to epistemological beliefs in that they are slow to change and more cognitive in nature than affective factors, such as attitudes and emotions. However, beliefs about self differ from epistemological beliefs in that they are more strongly associated with achievement motivation. Investigations exploring beliefs have not always clearly distinguished between beliefs about self and other types of beliefs (Kloosterman & Stage, 1992; Mason, 2003; Schommer-Aikins et al., 2005; Stage & Kloosterman, 1995). Due to the ambiguous distinction between beliefs about mathematics as a discipline and beliefs about self, the relationship between the two constructs and their combined effect on student behavior or performance is unclear. Several researchers have discussed the need

for exploring the relationship between epistemological beliefs about mathematics and beliefs about self (De Corte et al., 2002; McLeod, 1992; Schommer-Aikins et al., 2005).

Researchers have consistently shown a direct relationship between measures of confidence in mathematical ability and academic performance in mathematics (Kloosterman et al., 1996; McLeod, 1992; Reyes, 1984; Schoenfeld, 1983; Schoenfeld, 1985). Confidence has been studied under various constructs, including self-efficacy, self-concept, and attribution theory. Academic self-concept is measured at the domain-specific level (academic subject or discipline), whereas self-efficacy is task-specific within a domain (Seegers & Boekaerts, 1996). Attribution style refers to perceived causation of success or failure and is a strong predictor of self-concept (Powers et al., 1985).

Perceptions about self are formed through experiences with the environment and are influenced by significant others (Marsh & Shavelson, 1985). As such, they are influenced by individual characteristics of gender, age, and ethnicity. Women tend to have lower self-concepts about mathematical ability than men (Marsh, 1989a; McLeod, 1992). This trend is most pervasive during preadolescent years. Facets of self-concept become more distinct as students age and more strongly affect academic achievement (Marsh & O'Niell, 1984). Further research is needed to explore the relationship of mathematics self-concept with mathematics achievement at the college level and the influences of gender, age, and ethnicity.

The student population in developmental mathematics has increased over the last two decades and has become more diverse with respect to gender, age, ethnicity, family history, responsibilities, and personal goals (National Science Board, 2006). Students, underprepared for entry-level college mathematics, enroll in developmental mathematics to improve their mathematical knowledge and skills (Penny & White, 1998). They come

to the classroom with beliefs about mathematics as a discipline and beliefs about self as learners of mathematics that have been influenced by social and academic experiences. These beliefs may very well affect their performance in developmental mathematics and their success in subsequent mathematics courses.

Chapter 3

Methodology

Introduction

This chapter explains the methodology used in this research. The research questions are given followed by an overview of the research design. Details of the design are then discussed, including the participants in the study, the instrumentation, variables of interest, and the data collection procedures. Also discussed are the assumptions that guided this research and the data analysis procedures used.

Research Questions

The following research questions were used to guide this study:

1. What are the effects of epistemological beliefs about mathematics and mathematics self-concept on mathematics performance?
2. Are there significant differences in the effects of epistemological beliefs and self-concept on mathematics performance between men and women?
3. Are there significant differences in the effects of epistemological beliefs and self-concept on mathematics performance between adult learners and younger students?
4. Are there significant differences in the effects of epistemological beliefs and self-concept on mathematics performance between ethnic groups?
5. Are there significant interaction effects on mathematics performance between epistemological beliefs, self-concept, and the personal characteristics of gender, age, and ethnicity?

Research Design Overview

A quantitative study was used to investigate the research questions. Specifically, a survey methodology was employed to gather information on students' epistemological beliefs about mathematics and mathematics self-concept. In survey research, a sample of respondents from a population is selected and a standardized questionnaire is administered (Barribeau et al., 2005). Survey methods focus on answering specific questions and, therefore, are more target-oriented than most qualitative methods (Kratwohl, 1998). The following advantages of survey methods (Barribeau et al., 2005) were relevant to this research:

- Surveys are relatively inexpensive.
- Surveys are useful in describing the characteristics of a large population or sample.
- Many questions can be asked about a given topic, giving considerable flexibility to the analysis.
- There is flexibility at the creation phase in deciding how the questions will be administered.
- Standardized questions make measurement more precise by enforcing uniform definitions upon the participants.
- Standardization ensures that similar data can be collected by groups, than interpreted comparatively.
- By presenting all subjects with a standardized stimulus, observer subjectivity is greatly eliminated.

Participants

The population for this study consisted of all students enrolled in Intermediate Algebra in April 2006 and November 2006 at Wichita State University, Friends University, and Newman University. Wichita State University is an urban, state-supported school located in Wichita, the largest city in Kansas. It has an enrollment of more than 15,000 students. The average age of undergraduates is 24. Approximately half attend full-time. Newman University is a private, liberal arts Catholic university. It is also an urban school located in Wichita with an enrollment of more than 2,000 students. Friends University is a nondenominational Christian school, also located in Wichita. It has an enrollment of more than 3,000 students with more than 1,000 enrolled in traditional undergraduate programs. The intermediate algebra courses for the three institutions are similar according to their objectives (see Appendix I).

A total of 377 students were enrolled in Intermediate Algebra for the 2006 spring and fall semesters at all three institutions. A total of 159 students participated, most of whom were from Wichita State University (N=115). The number of students participating from Friends University (N=11) and Newman University (N=33) accurately reflected the enrollment in Intermediate Algebra at the time. There were several reasons for the differences in numbers between students who were enrolled and those who participated. Not all Wichita State University Intermediate Algebra instructors in the spring semester participated. However, all Wichita State University Intermediate Algebra instructors in the fall semester did participate. Students may also have withdrawn from the course, or may have been absent from the class on the days that the surveys were distributed. Even though students were given a choice as to whether or not to participate, all those in attendance participated. The sample was diverse with respect to gender, age, and

ethnicity. Of the students who participated, 60% were women (N=95), 30% were adult learners (N=47), and 37% were non-Caucasian (N=58).

Instrumentation

A survey questionnaire was designed to measure students' epistemological beliefs about mathematics and mathematics self-concept (see Appendix H). The Mathematics Belief Scales (MBS) was modified from three existing scales: the Indiana Mathematics Belief Scales as proposed by Kloosterman and Stage (1992), Fennema-Sherman's (1976) Usefulness of Mathematics scale, and the mathematics self-concept subscale from Herbert Marsh's (1989b) Self-Description Questionnaire III (see Appendix C).

The Indiana Mathematics Belief Scales (IMBS)

The Indiana Mathematics Belief Scales (IMBS) was modified to measure epistemological beliefs about mathematics. IMBS as described by Kloosterman and Stage (1992) consist of six subscales:

Scale	Measured Belief
Difficult Problems Steps	I can solve time-consuming mathematics problems. There are word problems that cannot be solved with simple, step-by-step procedures.
Understanding	Understanding concepts is important.
Word Problems	Word problems are important in mathematics.
Effort	Effort can increase mathematical ability.
Usefulness	Mathematics is useful in daily life.

The Difficult Problems and Effort scales measure beliefs about the individual as a learner of mathematics. The Understanding, Steps, and Word Problems scales measure beliefs about the discipline of mathematics. The Usefulness of Mathematics scale is a slightly reworded subset of the Fennema-Sherman Usefulness scale. The IMBS scales were developed using a Likert-type format of strongly agree, agree, uncertain, disagree, or

strongly disagree. Each scale had six items, three of which were written with positive wording and three of which were written with negative wording (see Appendix A).

The Indiana Mathematics Belief Scales (IMBS) was designed for use with students at the secondary school or college age level, but has also been used with middle school students (Schommer-Aikins et al., 2005). IMBS has been utilized in multiple studies, including two by Kloosterman and Stage (1992, 1995) and several more recent studies (Abdul Rahman, Ghazali, & Ismail, 2003; Benbow, 1993; Benbow, 1995; Mason, 2003; Schommer-Aikins et al., 2005). Results from studies using IMBS indicated that beliefs influence mathematics achievement. Stage and Kloosterman (1995) found that beliefs about mathematics were related to success in the classroom for women. Mason (2003) also found a predictive relationship between beliefs and grades. Specifically, “The more students believe in their ability to solve difficult problems, no memorized rules to follow, maths’ usefulness, and the importance of understanding a procedure and not only its memorization, the better their math grades” (p. 79). Schommer-Aikins’ (2005) results indicated that students’ perceptions about the usefulness of mathematics was related to mathematics achievement.

Stage and Kloosterman (1995) administered the Indiana Mathematics Belief Scales (IMBS) to 236 undergraduates enrolled in college remedial algebra. Results indicated that belief about the ability to do difficult problems was related to mathematics achievement, particularly for women. Similarly, the perception about mathematics as a series of steps was related to mathematics achievement for women. In Mason’s (2003) study of Italian high school students, the Difficult Problems scale, Steps scale, and Understanding scale positively contributed to mathematics grades. There was no relationship between Effort scale and Word Problems scale with mathematics grade.

Modified versions of the Difficult Problems, Steps, and Understanding scales were used in the Mathematics Belief Scales questionnaire for this research. Kloosterman and Stage (1992) tested the original scales for reliability on a sample of 517 college students. Cronbach's α was 0.77 for the Difficult Problems scale, 0.67 for the Steps scale, and 0.76 for the Understanding scale. The Difficult Problems scale was significantly correlated with the Understanding scale, but the correlation was relatively small at 0.23. Mason (2003) administered IMBS to 599 students from two high schools in Italy. Cronbach's α was 0.76 for the Difficult Problems scale, 0.59 for the Steps scale, and 0.72 for the Understanding scale. Inter-scale correlations indicated a significant correlation between the Understanding scale with the Difficult Problems scale and the Steps scale, but the correlations were both under 0.30.

The Usefulness Scale

Additionally, the Usefulness of Mathematics scale was used independently of the Indiana Mathematics Belief Scales in several studies (Elliott, 1990; Fennema & Sherman, 1978; Leedy et al., 2003). Fennema and Sherman (1978) found a predictive relationship in perceptions about the usefulness of mathematics and mathematics learning, as well as a relationship between perceptions about the usefulness of mathematics and gender.

The Usefulness of Mathematics scale, as described by Fennema and Sherman (1976), was "...designed to measure students' beliefs about the usefulness of mathematics currently, and in relationship to their future education, vocation, or other activities" (p. 326). Fennema and Sherman (1976) designed the scale with six positively stated and six negatively stated items. The response alternatives were: strongly agree, agree, undecided, disagree, or strongly disagree. The scale was administered to 589 students from four Madison, Wisconsin high schools. The subjects, in grades nine through twelve, were in college preparatory mathematics classes. The reliability score for

the Usefulness of Mathematics scale was 0.88. Also, the total score for the Usefulness of Mathematics scale was found to be significantly related to gender. Kloosterman and Stage (1992) used a slightly reworded subset of the Fennema-Sherman Usefulness of Mathematics scale and administered the revised version integrated within the Indiana Mathematics Belief Scales (IMBS) to 517 college students. A little more than half the sample was enrolled in remedial mathematics while the remainder was enrolled in an elementary mathematics methods course within the School of Education. The revised version consisted of three positively stated and three negatively stated items. The response alternatives were: strongly agree, agree, uncertain, disagree, or strongly disagree. The reliability estimate, Cronbach's α , was 0.86. The correlation of this scale with the other IMB scales was 0.48 ($p < 0.05$).

Validity was evidenced in this scale's prediction of students' mathematics achievement. Schommer-Aikins, et al. (2005) administered Kloosterman and Stage's revised version of the Usefulness of Mathematics scale to 1,269 middle school students. Cronbach's α was 0.80. Students who tended to believe mathematics is not useful were less likely to solve problems successfully. Mason (2003) utilized the revised version of the Usefulness of Mathematics scale with a sample of 599 students from two high schools in Italy. Cronbach's α for this study was 0.82. Mason found that the more students believed in the usefulness of mathematics, the better their mathematics grades.

Modifications to the Indiana Mathematics Belief Scales

Kloosterman and Stage (1992) explained that the Indiana Mathematics Belief Scales can be used independently of each other. Modified versions of the Difficult Problems, Steps, and Understanding scales were used in the Mathematics Belief Scales questionnaire for this research as well as Kloosterman and Stage's modified version of Fennema-Sherman's Usefulness of Mathematics scale (see Appendix B). Kloosterman

and Stage (1992) cautioned against using the “Word Problems” scale unless the term “word problems” could be carefully defined to the participants. In Kloosterman and Stage’s study, the Word Problems scale was not found to be as reliable as the other scales. Consequently, the “Word Problems” scale was not included in the questionnaire used in this research.

The Difficult Problems scale measures a construct similar to mathematics self-confidence (Stage & Kloosterman, 1995). However, an epistemological belief about the discipline of mathematics seems to also be incorporated in this scale. That is, belief about the ability to solve time-consuming mathematics problems is not separated from the belief about the length of time it should take to solve mathematics problems. Due to the ambiguity of this scale, the Difficult Problems scale was rewritten for this research to more clearly distinguish it as a belief about mathematics as a discipline rather than as a self-confidence measure. It has been relabeled as the Time scale.

The Understanding scale was also included in the questionnaire, but modified slightly. The item, “Time used to investigate why a solution to a math problem works is time well spent” measures a belief in part about the time it takes to solve a mathematics problem. Due to the possible correlation with the Time scale, this item was changed to “Investigating why a solution to a math problem works is as important as getting the correct answer”.

The Steps scale was modified so as not to contain the ambiguous term, “word problems”. The term, “math problems”, was used in place of the term, “word problems”. As with the Difficult Problems scale, the Effort scale is related to mathematical ability. To more clearly distinguish between epistemological beliefs about mathematics and mathematics self-concept, the Effort scale was not included. The Fennema-Sherman

Usefulness Scale as modified by Kloosterman and Stage (1992) was included in the questionnaire without further modification.

Self Description Questionnaire III (Mathematics Self-Concept Subscale)

Students' perceptions of their mathematical skills and reasoning ability were measured by the Mathematics Self-Concept subscale of Marsh's (1989) Self Description Questionnaire III (SDQ-III) (see Appendix C). SDQ- III is based upon the Shavelson (1982) model and was designed to measure self-concepts for late adolescents and adults. One item was slightly modified to be more appropriate for college students. The item, "At school, my friends always came to me for help in mathematics" was changed to "Others come to me for help in mathematics." SDQ-III has been extensively psychometrically validated in multiple studies (Byrne, 1988; Leach, Henson, Odom, & Cagle, 2006; Maggi, 2001; Marsh & O'Niell, 1984; Marsh, 1987; Marsh, 1989a; Marsh & Byrne, 1992; Marsh et al., 1988). In a study of 2,436 responses from Australian subjects, Marsh (1989a) found that mathematics self-concept was significantly related to gender, age, and student achievement.

Marsh (1989b) designed the Mathematics Self-Concept subscale with five positively worded items and five negatively worded items. The response alternatives were: definitely false, false, mostly false, more false than true, more true than false, mostly true, true, or definitely true. Marsh (1989b) tested the reliability of the Mathematics Self-Concept subscale of SDQ-III by measuring the internal consistency of the ten items. The SDQ-III instrument was completed by 1,093 Australian subjects between the ages of 13 and 48. Some subjects completed the SDQ-III more than once, yielding 2,436 sets of responses. The coefficient alpha estimate for the Mathematics Self-Concept subscale was 0.94. A correlation analysis also revealed that every individual item within the Mathematics scale is significantly and substantially correlated with the

other items within the Mathematics scale. Leach, et al. (2006) performed a reliability generalization study of SDQ-III. The SDQ-III reliability estimates of 19 studies provided relatively strong evidence of the instrument's ability to yield reliable scores.

Construct validity provides the empirical basis for the structure and dimensions of the SDQ-III. SDQ-III is based on the Shavelson model. Shavelson, et al. (1976) presented a multifaceted, hierarchical model of self-concept. The SDQ-III instrument includes items for 13 factors: academic (Mathematics, Verbal, General Academic, and Problem Solving), nonacademic (Physical Ability, Physical Appearance, Same Sex Peer Relations, Opposite Sex Peer Relations, Parent Relations, Spiritual Values/Religion, Honest/Trustworthiness, and Emotional Stability), and general (Esteem). Marsh (1989b) performed factor analysis on the 2,436 sets of responses to the SDQ-III. The results clearly identified each of the SDQ-III factors. Furthermore, the factor structure was found to be similar across sex and age.

Marsh (1989b) found strong support for the multidimensionality of self-concept and the content specificity of mathematics self-concept with the SDQ-III instrument. Academic achievement was more highly correlated with academic facets of self-concept than with General Esteem. Also, mathematics achievement was more highly correlated with mathematics self-concept than with other areas of self-concept. Marsh and O'Neill (1984) also found that self-concept was multifaceted among secondary school girls with the SDQ-III instrument. Results indicated that achievement measures were correlated with academic self-concepts, but not with nonacademic factors. The relationships were particularly strong for Math and Verbal self-concepts and specific to the subject area. The general self-concept factor was not correlated with any other factors, indicating that as individuals get older, facets become more distinct and the hierarchical structure begins to diminish. Marsh, Byrne, and Shavelson (1988) explored the relationship between two

academic facets, verbal and math, with SDQ III. Math self-concept was positively related to math achievement but negatively related to verbal achievement and unrelated to general school achievement. Verbal self-concept was positively related to verbal achievement, negatively related to math achievement, and also unrelated to general school achievement. General self-concept was unaffected by verbal, math, or school achievements.

The Mathematics Belief Scales Questionnaire

The Mathematics Belief Scales (MBS) questionnaire consisted of the following scales: Time, Steps, Understanding, Usefulness, and Self-Concept. The epistemological belief scales of Time, Steps, Understanding, and Usefulness each had six items, three of which were positively worded and three of which were negatively worded. The Self-Concept scale had ten items, five of which were positively worded and five of which were negatively worded. The same Likert-type format for IMBS was used for MBS. The response alternatives for each item of MBS were: (1) strongly agree, (2) agree, (3) not certain, (4) disagree, or (5) strongly disagree. The items for the scales were randomly distributed using a random number generator.

In addition to the scale items, the Mathematics Belief Scales questionnaire included five multiple choice questions in reference to grade expectations and perceptions about ability and effort. Since beliefs are formed within the context of academic experiences, these questions were added to provide a framework for students' current academic experiences. Seven open ended questions were also included to gain further understanding to responses of scale items. These seven questions asked students to comment on their beliefs about mathematics.

Variables of Interest

The dependent variable pursuant to the research questions was mathematics performance. It was measured by the percent correct on the final examination for Intermediate Algebra during the semester of enrollment. Since different institutions have different final exams, only Wichita State's final exam scores were used in analyses involving the dependent variable. Final exams (Appendixes J and K) also differed between semesters. However, the distribution of scores for Wichita State between the spring semester and the fall semester was not significantly different. Therefore, final exam scores for both semesters were used. The final exams were designed to assess students' mathematics performance with respect to the objectives of the course, as given in Appendix I. The sample size for those who took the exam, Wichita State only, was 109. This sample size differs slightly from those participants who took the survey (N=115) since some students did not take the final exam.

The independent variables were epistemological beliefs about mathematics, mathematics self-concept, and the demographic variables of gender, age, and ethnicity. All variables were shown in the literature to have significant direct or indirect effects on mathematics performance. Numerous studies indicated a positive relationship between availing epistemological beliefs about mathematics and mathematics performance (Buehl & Alexander, 2005; Cobb, 1986; Garofalo, 1989a; Kloosterman & Stage, 1992; Kloosterman & Cougan, 1994; Mason, 2003; Muis, 2004; Schoenfeld, 1989; Schommer, 1990; Schommer-Aikins et al., 2000; Schommer-Aikins et al., 2005; Silver, 1985; Szydlik, 2000). Similarly, a positive mathematics self-concept predicts better mathematics performance (Guay et al., 2003; House, 2000; Kloosterman, 1988; Kloosterman et al., 1996; Silver, 1985; Wilkins, 2004). Gender has been shown to be related to mathematics performance (Ingels et al., 2005), epistemological beliefs about

mathematics (Fennema & Sherman, 1977; Leder, 1992; Mason, 2003; Muralidhar, 2003; Stage & Kloosterman, 1995; Wilkins, 2003), and mathematics self-concept (American Association of University Women, 1991; Bong, 1999; Fennema & Sherman, 1977; House, 2000; Leedy, LaLonde, & Runk, 2003; H. W. Marsh, 1989a; Marsh et al., 1988; McLeod, 1992; Ramos, 1996; Royster et al., 1999; Seegers & Boekaerts, 1996; Stage & Kloosterman, 1995; Tapasak, 1990). Age is related to mathematics performance (Fredrick et al., 1984; Johnson, 1996; Walker & Plata, 2000), general epistemological beliefs and epistemological beliefs about mathematics (Baxter Magolda, 1992; King & Kitchener, 1994; Miglietti & Strange, 1998; Schommer, 1998; Stage & McCafferty, 1992) as well as mathematics self concept (Elliott, 1990; Guay et al., 2003; Marsh & O'Niell, 1984; Marsh & Shavelson, 1985; Marsh, 1989a; Schunk & Pajares, 2005). Ethnicity has also been shown to be related to mathematics performance (Ingels et al., 2005; Penny & White, 1998; Secada, 1992; Walker & Plata, 2000), epistemological beliefs about mathematics (Wilkins, 2003), and mathematics self-concept (American Association of University Women, 1991; Bempechat et al., 1996; O'Brien et al., 1999; Stevens et al., 2004).

The variable, epistemological beliefs about mathematics, was measured by the following scales of the Mathematics Belief Scales (MBS): Time, Steps, Understanding, and Usefulness. As described earlier, the Time, Steps, and Understanding scales were modified scales of the Indiana Mathematics Belief Scales (IMBS) (P. Kloosterman & Stage, 1992). The Usefulness scale was also a scale of IMBS, but was initially developed by Fennema and Sherman (1976) and modified slightly by Kloosterman and Stage (1992). The Time scale measured beliefs about the time it takes to solve mathematics problems. The Steps scale measured beliefs about the complexity of mathematics problems. The Understanding scale measured beliefs about the importance of

understanding concepts in mathematics. The Usefulness scale measured beliefs about the usefulness of mathematics in daily life. Mathematics self-concept was measured by the Mathematics Self-Concept subscale of the SDQ-III (Marsh, 1989b).

The demographic variables of gender, age, and ethnicity were self-reported by participants through a Personal Data Inventory sheet attached to the MBS questionnaire (see Appendix G). The Personal Data Inventory sheet differed slightly between the spring and fall semesters. Participants were asked to check the correct age category on the spring Personal Data Inventory Sheet according to the following age groupings: 18-21, 22-24, 25-30, 31-35, 36-40, 41-50, and over 51. In an effort to gather more precise data, participants were asked to give their actual age on the fall Personal Data Inventory Sheet. Additionally, the Interracial category was added to the categories of ethnic backgrounds on the fall Personal Data Inventory Sheet.

Data Collection Procedures

The institutional review boards for Wichita State University, Friends University, and Newman University approved the research project. Prior to administering the Mathematics Belief Scales questionnaire, departmental consent to conduct the research was received by each of the universities. Within the first month of each semester, instructors of the Intermediate Algebra classes were informed of the research project by telephone or email. A request was also made at this time for the instructors' assistance in the distribution of the surveys. Dr. Stephen Brady oversees instruction of Intermediate Algebra courses at Wichita State University. For the fall semester, Dr. Brady convened a meeting of all Intermediate Algebra instructors to inform them of the research and to ask for their cooperation. The surveys were distributed to the instructors several weeks prior to the date for the final examinations. Instructions accompanied each set of surveys (see Appendix E). A gift card to Borders book store was also enclosed as a gesture of

appreciation for their time and cooperation. The instructions requested instructors to distribute the surveys to students during class time within two weeks of the final examination date. Instructors were requested to pick a day that was convenient to them, but also was expected to have good attendance. The instructions included asking students to sign an informed consent page which stated that participation is voluntary and not related in any way to their course grade (see Appendix F). The informed consent page explained to students that responses to the questionnaire were anonymous. After signing the consent page, participating students completed a Personal Data Inventory sheet (Appendix G) and the MBS questionnaire (Appendix H). The time to complete the inventory sheet and the questionnaire took approximately 15 to 20 minutes. After the final examination was given, instructors posted the percent of problems that were correct on the Personal Data Inventory sheet and returned the completed forms to the main office for pick up.

Assumptions

The assumptions that guided this research were as follows:

- Mathematics is a complex subject with interrelated concepts that can be applied in a variety of meaningful situations. The nature of mathematics extends beyond a set of distinct facts, rules, and procedures.
- Students hold epistemological beliefs about the understanding of mathematics and mathematics as a discipline.
- Students have perceptions about their own mathematical skills and reasoning ability.
- Epistemological beliefs range on a continuum from nonavailing to availing.
- Self-concepts about mathematics range on a continuum from low to high.

- Students' scores on the final exam are an indication of mathematics performance.
- The participants in the study will answer the survey questions honestly.

Data Analysis Procedures

The statistical software package, SPSS, was used for all statistical analyses on the data set. Prior to analysis, scale items were recoded so that higher scores indicated a more positive response. Item scores within each scale were summed to give a total scale score. The data sets from the 2006 spring and fall semesters for all three institutions ($N=159$) were used to calculate the reliability estimates of the scales and to investigate the beliefs held by students. The data sets from the 2006 spring and fall semesters for WSU only ($N=109$) were used in any analyses involving the dependent variable, mathematics performance, as measured by the percent correct on the final exam. Descriptive statistics, including frequencies, measures of central tendency, and measures of variation, were used to analyze the diversity of the sample with respect to gender, age, and ethnicity and the distribution of percent correct on the final exam by demographic groups. The interaction effects of gender, age, and ethnicity with belief scale on mathematics performance were explored using analysis of variance techniques.

Correlation analysis measured the extent of the relationship between scale scores and percent correct on the final exam. A series of hierarchical regression analyses determined the predictive relationship between mathematics performance and selected significant independent variables as well as the interaction of independent variables. Variables for possible inclusion were scale scores for Understanding, Usefulness, and Self-Concept. Other possible variables were the demographic variables of gender, age, and ethnicity, and interaction variables, such as gender x age x self-concept.

Summary

A survey was designed to gather data on epistemological beliefs about mathematics and self-concept. The survey questionnaire consisted of a modified version of Kloosterman and Stage's (1992) Indiana Mathematics Belief Scales (IMBS), the Fennema-Sherman (1976) Usefulness Scale, and the Mathematics subscale of Marsh's (1989) Self-Description Questionnaire III. Modifications to the IMBS were made primarily to distinguish beliefs about mathematics as a discipline from beliefs about the ability to do well in mathematics. The three instruments were chosen due to their consistent use, reliability, and construct validity. The final survey instrument, the Mathematics Belief Scales, included four scales which measured epistemological beliefs about mathematics and one scale which measured mathematics self-concept. The four scales which measured epistemological beliefs about mathematics were labeled: Time, Steps, Understanding, and Usefulness.

The dependent variable, mathematics performance, was measured by the percent correct on the final exam for the Intermediate Algebra course. The independent variables included the demographic variables of gender, age, and ethnicity, epistemological beliefs about mathematics, and mathematics self-concept. Students provided the demographic data on a Personal Data Inventory sheet. The survey was used to gather data on the remaining variables.

Epistemological beliefs about mathematics included beliefs about the time it takes to solve mathematics problems, the complexity of mathematics problems, the importance of understanding mathematics, and the usefulness of mathematics. The scales used in the survey that measured these beliefs were, respectively, Time, Steps, Understanding, and Usefulness. The variable, mathematics self-concept, was measured by the Self-Concept scale.

Procedures for the study required that the surveys be distributed to students enrolled in Intermediate Algebra for the 2006 spring and fall semesters. The surveys were distributed during class time within two weeks of the final exam date. Students signed an informed consent sheet prior to completing the Personal Data Inventory sheet and the survey. Instructors provided the percent correct on the final exam for each student. Appropriate quantitative methods were used to analyze the responses, including descriptive statistics, correlation analysis, analysis of variance techniques, and hierarchical regression analysis.

Chapter 4

Results

Introduction

This chapter reports the findings of the research. An overview of the study is included followed by discussions of internal consistency reliability of the instrument, demographic characteristics of the population, and descriptions and summary statistics for the dependent and independent variables. Pursuant to the research questions, the variables influencing final performance are also discussed followed by regression analysis results. The common themes found in the survey responses of the qualitative questions are also reported.

Overview

This study investigated the relationship between college students' epistemological beliefs about mathematics and mathematics self-concept with mathematics performance. Survey methodology was used to gather information on students' epistemological beliefs about mathematics and mathematics self-concept. The Mathematics Belief Scales (MBS), as described in the previous chapter, was administered to students enrolled in Intermediate Algebra at Friends University, Newman University, and Wichita State University for the spring and fall semesters of 2006. Mathematics performance was measured by the percent correct on the Intermediate Algebra final examinations.

Internal Consistency Reliability Estimates

Responses to the items from all three institutions were analyzed using the reliability procedure from SPSS ($N=159$). Means, standard deviations, and internal reliabilities (Cronbach's α) of the total scale scores are shown in Table 3. The reliability estimates did not improve with the deletion of any single item. Cronbach's alphas for the

Understanding, Usefulness, and Self-Concept scales were very strong at .90 or above.

Cronbach's alphas for the Time scale and Steps scale were moderate to low compared to the other scales. These scales were reworded from the Difficult Problems scale and Steps scale of the Indiana Mathematics Belief Scales (IMBS). However, Cronbach's alphas for the Time scale and Steps scale of the Mathematics Belief Scales were higher than the Cronbach's alphas reported by Kloosterman and Stage (1992) and Mason (2003) for the Difficult Problems scales and the Steps scales of IMBS, respectively.

Table 3
Summary Statistics and Reliabilities (Cronbach's Alpha) for the Mathematics Belief Scales

Scale	N	Mean	S.D.	Cronbach's α
Time	153	22.16	4.28	0.79
Understanding	155	22.15	5.31	0.90
Steps	156	14.76	3.97	0.71
Usefulness	156	19.55	6.16	0.91
Self-Concept	156	26.12	8.85	0.90

Note. N is the number of cases excluding cases with missing data.

Table 4 gives the inter-scale correlations based on the total scale scores. One purpose for the modifications of the Indiana Mathematics Belief Scales was to distinguish belief about the time it takes to solve mathematics problems from a self-concept measure. The Time scale was significantly correlated with the Self-Concept scale ($p < .05$). However, the correlation was relatively small at less than .20. Steps and Usefulness were also correlated with Self-Concept, but the Steps scale had a relatively small correlation with Self-Concept as well. The Understanding scale was not significantly correlated with Self-Concept. All of the belief scales were significantly correlated with each other. For example, those that believed understanding concepts is important in mathematics also

believed that mathematics is useful and that it takes time to solve mathematics problems. One puzzling result was that the Steps scale was negatively correlated with the other belief scales. In other words, those that believed understanding concepts is important and that it takes time to solve math problems also believed that problems must be solved by remembering formulas or following step by step procedures. Therefore, there was a possible association between belief in the importance of formulas and procedures, the length of time it takes to learn formulas and procedures, and students' perceptions about what it means to understand math concepts.

Table 4
Inter-Scale Correlations

	Understanding	Steps	Usefulness	Self-Concept
Time	.716*	-.531*	.433*	-.195*
Understanding		-.511*	.561*	-.033
Steps			-.277*	.172*
Usefulness				.397*

Note. * Correlation is significant at the 0.05 level (2-tailed).

Population and Sample

Table 5 displays the total number of students by semester and university who were enrolled in the courses and who completed the surveys. Also displayed is the total number of students who took the final exams. There are several reasons for the differences between those who were enrolled in the courses and those who completed the surveys. Not all WSU intermediate algebra instructors in the spring semester participated. However, all WSU intermediate algebra instructors in the fall semester did participate. Students may also have withdrawn from the course, or may have been absent from the class on the days that the surveys were distributed. Even though students were not required to participate, all those in attendance participated.

Table 5			
<i>Population and Sample Sizes by Institution and Semester</i>			
University	Number of Students Enrolled	Number Who Completed the Surveys	Number Who Took the Final Exam
Spring 2006			
Wichita State	148	35	33
Friends	14	11	11
Newman	23	20	20
Spring Totals	185	66	64
Fall 2006			
Wichita State	172	80	76
Newman	20	13	11
Fall Totals	192	93	87
Spring and Fall 2006 Combined			
Wichita State	320	115	109
Friends	14	11	11
Newman	43	33	31
Grand Totals	377	159	151

Demographic Characteristics

On the Personal Data Inventory Sheet, students were asked to list their gender, age, and ethnicity. For age, participants were asked to check the correct age category on the spring Personal Data Inventory Sheet according to the following age groupings: 18-21, 22-24, 25-30, 31-35, 36-40, 41-50, and over 51. In an effort to gather more precise data, participants were asked to give their actual age on the fall Personal Data Inventory Sheet. Ethnicity was categorized as American Indian, Asian, Caucasian, Hispanic,

African-American, Interracial, and Other. The total spring and fall frequencies for each category within gender, age, and ethnicity are listed by institution in the tables below.

Table 6
Frequencies by Institution and Gender

	Wichita State	Friends	Newman	Total
Gender				
Men	43	7	14	64
Women	72	4	19	95
Totals	115	11	33	159

Table 7
Frequencies by Institution and Age

	Wichita State	Friends	Newman	Total
Age				
18-21	66	10	22	98
22-24	8	1	5	14
25-30	18	0	2	20
31-35	6	0	1	7
36-40	3	0	2	5
41-50	10	0	1	11
Over 50	4	0	0	4
Totals	115	11	33	159

Table 8
Frequencies by Institution and Ethnicity

	Wichita State	Friends	Newman	Total
Ethnicity				
American Indian	4	0	0	4
Asian	5	0	6	11
Caucasian	76	8	15	99
Hispanic	4	2	7	13
African-American	14	1	3	18
Interracial	5	0	0	5
Other	7	0	2	9
Totals	115	11	33	159

The literature often distinguishes the adult learner from traditional age students with a cut-off age of 25 (King and Kitchener, 1994; National Center for Education Statistics, 2006; Miglietti & Strange, 1998; F. K. Stage & McCafferty, 1992; Fredrick et al., 1984; Johnson, 1996; Walker & Plata, 2000). For example, in a study of epistemological development, King and Kitchener found that most participants 25 and older were in stages of reflective thinking. The numbers of traditional age students and adult learners are listed by gender and institution in Table 9. Adult learners were well represented in the sample. Approximately one-third of the total number of participants was adult learners.

Gender	Age	Newman	Friends	Wichita State	Combined
Men	18-24	14	7	28	49
	25 +	0	0	15	15
Women	18-24	13	4	46	63
	25 +	6	0	26	32
Totals	18-24	27	11	74	112
	25 +	6	0	41	47
Grand Totals		33	11	115	159

In addition to the Personal Data Inventory Sheet and the belief scales, participants were asked five questions about their grade expectations and effort in the course. Epistemological beliefs and self-concept are formed within the context of the individual's mathematical experiences (Cobb, 1986; Garofalo, 1989b). These questions were asked in an effort to understand students' perspectives of their current experiences with mathematics. The summary frequencies for each question are listed in the following tables.

As indicated in Table 10, most students, 91%, were confident that they would perform “C” work or better in the course.

Table 10

Frequencies for Survey Item 35

I expect the following grade for this course.	Frequency	Valid Percent
F	4	2.5
D	10	6.4
C	66	42.0
B	47	29.9
A	30	19.1
Total	157	100.0

Approximately 90% were confident that they would pass the final exam with a “C” grade or better.

Table 11

Frequencies for Survey Item 36

I expect the following grade on the final.	Frequency	Valid Percent
F	4	2.5
D	12	7.6
C	69	43.9
B	47	29.9
A	25	15.9
Total	157	100.0

Even though most students were confident they would pass the final exam, at least 30% of the students believed their personal mathematics ability was below average.

Table 12

Frequencies for Survey Item 37

Compared to other students in mathematics ability, I'm...	Frequency	Valid Percent
Top10%	16	10.3
Above average	19	12.2
Average	74	47.4
Below average	36	23.1
Bottom10%	11	7.1
Total	156	100.0

About half the students believed that their effort towards the course was average compared to other students. Approximately 27% rated themselves above average in effort while 23% rated themselves below average.

Table 13

Frequencies for Survey Item 38

Compared to how hard other students work at mathematics, I'm...	Frequency	Valid Percent
Top10%	13	8.3
Above average	30	19.1
Average	77	49.0
Below average	31	19.7
Bottom10%	6	3.8
Total	157	100.0

More than 70% of the students completed the homework only some of the time or less.

Table 14

Frequencies for Survey Item 39

During this semester, I've done the homework assigned to me...	Frequency	Valid Percent
Always	13	8.3
Most of the time	30	19.1
Some of the time	77	49.0
Almost never	31	19.7
Never	6	3.8
Total	157	100.0

The perspectives about students' current academic situation in Intermediate Algebra provided a framework for understanding students' beliefs and how these beliefs relate to mathematics performance. In general, students were confident that they would perform adequately in the course, yet many (30%) were not confident in their own ability and a majority did not complete all of the homework.

Dependent Variable

The dependent variable was mathematics performance as measured by the percent correct on the Intermediate Algebra final exam. Since different institutions have different final exams, only Wichita State's final exam scores were used in further analyses involving the dependent variable. Final exams also differed between semesters. However, the distribution of scores for Wichita State between the spring semester ($N = 33$, $M = .56$, $SD = .205$) and the fall semester ($N = 76$, $M = .58$, $SD = .197$) was not significantly different, $t(107) = -0.53$, $p = .600$ (two-tailed). The t-test revealed no significant differences in the means. Histograms also revealed similar shapes of the distributions

(Appendix L). Therefore, final exam scores for both semesters were used in further analyses ($N=109$).

Independent Variables

The independent variables were epistemological beliefs about mathematics, mathematics self-concept, and the demographic variables of gender, age, and ethnicity. Epistemological beliefs about mathematics were measured by the four belief scales of the Mathematics Belief Scales (MBS): Time, Understanding, Steps, and Usefulness. Mathematics self-concept was measured by the Self-Concept scale. Additionally, comments to five open-ended questions helped to gain understanding of responses to the scale items.

The summary statistics for each scale is given in Table 15. Each of the belief scales had six items on a scale of 1 to 5. A higher score indicated a more positive response. Total scale scores for individuals could range from 6 to 30, with those above 18 indicating a more positive response. The mean scale scores indicated that students generally had more positive beliefs about Time, Understanding, and Usefulness and less positive beliefs about Steps. In particular, students generally believed that understanding mathematics may take time, understanding concepts is important in mathematics, and mathematics is useful in daily life. Students generally did not believe that math problems can be solved with logic and reason instead of learned math rules. The Self-Concept scale had 10 items on a scale of 1 to 5. A higher score indicated a more positive response. Total scale scores ranged from 10 to 50, with those above 30 indicating a more positive response. The mean Self-Concept score indicated that students generally had a low Self-Concept about mathematics.

Table 15
Summary Statistics for Belief Scales and Self-Concept

Scale	N	Mean	Std. Deviation
Time	110	23.34	2.97
Understanding	112	23.49	3.59
Steps	112	13.78	3.37
Usefulness	112	20.20	6.05
Self-Concept	112	24.93	9.20

The following histograms also indicate that students generally had more positive beliefs about Time, Understanding, and Usefulness and less positive beliefs about Steps and Self-Concept.

Figure 3
Histogram of the Time Scale Scores

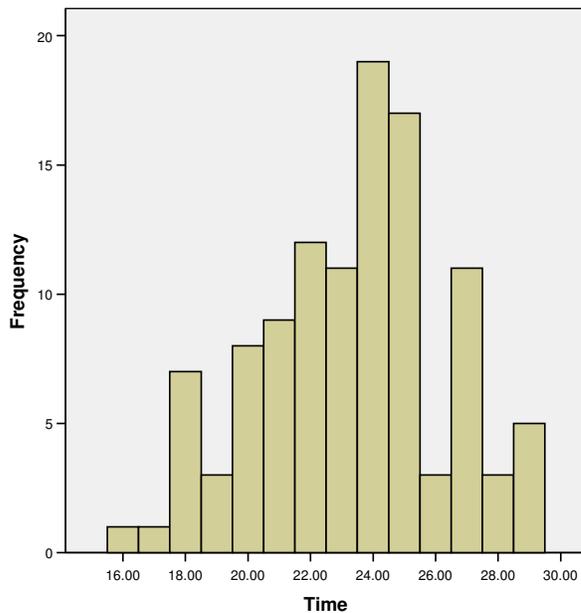


Figure 4
Histogram of the Understanding Scale Scores

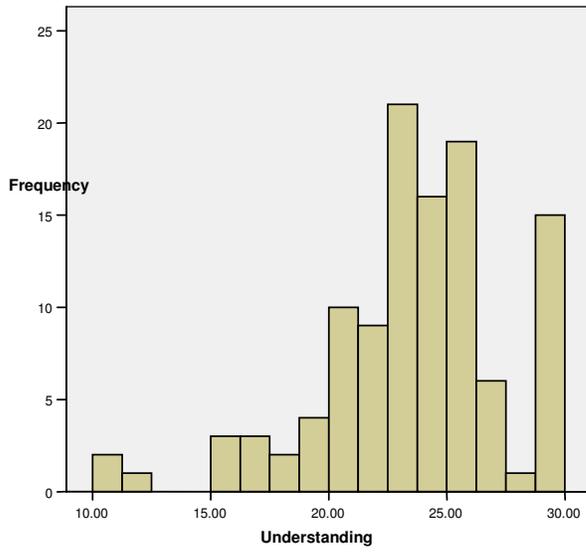


Figure 5
Histogram of the Steps Scale Scores

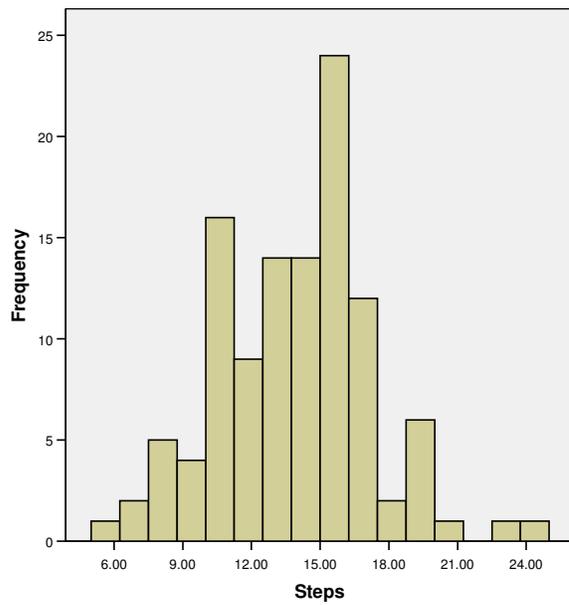


Figure 6
Histogram of the Usefulness Scale Scores

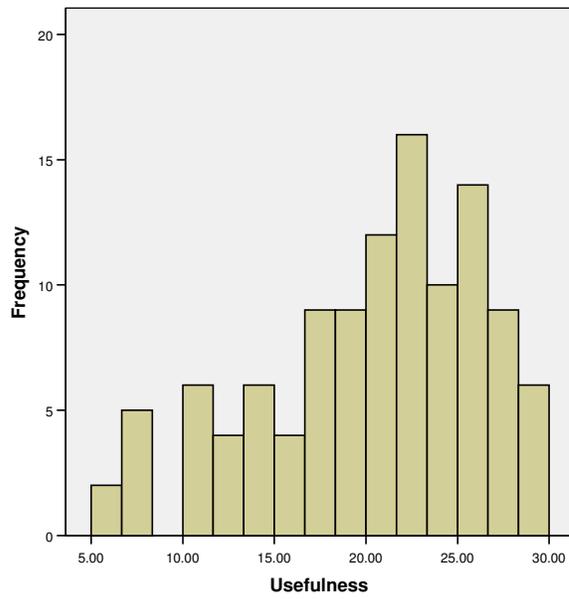
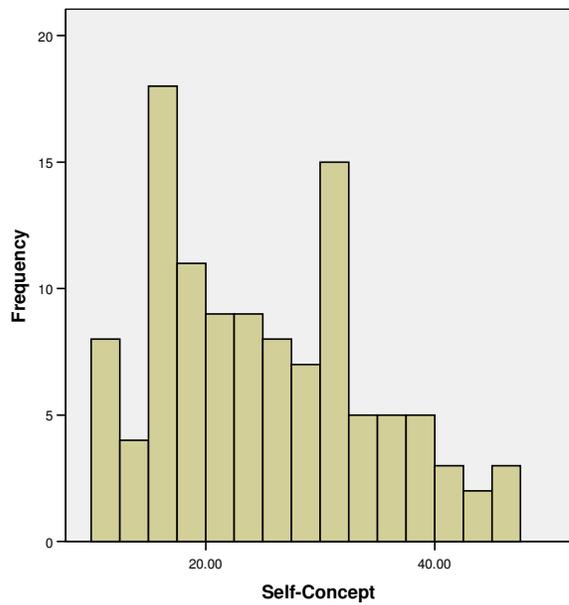


Figure 7
Histogram of the Self-Concept Scale Scores



Qualitative Responses

Seven open ended questions were included in the questionnaire to gain further understanding of responses to scale items. The questions asked students to comment about their beliefs about mathematics. Five of the questions were referenced to the four belief scales. With respect to Time, students were asked, “If you understand the material, how long should it take to solve a typical homework problem?” Approximately 60% of the 155 respondents believed that a typical problem should only take 2-3 minutes to solve. A few (3%) believed that it should take less than a minute. One student commented, “If I understand the concept of a math problem, it will take me less than 30 seconds to finish. The amount of time spent on one problem should take no longer than 4 minutes, because anytime thereafter, the problem only becomes more complicated”. Less than 20% judged that it should take more than 10 minutes. The remaining 17% thought that it depends on the type of problem. About one third of the students believed that a problem should take less than 15 minutes before it is considered impossible to solve.

In reference to the Understanding scale, students were asked, “How can you know whether you understand something in math?” and “What do you do to measure (test) yourself”? Almost one third of the 147 respondents believed that grades on homework or tests determine their understanding of math. Others considered that being able to remember steps or formulas or being able to work problems quickly is a determination of understanding. More than one third of the students, 37%, believed that they are understanding concepts when they are able to work independently or explain it to others. For example, one student commented, “I think you know when you understand something in math when you have the courage to apply it to problem solving factors in your personal life”.

There were two survey questions that can be referenced to the Steps scale. The first question asked, “Do you think that students can discover mathematics on their own, or does all mathematics have to be shown to them”? Of the 155 respondents, almost half (48%) believed that math must be taught or shown. One student very specifically stated, “Math is something that you understand after it has been taught to you”. Another student commented, “I think it has to be shown to them for the simple reason of no one thinks in terms of numbers”. Many students (27%) believed that math can be discovered or shown, depending on the individual’s intelligence and native ability. For example, one student stated, “This is entirely dependent on the student. Brilliant mathematicians came from somewhere, and the principles of mathematics were discovered by someone...so no, not all students need to be taught to discover”. The remaining students, for the most part, judged that mathematics can be discovered. For example, a student commented, “Of course they can, it’s just a matter of connecting early to the math that’s existing everywhere every day”. Students were also asked the question, “How important is memorizing in learning mathematics”? Most of the students (86%) considered memorization as very important in learning mathematics. Student comments included, “For the class, it’s important so you can pass” and “memorizing is important because there are a number of steps and formulas a person has to memorize to get to the correct answer”. Others believed that memorizing is not as important as understanding principles. A student commented, “It doesn’t seem quite so much like memorizing as understanding principles. If you don’t understand basic principles of mathematics, you will never understand what follows”.

With respect to the Usefulness scale, students were asked, “In what way, if any, is the math you’ve studied useful?” Of the 147 respondents, 44% said that math is not useful at all or that only basic math is useful in everyday life. A common response was

“It’s not” or “I have never used any of it”. One particularly negative comment was, “I think taking math courses not related to area of study is useless and a waste of time. It takes away time and energy needed to be spent on more degree related courses. I barely pass these math classes and will never ever use this information ever again for the rest of my life. I see it as a waste of time and source of much frustration”. Approximately 23% of the respondents believed math is only useful towards completing college requirements. For example, one student commented, “I have to pass College Algebra to get my degree, and I have to take this class to get to that class”. Only 22, or 15%, believe that math would be useful in a career and another 18% think that math is useful in developing problem solving skills, logic, and reasoning abilities. One student commented that mathematics “provides building blocks of reasoning and complex thinking that can be carried over to other situations”. Those that judged mathematics useful in developing personal skills, such as problem solving, tended to be adult learners.

The Interaction of Beliefs with Gender, Age, and Ethnicity

For each belief scale, individual t-tests determined the significance of differences in mean scores for groups defined by gender, age, and ethnicity. Data from all three institutions were used. With respect to gender, men and women’s epistemological beliefs about mathematics did not differ significantly. However, men’s self-concept was significantly higher than women’s self-concept at $\alpha = 0.05$. Summary statistics by scale and gender are listed in Table 16. The t-test results for each scale are given in Table 17.

Table 16

Summary Statistics for Belief Scales and Self-Concept by Gender

Scale	Gender	N	Mean	Std. Deviation	Std. Error Mean
Time	Male	63	21.87	4.35	0.55
	Female	90	22.37	4.24	0.45
Understanding	Male	62	22.13	5.42	0.69
	Female	93	22.17	5.27	0.55
Steps	Male	64	14.91	4.39	0.55
	Female	92	14.66	3.67	0.38
Usefulness	Male	63	19.37	6.01	0.76
	Female	93	19.68	6.28	0.65
Self-Concept	Male	62	28.34	8.36	1.06
	Female	94	24.65	8.90	0.92

Table 17

t-Tests for the Mean Differences in Mathematics Belief Scales between Men and Women

Scale	t	Df	Sig. (2-tailed)	Mean Difference	SE Difference
Time	-0.70	151	0.48	-0.49	0.70
Understanding	-0.05	153	0.96	-0.04	0.87
Steps	0.38	154	0.71	0.24	0.65
Usefulness	-0.31	154	0.76	-0.31	1.01
Self-Concept	2.60	154	0.01	3.69	1.42

As mentioned previously, the literature often distinguishes the adult learner from traditional age students with a cut-off age of 25 (King and Kitchener, 1994; National Center for Education Statistics, 2006; Miglietti & Strange, 1998; F. K. Stage & McCafferty, 1992; Fredrick et al., 1984; Johnson, 1996; Walker & Plata, 2000). For

example, in a study of epistemological development, King and Kitchener found that most participants 25 and older were in stages of reflective thinking. That is, they believed that knowledge is actively constructed and situated within the context of knowledge claims. For this study, then, adult learners were defined as 25 years of age or older. Traditional age students were defined as younger than 25. The group statistics of mean scores by the two age groups showed that adult learners had higher mean scores than traditional age students for Time, Understanding, Usefulness, and Self-Concept. The difference in mean scores between adult learners and traditional age students for Self-Concept was significant at the 5% significance level. Adult learners had more positive beliefs than traditional age students about their ability to do well in mathematics.

Scale	Age	N	Mean	Std. Deviation
Time	>= 25	58	22.52	4.35
	< 25	95	21.95	4.24
Understanding	>= 25	59	22.46	5.90
	< 25	96	21.97	4.94
Steps	>= 25	60	14.20	4.57
	< 25	96	15.11	3.52
Usefulness	>= 25	60	20.45	6.45
	< 25	96	18.99	5.93
Self-Concept	>= 25	59	28.19	9.17
	< 25	97	24.86	8.45

Table 19
t-Tests for the Mean Differences in Mathematics Belief Scales between Traditional Age Students and Adult Learners

Scale	t	df	Sig. (2-tailed)	Mean Difference	SE Difference
Time	0.80	151	0.43	0.57	0.71
Understanding	0.56	153	0.58	0.49	0.88
Steps	-1.40	154	0.16	-0.91	0.65
Usefulness	1.45	154	0.15	1.46	1.01
Self-Concept	2.31	154	0.02	3.33	1.44

Regarding ethnicity, mean score differences were compared with the categories that have the highest number of students: Caucasian (N=99) and African-American (N=18). Other categories had too few numbers for comparison. African-American students had higher mean scores than Caucasian students for the Time, Steps, Usefulness, and Self-Concept scales. There were no significant differences in the mean scores for any of the scales between Caucasian and African-American students.

Table 20

Summary Statistics for Belief Scales and Self-Concept by Ethnicity

Scale	Ethnicity	N	Mean	Std. Deviation
Time	Caucasian	97	22.39	3.54
	African-American	16	23.06	4.96
Understanding	Caucasian	97	22.85	4.29
	African-American	17	21.41	5.57
Steps	Caucasian	98	14.23	3.42
	African-American	17	15.24	4.72
Usefulness	Caucasian	97	19.44	6.30
	African-American	17	21.53	4.87
Self-Concept	Caucasian	99	25.85	9.15
	African-American	16	28.75	8.19

Table 21

t-Tests for the Mean Differences in Mathematics Belief Scales between Caucasians and African-Americans

Scale	t	Df	Sig. (2-tailed)	Mean Difference	SE Difference
Time	-0.66	111	.51	-0.67	1.02
Understanding	1.21	112	.23	1.43	1.18
Steps	-1.05	113	.30	-1.00	0.95
Usefulness	-1.30	112	.20	-2.09	1.61
Self-Concept	-1.91	113	.24	-2.90	2.43

Because there were significant differences in the mean Self-Concept scores for gender and age, analysis of variance was used to determine any interaction effects on Self-Concept by gender and age. Descriptive statistics and analysis of variance summaries are given in Table 22. Because cell sizes were unequal for all belief scales, the

Type III sum of squares were reported in the analysis of variance, as shown in Table 23.

As Table 23 indicates, there was no significant interaction effect on Self-Concept scores between gender and age.

Table 22

Mean Self-Concept Scores by Gender and Age

Age	Gender	Mean	Std. Deviation	N
less than 25	Men	27.75	7.62	48
	Women	24.14	8.99	63
	Total	25.70	8.58	111
25 or greater	Men	30.36	10.62	14
	Women	25.68	8.76	31
	Total	27.13	9.51	45
Total	Men	28.34	8.36	62
	Women	24.65	8.90	94
	Total	26.12	8.85	156

Table 23

Tests of Between Subject Effects for Self-Concept Against Age, Gender, and Age x Gender

Source	Type III SS	df	Mean Square	F	Sig.
Corrected Model	631.22	3	210.41	2.78	0.04
Intercept	82969.44	1	82969.44	1095.81	0.00
Gender	489.14	1	489.14	6.46	0.01
Age	122.18	1	122.18	1.61	0.21
Gender * Age	8.19	1	8.19	0.11	0.74
Error	11508.70	152	75.72		
Total	118534.00	156			
Corrected Total	9401.429	111			

In summary, men's self-concept was significantly higher than women's self-concept. Also, adult learners had significantly higher self-concept scores than traditional age students. African-American students and Caucasian students did not have any significant differences in beliefs. The influences of epistemological beliefs, self-concept, and their interactions with personal characteristics on mathematics performance are discussed further.

Variables Influencing Final Performance

Mathematics performance was measured by the percent correct achieved on the final examination for the course. Sample data for Wichita State University only was used for any analyses involving final examination scores. The mean final exam scores is .568 with a standard deviation of .203. This mean is typical for this exam at Wichita State University. Pursuant to the research questions, the relationship between epistemological beliefs and self-concept with mathematics performance was explored. The following

correlation analysis revealed a positive association of the Understanding and Usefulness belief scales with final exam score at the 5% significance level. Self-Concept was also significantly and positively correlated with final exam score. The Time and Steps belief scales were not significantly correlated with final exam scores.

Table 24

Correlations of Final Exam Score, the Belief Scales, and Self-Concept

	Time	Understanding	Steps	Usefulness	Self-Concept
Final Exam Score	.085	.250*	-.010	.197*	.316*
Time		.438*	-.320*	.214*	-.068
Understanding			-.253*	.414*	.125
Steps				-.108	.050
Usefulness					.558*

Note. * Correlation is significant at the 0.05 level (2-tailed).

The following boxplots helped to visualize any differences in mathematics performance between men and women, traditional age students and adult learners, and Caucasian students and African-American students. The mean final exam score was lower for women ($N = 65, M = .56$) than for men ($N = 36, M = .60$), but the t-test indicated that the difference was not significant, $t(100) = .847, p = .399$. Any differences between traditional age students ($N = 65, M = .57$) and adult learners ($N = 36, M = .58$) were also not significant ($t(100) = -.119, p = .906$), as well as between Caucasian students ($N = 66, M = .57$) and African-American students ($N = 13, M = .55, t(77) = .387, p = .70$).

Figure 8
Boxplots of Final Exam Scores by Gender

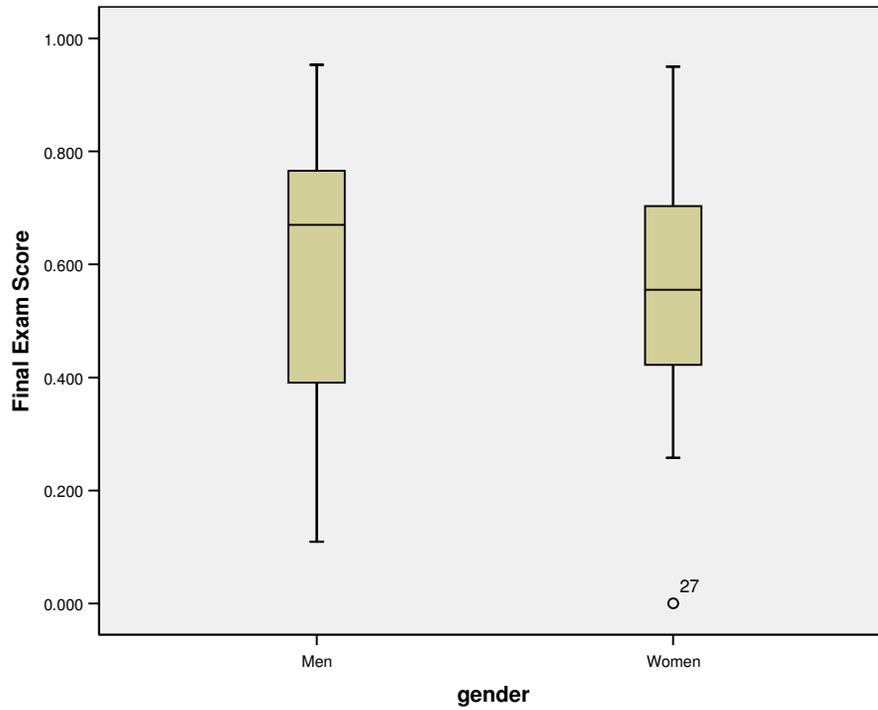


Figure 9
Boxplots of Final Exam Scores by Age

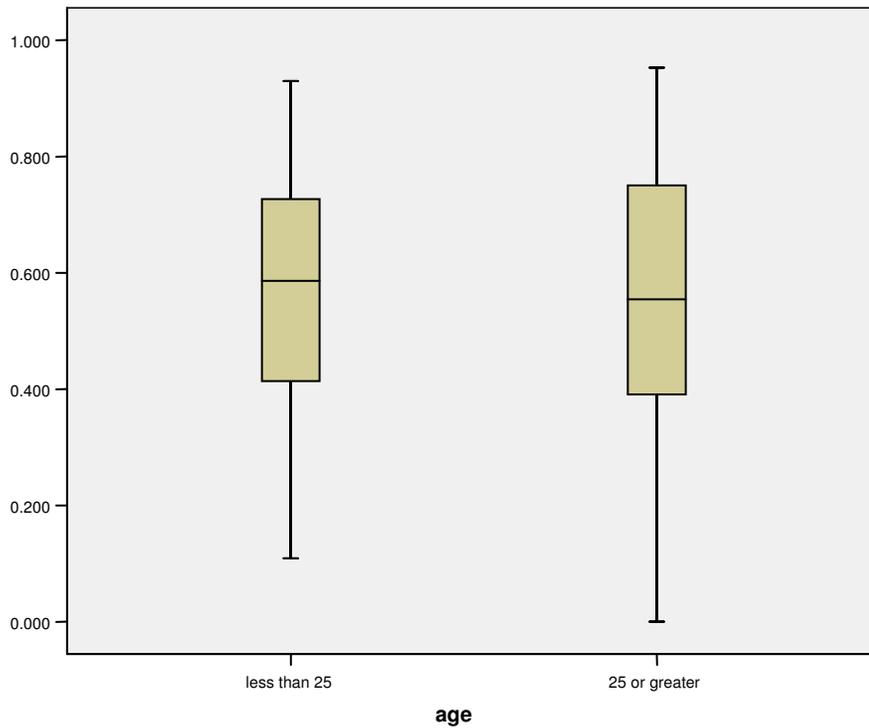
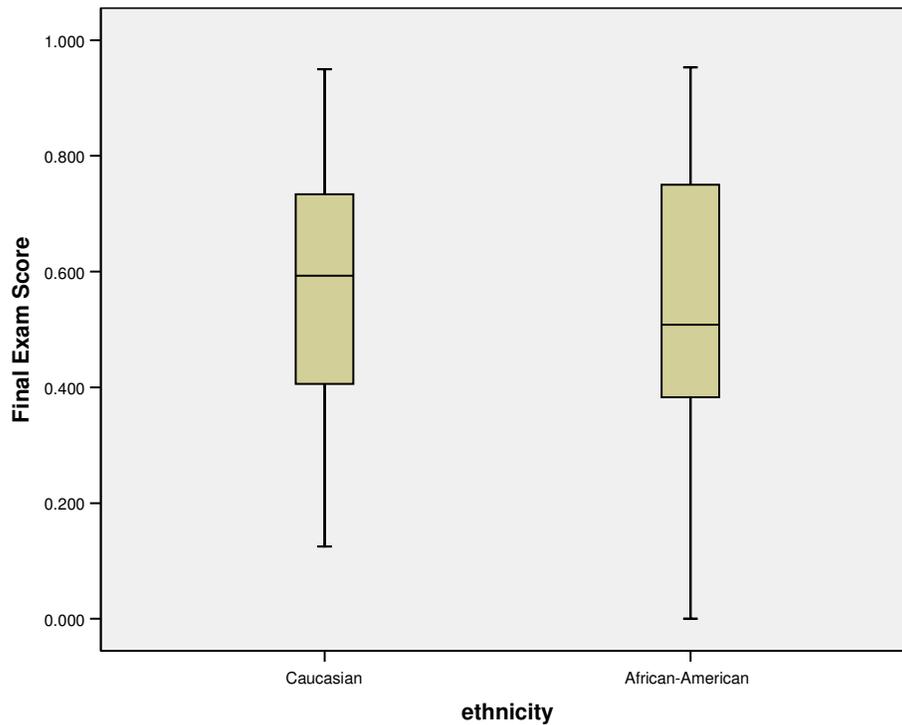


Figure 10
Boxplots of Final Exam Score by Ethnicity



As previously discussed, Understanding, Usefulness, and Self-Concept were significantly correlated with final exam scores. The interaction effects of gender, age, and ethnicity with Self-Concept and the Understanding scale on mathematics performance were explored using analysis of variance techniques. Because the Usefulness scale was also correlated with Understanding and had a lower Pearson-Correlation Coefficient than Understanding, it was not explored further.

The interactions effects of gender, age, and ethnicity with Self-Concept and Understanding were not significant at $\alpha = .05$. A more positive response for Understanding (high score) was defined as a score greater than or equal to 18. A score below 18 indicates a low score. Most participants, men and women, scored above 18 for Understanding. That is, most students had positive beliefs about the importance of

understanding mathematical concepts. The comparison between those with high Understanding scores and those with low Understanding scores must be made with caution since there were very few men and women who scored below 18. A more positive response for Self-Concept (high score) was defined as a score greater than or equal to 30. A score below 30 indicated a low score. Approximately 40% of the men had low Self-Concept scores, whereas 60% of the women had low Self-Concept scores.

Table 25
Mean Final Exam Scores by Gender and Understanding

Gender	Understanding	Mean	Std. Deviation	N
Men	low score	0.38	0.19	4
	high score	0.62	0.22	32
	Total	0.60	0.23	36
Women	low score	0.50	0.18	6
	high score	0.56	0.19	57
	Total	0.55	0.19	63
Total	low score	0.45	0.19	10
	high score	0.58	0.20	89
	Total	0.57	0.21	99

Table 26

Tests of Between Subject Effects for Final Exam Score against Understanding, Gender, and Understanding x Gender

Source	Type III SS	df	MS	F	Sig.
Corrected Model	0.27(a)	3	0.09	2.25	0.09
Intercept	9.16	1	9.16	225.74	0.00
Gender	0.01	1	.01	0.19	0.67
Understanding (low/high)	0.19	1	.19	4.79	0.03
Gender * Understanding	0.08	1	.08	1.91	0.17
Error	3.85	95	.04		
Total	36.19	99			
Corrected Total	4.13	98			

Note. a R Squared = .066 (Adjusted R Squared = .037)

Table 27

Mean Final Exam Score by Self-Concept and Gender

Gender	Self-Concept	Mean	Std. Deviation	N
Men	low score	.47	0.23	15
	high score	.66	0.19	21
	Total	.58	0.22	36
Women	low score	.51	0.19	38
	high score	.62	0.17	26
	Total	.55	0.19	64
Total	low score	.50	0.20	53
	high score	.64	0.18	47
	Total	.56	0.20	100

Table 28

Tests of Between Subject Effects for Final Exam Score against Self-Concept, Gender, and Self-Concept x Gender

Source	Type III SS	Df	MS	F	Sig.
Corrected Model	0.52(a)	3	0.17	4.73	0.00
Intercept	28.55	1	28.55	779.27	0.00
Gender	0.00	1	0.00	0.00	0.97
Self-Concept	0.50	1	0.50	13.71	0.00
Gender * Self-Concept	0.04	1	0.04	0.94	0.33
Error	3.52	96	0.04		
Total	35.86	100			
Corrected Total	4.04	99			

Note. a R Squared = .129 (Adjusted R Squared = .102)

Separate correlation analyses for men and women were used to further explore the differences in the relationship between belief scales and Self-Concept with final exam scores between genders. The correlation analysis for men revealed that only Understanding was significantly and positively correlated with final exam score. For women, Self-Concept and Usefulness were both significantly and positively correlated with final exam score.

Table 29
Correlation Analysis of Beliefs and Self-Concept with Final Exam Scores (Men Only)

Final Exam Score			
Scale	Pearson Correlation	Sig. (2-tailed)	N
Time	.055	.751	36
Understanding	.427	.009	36
Steps	.102	.550	37
Usefulness	.083	.631	36
Self-Concept	.290	.087	36

Table 30
Correlation Analysis of Beliefs and Self-Concept with Final Exam Scores (Women Only)

Final Exam Score			
Scale	Pearson Correlation	Sig. (2-tailed)	N
Time	.115	.377	61
Understanding	.129	.312	63
Steps	-.112	.385	62
Usefulness	.288	.021	64
Self-Concept	.325	.009	64

With respect to age, the descriptive statistics for mean Understanding scores as shown Table 31 revealed that most participants, traditional age students and adult learners, had more positive beliefs about the importance of understanding mathematical concepts. Since there were so few adult learners that had a low score for Understanding, a comparison of the Understanding scale between the two age groups was not reasonable. However, the Self-Concept scale was more diverse among traditional age students and

adult learners (Table 32). The interaction between age and Self-Concept was not significant as shown in Table 33.

Age	Understanding	Mean	Std. Deviation	N
less than 25	low score	0.49	0.17	8
	High score	0.58	0.18	56
	Total	0.57	0.18	64
25 or greater	low score	0.30	0.25	2
	High score	0.58	0.24	33
	Total	0.57	0.25	35
Total	low score	0.45	0.19	10
	High score	0.58	0.20	89
	Total	0.57	0.21	99

Table 32
Mean Final Exam Scores by Age and Self-Concept

Age	Self-Concept	Mean	Std. Deviation	N
less than 25	low score	0.51	0.18	35
	High score	0.63	0.17	30
	Total	0.57	0.18	65
25 or greater	low score	0.47	0.24	18
	high score	0.66	0.19	17
	Total	0.56	0.24	35
Total	low score	0.50	0.20	53
	high score	0.64	0.18	47
	Total	0.56	0.20	100

Table 33
Tests of Between Subject Effects for Final Exam Score against Age, Self-Concept, and Age x Self-Concept

Source	Type III SS	Df	MS	F	Sig.
Corrected Model	2.11	50	0.04	1.08	0.40
Intercept	22.87	1	22.87	582.41	0.00
Age	0.10	1	0.10	2.56	0.12
Self-Concept	1.72	34	0.05	1.29	0.21
Age * Self-Concept	0.47	15	0.03	0.79	0.68
Error	1.92	49	0.04		
Total	35.86	100			
Corrected Total	4.04	99			

With respect to ethnicity, the descriptive statistics revealed that most Caucasian students and African-American students had high Understanding scores. A comparison of the Understanding scale between the two groups was not reasonable since there were too few African-American students with low Understanding scores. The Self-Concept scores were almost evenly split between low scores and high scores among Caucasian students as well as among African-American students. As Table 34 indicates, the sample sizes were still too small to reasonably check for interaction.

Table 34
Mean Final Exam Scores by Ethnicity and Self-Concept

Ethnicity	Self-Concept	Mean	Std. Deviation	N
Caucasian	low score	0.50	0.19	36
	high score	0.66	0.15	30
	Total	0.57	0.19	66
African-American	low score	0.40	0.28	5
	high score	0.64	0.21	7
	Total	0.54	0.26	12
Total	low score	0.49	0.20	41
	high score	0.66	0.16	37
	Total	0.57	0.20	78

Regression Analysis Results

A series of hierarchical regression analyses was conducted to determine the predictive relationship between epistemological beliefs and self-concept on mathematics performance. Correlation analysis revealed that Understanding, Usefulness, and Self-Concept were all significantly and positively correlated with final exam score (Table 24).

Usefulness was also highly correlated with Self-Concept. For this reason, Usefulness was excluded from the regression analysis.

Separate correlation analyses for men and women also revealed that Understanding was correlated with final exam scores for men, but not for women (Table 29). Self-Concept was correlated with final exam scores for women, but not for men (Table 30). Additionally, other studies have shown that self-concept affects mathematics performance more strongly for women than for men (Mason, 2003; Stage & Kloosterman, 1995). For these reasons, hierarchical regression analysis was conducted separately for men and women as well as combined.

For men only, the ordering of the predictor variables was Understanding and then Self-Concept. Understanding was chosen to enter the model first because correlation analysis revealed that Understanding was significantly and positively correlated with final exam scores for men. Model 1 contained only the variable, Understanding. Model 2 contained the variables, Understanding and Self-Concept. The change in the R-square statistic did not indicate significant improvement by adding Self-Concept. Only the Understanding variable was significant at the 5% significance level, as the results in Table 35 indicate. The Understanding variable explained 15% of the variation in final exam scores for men.

Table 35
Model Summary for Model 1 and Model 2 (Men Only)

Model	R	R Square	Adj. R Square	SE of the Estimate	R Square Change	Sig. F Change
1	0.39 (a)	0.15	0.12	0.21	0.15	0.02
2	0.43(b)	0.18	0.13	0.21	0.03	0.27

ANOVA

Model		SS	Df	Mean Square	F	Sig.
1	Regression	0.26	1	0.26	5.84	.02
	Residual	1.47	33	0.05		
	Total	1.73	34			
2	Regression	0.32	2	0.16	3.58	.04
	Residual	1.41	32	0.04		
	Total	1.73	34			

Note. a Predictors: (Constant), Understanding; b Predictors: (Constant), Understanding, Self-Concept
 Dependent Variable: Final Exam Score

Table 36
Hierarchical Regression Coefficients for Model 1 and Model 2 (Men Only)

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.		
		B	Std. Error	Beta				
1	(Constant)	0.10	0.20		0.50	0.62		
	Understanding	0.02	0.01	0.39			2.42	0.02
2	(Constant)	0.02	0.22		0.09	0.93		
	Understanding	0.02	0.01	0.34			2.09	0.04
	Self-Concept	0.01	0.00	0.19			1.13	0.27

For women only, the ordering of the predictor variables was Self-Concept first, then Understanding. Self-Concept was chosen to enter the model first because correlation analysis revealed that Self-Concept was significantly and positively correlated with final exam scores for women. Model 1 contained only the variable Self-Concept. Model 2 contained the variables Self-Concept and Understanding. The change in the R-square

statistic did not indicate significant improvement by adding Understanding. Only the Self-Concept variable was significant at the 5% significance level, as the results in Table 38 indicate. The variable, Self-Concept, explained 11% of the variation in final exam scores for women.

Table 37

Model Summary for Model 1 and Model 2 (Women Only)

Model	R	R Square	Adj. R Square	SE of the Estimate	R Square Change	Sig. F Change
1	.33(a)	0.11	0.10	0.18	0.11	0.01
2	.35(b)	0.12	0.09	0.18	0.01	0.35

ANOVA

Model		SS	df	Mean Square	F	Sig.
1	Regression	0.25	1	0.25	7.46	0.01
	Residual	2.00	61	0.03		
	Total	2.25	62			
2	Regression	0.27	2	0.14	4.17	0.02
	Residual	1.97	60	0.03		
	Total	2.25	62			

Note. a Predictors: (Constant), Self-Concept; b Predictors: (Constant), Self-Concept, Understanding
Dependent Variable: Final Exam Score

Table 38
Hierarchical Regression Coefficients for Model 1 and Model 2 (Women Only)

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	0.39	0.06		6.16	0.00
	Self-Concept	0.01	0.00	0.33	2.73	0.01
2	(Constant)	0.27	0.15		1.81	0.08
	Self-Concept	0.01	0.00	0.33	2.68	0.01
	Understanding	0.01	0.01	0.12	0.95	0.35

For the combined sample, including men and women, variables considered were Self-Concept, Understanding, and the interaction variables of Gender x Self-Concept, and Gender x Understanding. The ordering of the predictor variables for Self-Concept and Understanding was determined by the magnitude of the Pearson-Correlation Coefficient in the correlation analysis of the combined sample (Table 24). The ordering of the predictor variables was Self-Concept, Understanding, Gender x Self-Concept, and Gender x Understanding. Model 2, consisting of the variables Self-Concept and Understanding, was the best model. Both variables were significant at the 5% significance level (Table 39). The R-square statistic did not improve significantly with the entry of the interaction variables. The degree of multicollinearity among the variables was also tested. None of the variance inflation factors (VIF) exceeded 10 (Table 40), therefore the variables were not investigated further for any collinearity problems. The variables, Self-Concept and Understanding, explained 14% of the variation in final exam scores.

Table 39

Model Summary for Models 1, 2, 3, and 4 (Men and Women)

Model	R	R Square	Adj. R Square	SE of the Estimate	R Square Change	Sig. F Change
1	.31(a)	0.10	0.09	0.19	0.10	0.00
2	.37(b)	0.14	0.12	0.19	0.04	0.04
3	.37(c)	0.14	0.11	0.19	0.00	0.82
4	.38(d)	0.15	0.11	0.19	0.01	0.38

ANOVA

Model		SS	Df	Mean Square	F	Sig.
1	Regression	0.39	1	0.39	10.45	.00
	Residual	3.61	96	0.04		
	Total	4.00	97			
2	Regression	0.55	2	0.28	7.58	.00
	Residual	3.45	95	0.04		
	Total	4.00	97			
3	Regression	0.55	3	0.18	5.02	.00
	Residual	3.45	94	0.04		
	Total	4.00	97			
4	Regression	0.58	4	0.15	3.95	.01
	Residual	3.42	93	0.04		
	Total	4.00	97			

Note. a Predictors: (Constant), Self-Concept; b Predictors: (Constant), Self-Concept, Understanding; c Predictors: (Constant), Self-Concept, Understanding, GXSC; d Predictors: (Constant), Self-Concept, Understanding, GXSC, GXB2

Table 40

Hierarchical Regression Coefficients for Models 1, 2, 3, and 4 (Men and Women)

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	VIF.
		B	Std. Error	Beta			
1	(Constant)	0.39	0.06		6.77	0.00	
	Self-Concept	0.01	0.00	0.31	3.23	0.00	1.00
2	(Constant)	0.17	0.12		1.38	0.17	
	Self-Concept	0.01	0.00	0.29	3.07	0.00	1.01
	Understanding	0.01	0.01	0.20	2.09	0.04	1.01
3	(Constant)	0.17	0.12		1.38	0.17	
	Self-Concept	0.01	0.00	0.29	3.02	0.00	1.02
	Understanding	0.01	0.01	0.20	2.08	0.04	1.01
	GXSC	0.00	0.00	-0.02	-0.23	0.82	1.01
4	(Constant)	0.17	0.12		1.41	0.16	
	Self-Concept	0.01	0.00	0.25	2.36	0.02	1.24
	Understanding	0.01	0.01	0.22	2.23	0.03	1.01
	GXSC	0.00	0.00	0.22	0.76	0.45	9.17
	GXB2	-0.00	0.00	-0.26	-0.89	0.38	9.67

Summary

Students enrolled in Intermediate Algebra classes at WSU, Newman, and Friends during spring and fall semesters of 2006 were asked to complete the MBS survey regarding epistemological beliefs and self-concept about mathematics. A total of 159 students participated. Students varied with respect to gender, age, and ethnicity. Participants included 95 women and 64 men, 18 African-Americans and 99 Caucasians, and 112 traditional age students and 47 adult learners.

From survey questions about grade expectations and effort, most students (90%, N=141) believed their performance in the class and on the final exam would be satisfactory. However, at least 30% (N=47) rated their ability below average and only 27% (N=43) said they completed the homework most or all of the time.

The independent variables were the belief scales of Time, Understanding, Steps, and Usefulness. Students generally believed that understanding mathematics may take time, understanding concepts is important in mathematics, and mathematics is useful in daily life. Students generally did not believe that math problems can be solved with logic and reason instead of learned math rules. Students tended to have a low self-concept about mathematics. There were no significant differences ($\alpha=.05$) in the dependent variables between gender, age, and ethnicity with the following exception. Men's self-concept was significantly higher than women's self-concept. Adult learners' self-concept was significantly higher than traditional age students. There were no interaction effects on the belief scales and self-concept between gender and age.

The dependent variable, final performance, was measured by the percent correct on the final exam. Only WSU scores were considered since final exams differed between institutions. Correlation analysis revealed that Understanding, Usefulness, and Self-Concept were significantly and positively correlated with final exam score. Since Usefulness was also significantly correlated with Self-Concept, Usefulness was not used in the regression analyses. Hierarchical regression analyses revealed that Understanding influenced final exam scores for men and Self-Concept influenced final exam scores for women. There were no interaction effects with ethnicity or age.

Chapter 5

Discussion

Introduction

This chapter provides a summary of the study design, the research questions and a discussion of the findings relevant to the research questions. The connection between the literature on epistemological beliefs about mathematics and mathematics self-concept and the research findings is discussed in detail. A discussion of recommendations for future research, and implications of the study are also included.

Summary of the Study Design

The relationship between college students' epistemological beliefs about mathematics and mathematics self-concept with mathematics performance was investigated. The survey instrument, the Mathematics Belief Scales (MBS), was used to gather information on students' beliefs about mathematics and beliefs about themselves as learners of mathematics. The population consisted of all students enrolled in Intermediate Algebra at Friends University, Newman University, and Wichita State University for the spring and fall semesters of 2006 (N=377). A total of 159 students participated. The dependent variable, mathematics performance, was measured by the percent correct on the Intermediate Algebra final examinations.

Research Questions

The following research questions were used to guide the study:

1. What are the effects of epistemological beliefs about mathematics and mathematics self-concept on mathematics performance?
2. Are there significant differences in the effects of epistemological beliefs and self-concept on mathematics performance between men and women?

3. Are there significant differences in the effects of epistemological beliefs and self-concept on mathematics performance between adult learners and younger students?
4. Are there significant differences in the effects of epistemological beliefs and self-concept on mathematics performance between ethnic groups?
5. Are there significant interaction effects on mathematics performance between epistemological beliefs, self-concept, and the personal characteristics of gender, age, and ethnicity?

Discussion of the Findings

The Distinction between Beliefs about Mathematics and Beliefs about Self

Investigations exploring beliefs have not always clearly distinguished between beliefs about self and epistemological beliefs about mathematics (Kloosterman & Stage, 1992; Mason, 2003; Schommer-Aikins et al., 2005; Stage & Kloosterman, 1995). More specifically, belief about the time it takes to solve mathematics problems was not always treated as a separate construct from beliefs about self as a learner of mathematics. An individual's perceived ability to solve time-consuming mathematics problems incorporates both a belief about self as a learner of mathematics and an epistemological belief about the nature of mathematics. Due to the ambiguous distinction between beliefs about mathematics as a discipline and beliefs about self, the relationship between the two constructs and their shared effect on student performance has been unclear. One goal of this research was to more clearly differentiate between self-concept and epistemological beliefs about mathematics. As evidenced by the reliability measures and inter-scale correlations of the MBS instrument, the belief about the time it takes to solve mathematics problems was more clearly differentiated from beliefs about self as a learner of mathematics.

What are Participants' Beliefs?

A review of the literature revealed that students at all levels hold nonavailing beliefs about the nature of knowledge in mathematics, the nature of knowing in mathematics, and about themselves as learners of mathematics (Kloosterman & Stage, 1992; McLeod, 1992; Muis, 2004; Schoenfeld, 1988). Much of the prior research investigated middle-school children or students at the secondary level. Consistent with prior research, the current findings indicated that college students taking Intermediate Algebra also hold nonavailing beliefs about mathematics. Four epistemological beliefs were explored: the learning of mathematics should occur quickly, mathematics is about getting the right answer, there is always a learned rule to follow in mathematics, and mathematics is not useful in daily life. These epistemological beliefs were respectively measured by the Mathematics Belief Scales of Time, Understanding, Steps, and Usefulness. The Self-Concept scale measured students' beliefs about themselves as learners of mathematics. The current findings indicated that students in particular held nonavailing beliefs with respect to the complexity of mathematics (Steps) and nonavailing beliefs about themselves as learners of mathematics (Self-Concept).

The current findings also indicated that many students held nonavailing beliefs about the time it takes to solve mathematics problems. Nonavailing beliefs about the time it takes to solve mathematics problems can limit expectations and cognitive resources and affect the goals and strategies individuals use to solve these problems (De Corte et al., 2002; L. Mason, 2003; Schoenfeld, 1983). The descriptive statistics of the Time scale indicated that students generally had positive beliefs about the time it takes to learn mathematics or to solve math problems, particularly with respect to more difficult problems. However, the individual comments revealed that less than 20% of the students believed that a typical mathematics problem should take more than 10 minutes to solve.

One-third of the students believed that a typical problem should take less than 15 minutes before it is considered impossible to solve. These comments were consistent with previous research which found that students typically believe that mathematical problems should be solved within five to ten minutes (Kloosterman & Stage, 1992; Mason, 2003; Schoenfeld, 1988; Spangler, 1992).

As with the Time scale, the descriptive statistics of the Understanding scale indicated that the majority of students believed understanding concepts in mathematics is important, as opposed to placing more importance on just getting the right answer. Learning mathematics involves being able to understand mathematics as a complex subject with interrelated concepts that can be applied in a variety of meaningful situations (Garofalo, 1989a; Schoenfeld, 1988). Even though students reported that understanding mathematical concepts is important, individual comments revealed that approximately one-third of the students believed understanding is measured by external means, such as grades on homework or tests, rather than the more meaningful measures of being able to work independently, explain the material to others, or make connections to other situations. These comments were consistent with Hofer's (2002) findings that students use authority and expertise to justify knowledge and truth in science.

Unlike the Time and Understanding scales, descriptive statistics of the Steps scale indicated that students clearly held nonavailing beliefs about the complexity of mathematics. Assumptions about the nature of mathematics should extend beyond a set of distinct facts, rules, and procedures (Garofalo, 1989a; Schoenfeld, 1988). It encompasses adaptive reasoning, which is the capacity for logical thought, reflection, explanation, and justification (National Research Council, 2001). Students generally believed that solving problems consisted of following a predetermined sequence of steps or the memorization of formulas, rules, and procedures. Individual comments confirmed

that most students (86%) believed that memorization is very important in learning mathematics. Almost half of the students believed that procedures, rules, and formulas must be taught or shown. Many students commented that mathematics cannot be discovered or learned through logic or reasoning, but must be taught. These students had an objective, dualistic perspective of the certainty of mathematical knowledge. In reference to Baxter Magolda's (2002) Epistemological Reflection Model, these students were still within the Absolute Knowing perspective. That is, students viewed knowledge as certain and relied on authorities to know the truth.

Belief about the usefulness of mathematics is related to motivation and mathematics achievement (Kloosterman & Stage, 1992; Schommer-Aikins et al., 2005). Mathematics proficiency should reflect a productive disposition, which is a view of mathematics as sensible, useful, and worthwhile (National Research Council, 2001). Descriptive statistics indicated that students generally held availing beliefs about the usefulness of mathematics. However, individual comments revealed that 44% of the students believed only basic mathematics, such as addition and subtraction, is useful in everyday life or that mathematics is not useful at all. These comments were also consistent with previous research which found that students believed mathematics in general is not useful in daily life as a tool or has little to do with real thinking or problem solving (Schoenfeld, 1985; Schommer-Aikins et al., 2005).

Beliefs about self are the beliefs individuals hold about their own competence (Schunk & Pajares, 2005). Confidence in learning mathematics has been discussed as one of the most important affective variables influencing motivation and academic performance in mathematics (Carmichael et al., 2005; Kloosterman et al., 1996; McLeod, 1992; Reyes, 1984; Schoenfeld, 1983; Schoenfeld, 1985). Prior investigations exploring beliefs with respect to mathematics have not always clearly distinguished between beliefs

about self and epistemological beliefs (Kloosterman & Stage, 1992; Mason, 2003; Schommer-Aikins et al., 2005; Stage & Kloosterman, 1995). The Mathematics Belief Scales survey instrument was designed to more clearly distinguish epistemological beliefs about mathematics and beliefs about self as a learner of mathematics. The Self-Concept scale measured students' beliefs about themselves as learners of mathematics. The findings of this research revealed that students had nonavailing beliefs with regard to mathematics self-concept. College students taking Intermediate Algebra were generally not confident in their ability to solve mathematics problems. Notably, the surveys were completed towards the end of the semester, indicating that students' self-concepts were low even after a semester of learning.

Do Beliefs Differ Between Genders, Ages, and Ethnicities?

Generally, students tend to hold nonavailing epistemological beliefs about mathematics regardless of gender (Stage & Kloosterman, 1995). Consistent with previous investigations, individual t-tests determined no significant differences in epistemological beliefs between men and women. This was not true for individuals' beliefs about themselves as learners of mathematics. A significant amount of research exploring the relationship between self-concept and gender indicates that girls tend to be less confident in learning mathematics than boys (Leedy, et al. 2003; McLeod, 1992). Most of the prior research investigated students at the secondary level or earlier. The current findings were consistent with prior investigations. Within the college-level Intermediate Algebra course, t-tests revealed that men tended to have higher self-concept than women.

Very little research has explored differences in epistemological beliefs about mathematics and self-concept between adult learners and traditional age students. Guay et al. (2003) found that as children grow older their academic self-concept becomes more reliable, more stable, and more strongly correlated with academic achievement. The

current findings revealed that there were no significant differences between adult learners and traditional age students in epistemological beliefs. However, there were significant differences in Self-Concept between adult learners and traditional age students. Adult learners were more confident than traditional age students about their ability to understand mathematics.

Research exploring the relationship between race/ethnicity and epistemological beliefs about mathematics is basically nonexistent. There were no significant differences in epistemological beliefs or self-concept between African-American students and Caucasian students. These results should be interpreted with caution since the sample size for African-American students was small (N=18).

Research Question 1: What are the effects of epistemological beliefs about mathematics and mathematics self-concept on mathematics performance?

Ample research has revealed that individuals' epistemological beliefs about mathematics and self-concept may indirectly or directly affect their mathematical performance (Buehl & Alexander, 2005; Garofalo, 1989a; Guay et al., 2003; House, 2000; Mason & Boscolo, 2004b; Schoenfeld, 1989; Szydlik, 2000). For example, Mason's (2003) study of secondary school students' beliefs about mathematics revealed that those who believe in the importance of understanding concepts have higher achievement than do those who do not believe in the importance of conceptual understanding. Findings from this research indicated that more availing beliefs about the importance of understanding mathematical concepts and about the usefulness of mathematics were significantly and positively correlated with performance on the final examination. Self-concept was also found to be significantly and positively correlated with performance on the final examination. Hierarchical regression analysis also revealed that achievement was influenced by students' beliefs about the importance of

understanding mathematical concepts and their self-concept. However, more positive beliefs about the time it should take to solve mathematics problems and mathematics as more than a set of rules and procedures were not found to be correlated with achievement. These beliefs were represented by the Time scale and Steps scale, respectively. These two scales had the lowest reliability measures. More defined scales may be necessary to further test the influence of these beliefs on mathematics achievement.

Research Question 2: Are there significant differences in the effects of epistemological beliefs and self-concept on mathematics performance between men and women?

Even though men and women both hold nonavailing beliefs about the nature of knowledge and the nature of knowing, their influence on achievement differs between men and women (Stage & Kloosterman, 1995). Baxter Magolda (1992) found that more women than men are relationship oriented in their views of knowledge. Muralidhar's (2003) study revealed that significantly more men than women view mathematics as a practical subject important to critical thinking and requiring perseverance. The findings from this study revealed that final exam scores did not differ between men and women. However, the importance of the understanding of mathematical concepts more strongly affected final exam scores for men than for women, and Self-Concept more strongly affected final exam scores for women than for men.

Research Question 3: Are there significant differences in the effects of epistemological beliefs and self-concept on mathematics performance between adult learners and younger students?

With respect to epistemological beliefs about mathematics and self-concept at the college-level, most research does not differentiate between traditional age students and adult learners. Research exploring differences between adult learners and traditional age

students is important because a significant number of adult learners are placed into a developmental mathematics course (Frederick et al., 1984; Johnson, 1996; Walker & Plata, 2000). The findings from this research indicated that adult learners had higher mean scores than traditional age students on Time, Understanding, Usefulness, and Self-Concept. The differences within any one scale were not significant. Because there were so few adult learners that had a low score for the Understanding scale, a comparison in the final exam scores of the Understanding scale between the two age groups was not reasonable. The Self-Concept scale was more diverse among traditional age students and adult learners. The interaction between age and Self-Concept on final exam scores was not significant.

Research Question 4: Are there significant differences in the effects of epistemological beliefs and self-concept on mathematics performance between ethnic groups?

Achievement disparities based on ethnicity are apparent across mathematical content areas and skill levels (Secada, 1992). However, much of this research has been based on the concept of ability. Kilpatrick and Silver (2000) discussed that children who lack ability may instead lack opportunities and support that would have helped them achieve success. The current findings did not find any disparities in final exam scores between African-American students and Caucasian students. As with age, the research exploring the relationship between ethnicity and epistemological beliefs about mathematics is basically nonexistent. The descriptive statistics in this study revealed that most Caucasian students and African-American students had high scores for the Understanding scale. A comparison in the final exam scores of the Understanding scale between the two groups was not reasonable since there were too few African-American students with low Understanding scores. The Self-Concept scores, however, were almost evenly split between low scores and high scores among Caucasian students as well as

among African-American students. There was not any significant interaction in the final exam scores between ethnicity and Self-Concept.

Research Question 5: Are there significant interaction effects on mathematics performance between epistemological beliefs, self-concept, and the personal characteristics of gender, age, and ethnicity?

Previous discussion has already reported the interaction effect of gender with epistemological beliefs and self-concept on mathematics performance. Likewise, the individual interaction effects of age and ethnicity with epistemological beliefs and self-concept on mathematics performance was reported. Further discussion is needed on the interaction of a combination of personal characteristics with beliefs and self-concept on mathematics performance. The AAUW (1991) study found that the gender gap in self-concept increases in age from elementary school to secondary school. Marsh (1989) also found that the gender gap for mathematics self-concept increases from young adulthood to adults age 21 and older. The findings from this research did not indicate that the gap between men and women in Self-Concept scores widens for older students. Therefore, the influence of a possible interaction between gender, age, and beliefs on final exam scores was not explored further. There were no other findings of interactions between personal characteristics with epistemological beliefs or self-concept.

In summary, the most significant findings were that students still hold nonavailing beliefs even after a semester of learning at the college level in a developmental mathematics class. Although epistemological beliefs do not differ between men and women, their influence on achievement does differ. The epistemology belief about the importance of understanding concepts in mathematics affected achievement more strongly for men than women. The belief about self as a learner of mathematics affected achievement more strongly for women than for men. Adult learners had higher mean

scores for most epistemological belief scales and significantly higher mean scores for self-concept.

Recommendations for Future Research

Based on the results of this study, the following recommendations for future research are offered:

1. In general, research at the college-level exploring epistemological beliefs about mathematics and beliefs about self as a learner of mathematics has been limited. Also, the sample in this study was relatively small and limited to a mid-western state university. The results of this study should be replicated by other studies with a similar design using larger more diversified samples.
2. The sample for this study was limited to students in college-level Intermediate Algebra. The results of this study may not generalize to students taking more advanced mathematics classes or to other college-level developmental courses, such as Arithmetic, Pre-Algebra, or Basic Algebra. Other studies should explore the influences of epistemological beliefs and self-concept on mathematics performance in other college-level mathematics classes.
3. Individual comments by the participants enhanced the understanding of the quantitative results of the Mathematics Belief Scales. More qualitative research is needed to expand on students' perceptions of how long it should take to solve math problems, what it means to understand mathematics, and the usefulness of mathematics, beyond basic math, to everyday life.
4. In other investigations, as well as this study, students hold very clear views about mathematics as a set of distinct facts, rules, and procedures. Schoenfeld (1988) states, "...thinking mathematically consists not only of mastering various facts and procedures, but also in understanding connections among

them; and thinking mathematically also consists of being able to apply one's formal mathematical knowledge flexibly and meaningfully in situations for which the mathematics is appropriate" (p. 164). Further investigations should explore how students' perceptions of mathematics can be challenged at the college-level and prior to college.

5. Self-concept has been shown to be an important affective variable which influences mathematics achievement. In this study, students had low self-concept, even after a semester of learning. Research is needed to explore how self-concept can be improved, particularly within a college-level developmental mathematics class.
6. More research is needed at the college-level to explore the relationship between gender and self-concept and the influence of self-concept on mathematics achievement for men and women. In this study, women had lower self-concept than men and self-concept influenced achievement more so for women than for men. More exploration is needed to explore the relationship between gender, age, and self-concept with mathematics achievement.
7. More research is needed to explore differences in epistemological beliefs and self-concept between traditional age students and adult learners, particularly within the developmental mathematics class. The current findings indicated that adult learners had mean scores that were higher than traditional age students on the amount of time it should take to solve math problems, the importance of understanding mathematical concepts, the usefulness of mathematics, and self-concept. This pattern should be investigated further. Further exploration is also needed to investigate the differences between adult

learners and traditional age students in the influences of epistemological beliefs and self-concept on mathematics achievement.

8. This study was limited in the investigation of the differences in epistemological beliefs or self-concept between ethnicities. A comparison of beliefs was made between African-American students and Caucasian students only. Other ethnic groups were not well represented in the sample. Secada (1992) discusses that ethnicity has conceptual cores that are socially constructed. Therefore, further research should explore the development of epistemological beliefs within different social contexts.
9. More research is also needed at the college-level to test the influences of epistemological beliefs on achievement. In particular, beliefs about the time it takes to solve math problems and beliefs about the nature of mathematics as a set of distinct facts, rules, and procedures were not correlated with achievement. However, the Time scale and the Steps scale both had lower reliability measures than the other scales. These scales may need to be further defined and then tested again for further exploration of their influence on achievement.

Implications

The student population in developmental mathematics has increased over the last two decades and has become more diverse with respect to gender, age, and ethnicity (National Science Board, 2006). Students underprepared for entry-level college mathematics enroll in developmental mathematics to improve their mathematical knowledge and skills (Penny & White, 1998). The success in developmental mathematics classes will largely determine success in subsequent mathematics classes, and ultimately persistence in college. Students come to the classroom with beliefs about mathematics as

a discipline and beliefs about self as learners of mathematics that have been influenced by social and academic experiences. Often these beliefs are nonadvantageous to learning.

Students' beliefs have been influenced by their academic experiences within secondary mathematics education. The mathematics education reform for secondary mathematics education has goals that go beyond the learning of specific concepts and skills (Trafton, et al., 2001). These goals include conceptual understanding, procedural fluency, strategic competence, adaptive reasoning, and productive disposition (National Research Council, 2001). However, much of current practice does not create a curriculum or an environment that helps students to reach these goals. The results of this study indicated that students do indeed enter college with nonavailing beliefs and that students' epistemological beliefs and beliefs about self as learners of mathematics influence their performance in developmental mathematics. These results indicate a need for academic experiences at the college-level that will challenge students' current belief system.

Instructors need to be aware students' beliefs may influence their performance and that these influences can differ between students. This study found differences between genders and ages in beliefs held by students and differences in the influences of these beliefs on mathematics performance. Self-concept influenced mathematics performance more so for women than for men. The importance of conceptual understanding influenced mathematics performance more so for men than for women. Instructors need to provide a variety of techniques that will enhance conceptual understanding and provide an environment that is supportive and conducive to building individual self-confidence.

This study provided an indication that adult learners have more availing beliefs about their ability to understand mathematics. Upon entry into college, a significant number of adult learners are placed into a developmental mathematics course (Fredrick,

Mishler, & Hogan, 1984; Johnson, 1996; Walker & Plata, 2000). Adult learners' low level placement is specific to mathematics but not to other subject areas. Adult learners may be at a disadvantage due to a gap in time since last attending school or due to competing responsibilities of family and work. Although adult learners appear to be at an initial disadvantage in college mathematics, they tend to be successful in developmental as well as entry level mathematics courses (Johnson, 1996; Walker & Plata, 2000). Adult learners also seem to have greater satisfaction and appreciation for mathematics education than younger students (Miglietti & Strange, 1998; Stage & McCafferty, 1992). It is reasonable to expect that adult learners' life experiences contribute to a more positive attitude towards education and more availing epistemological beliefs about mathematics. If students are given the opportunity to express these beliefs, the academic experiences for traditional age students and adult learners can be enhanced.

Academic experiences can indeed influence changes in students' beliefs about mathematics. Studies that examined whether students' beliefs can change as a result of changes in classroom practice have found positive results (Muis, 2004). Most of the studies focused on constructivist-oriented approaches to teaching mathematics. The participants were generally middle-school or high-school students. Instructors of developmental mathematics courses at the college-level can also influence change in students' beliefs by introducing mathematical concepts in meaningful contexts and by using collaboration and group activity in constructing mathematical knowledge. Mathematical proficiency goes beyond procedural fluency and strategic competence (National Research Council, 2001). Even though procedural fluency and strategic competence are important goals in mathematical proficiency, instructors need to find ways to develop conceptual understanding, adaptive reasoning, and a productive disposition.

Appendix A

Indiana Mathematics Belief Scales

Difficult Problems: *I can solve time-consuming mathematics problems.*

- + Math problems that take a long time don't bother me.
- + I feel I can do math problems that take a long time to complete.
- + I find I can do hard math problems if I just hang in there
- If I can't do a math problem in a few minutes, I probably can't do it at all.
- If I can't solve a math problem quickly, I quick trying.
- I'm not very good at solving math problems that take a while to figure out.

Steps: *There are word problems that cannot be solved with simple, step-by-step procedures.*

- + There are word problems that just can't be solved by following a predetermined sequence of steps.
- + Word problems can be solved without remembering formulas.
- + Memorizing steps is not that useful for learning to solve word problems.
- Any word problem can be solved if you know the right steps to follow.
- Most word problems can be solved by using the correct step-by-step procedure.
- Learning to do word problems is mostly a matter of memorizing the right steps to follow.

Understanding: *Understanding concepts is important in mathematics.*

- + Time used to investigate why a solution to a math problem works is time well spent.
- + A person who doesn't understand why an answer to a math problem is correct hasn't really solved the problem.
- + In addition to getting a right answer in mathematics, it is important to understand why the answer is correct.
- It's not important to understand why a mathematical procedure works as long as it gives a correct answer.
- Getting a right answer in math is more important than understanding why the answer works.
- It doesn't really matter if you understand a math problem if you can get the right answer.

Word Problems: *Word problems are important in mathematics.*

- + A person who can't solve word problems really can't do math.
- + Computational skills are of little value if you can't use them to solve word problems.
- + Computational skills are useless if you can't apply them to real life situations.
- Learning computational skills is more important than learning to solve word problems.
- Math classes should not emphasize word problems.
- Word problems are not a very important part of mathematics.

Effort: *Effort can increase mathematical ability.*

- + By trying hard, one can become smarter in math.
- + Working can improve one's ability in mathematics.
- + I can get smarter in math by trying hard.
- + Ability in math increases when one studies hard.
- + Hard work can increase one's ability to do math.
- + I can get smarter in math if I try hard.

Permission was granted by Peter Kloosterman, October 2005, to use a modified version of these scales. (Kloosterman & Stage, 1992, p. 115)

Appendix B
Fennema-Sherman Usefulness Scale

Usefulness: *Mathematics is useful in daily life.*

- + I study mathematics because I know how useful it is.
- + Knowing mathematics will help me earn a living.
- + Mathematics is a worthwhile and necessary subject.
- Mathematics will not be important to me in my life-s work.
- Mathematics is of no relevance to my life.
- Studying mathematics is a waste of time.

These items are a slightly reworded subset of the Fennema-Sherman (1976) Usefulness of Mathematics scale as modified by Kloosterman and Stage (1992).

Permission was granted by Peter Kloosterman, October 2005, and Elizabeth Fennema, October 2005, to use these scales.

Appendix C
Self Description Questionnaire III
Maths Subscale

- + I find many mathematical problems interesting and challenging.
- + I have generally done better in mathematics courses than other courses.
- + I am quite good at mathematics.
- + I have always done well in mathematics classes.
- + At school, my friends always came to me for help in mathematics.
- I have hesitated to take courses that involve mathematics.
- Mathematics makes me feel inadequate.
- I have trouble understanding anything that is based upon mathematics.
- I never do well on tests that require mathematical reasoning.
- I have never been very excited about mathematics.

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Appendix D
Mathematics Belief Scales Summary
 (Summary of statements and survey question correspondence)

Time: Solving mathematics problems may take time.
 Conversely: Learning of mathematics should occur quickly.
 (Modified Indiana Mathematics Belief Scales, Difficult Problems Scale, Kloosterman and Stage (1992))

	<u>Question</u>
+ Understanding mathematics sometimes takes a long time. *	23
+ Solving math problems may take a long time.*	4
+ Given enough time, hard math problems can be solved. *	18
- If a math problem can't be solved in a few minutes, it probably can't be solved. *	15
- Understanding mathematics should not take a long time. *	9
- Math problems should not take a long time to figure out. *	2

Also Question 42.

Steps: There are math problems that cannot be solved with simple, step-by-step procedures.
 Conversely: There is always a learned rule to follow in mathematics.
 (Modified Indiana Mathematics Belief Scales, Steps Scale, Kloosterman and Stage (1992))

+ Math problems can be solved without following a predetermined sequence of steps. *	20
+ Math problems can be solved without remembering formulas. *	1
+ Math problems can be solved with logic and reason instead of learned rules and procedures. *	22
- Learning to do math problems is mostly a matter of memorizing the right steps to follow. *	11
- To solve math problems, you have to be taught the right procedures. *	26
- One must use step by step procedures to solve math problems. *	14

Also Questions 41 and 44.

Understanding: Understanding concepts is important in mathematics.
 Conversely: Mathematics is about getting the right answer.
 (Modified Indiana Mathematics Belief Scales, Understanding Scale, Kloosterman and Stage (1992))

+ Investigating why a solution to a math problem works is as important as getting the correct answer. *	31
+ A person who doesn't understand why an answer to a math problem is correct hasn't really solved the problem.	33
+ In addition to getting a right answer in mathematics, it is important to understand why the answer is correct.	12
- It's not important to understand why a mathematical procedure works as long as it gives a correct answer.	17
- Getting a right answer in math is more important than understanding why the answer works.	5
- It doesn't really matter if you understand a math problem if you can get the right answer.	34

Also Question 51.

Appendix D (Cont.)
Mathematics Belief Scales Summary
(Summary of statements and survey question correspondence)

Usefulness: Mathematics is useful in daily life.
 Conversely: Mathematics is not useful in daily life.
(Fennema-Sherman Usefulness Scale (1976) as modified by Kloosterman and Stage (1992))

	<u>Question</u>
+ I study mathematics because I know how useful it is.	24
+ Knowing mathematics will help me earn a living.	30
+ Mathematics is a worthwhile and necessary subject.	28
- Mathematics will not be important to me in my life's work.	32
- Mathematics is of no relevance to my life.	29
- Studying mathematics is a waste of time.	7
Also question 40.	

Self Concept About Mathematics

(Self Description Questionnaire – III, Math Subscale, H. W. Marsh (1999))

+ I find many mathematical problems interesting and challenging.	16
+ I have generally done better in mathematics courses than other courses.	8
+ I am quite good at mathematics.	21
+ I have always done well in mathematics classes.	3
+ Others come to me for help in mathematics.*	10
- I have hesitated to take courses that involve mathematics.	19
- Trying to understand mathematics makes me feel inadequate.	6
- I have trouble understanding anything that is based upon mathematics.	27
- I never do well on tests that require mathematical reasoning.	13
- I have never been very excited about mathematics.	25

* These items were reworded from the original version.

Appendix E
Survey Instructions

Subject: Dissertation research surveys, “The effects of epistemological beliefs and self concept on performance in a developmental mathematics class”

Thank you for distributing the surveys to your students. Your cooperation is most valuable to my research. I will acknowledge the (*Institution Name*) in my dissertation and will gladly share my results with you. Please accept the enclosed Borders gift card as an expression of my appreciation. The surveys should take only 15 to 20 minutes of class time. Pick a day any time before the final exam that works best for you. I would prefer, however, a day when most students are in attendance. Below are some brief instructions.

- Students will need to sign the first page, which states that they consent to participate. No student is required to participate.
- Since I am comparing survey results to performance in the classroom, I will need students’ final exam score. Please write the final exam score, percent correct, on the Personal Data Inventory sheet.
- For purposes of anonymity and after the final grade has been listed, the signed consent form should be separated from the other pages.
- After the final grades have been listed, please return all surveys and signed consent forms to the main office.

Please feel free to call me with any questions.

Lori Steiner
942-4291,x2263

Appendix F
Informed Consent Form

Dear Participant,

I am a doctoral student in adult education at Kansas State University. Your instructor has agreed to distribute to you the following survey for my research. The data gathered from this survey will be used to explore the relationship between students' beliefs about mathematics and their mathematics performance. The results of this research will aid teachers and researchers in understanding which beliefs are important in the mathematics classroom.

The attached survey asks you about your personal beliefs about mathematics. These results will be compared to the grade you get on the final examination. Your responses are completely confidential and anonymous to the research team. Your participation is voluntary and not related in any way to your grade in this class.

If you choose to complete the survey, please respond honestly to the questions regarding your beliefs about mathematics. The survey will take about 15 to 20 minutes. There are no right or wrong answers. This is not a test. Your instructor and the Mathematics Department will receive feedback on the results of the research. Thank you for your cooperation.

The following contact information is provided for any questions or concerns you might have regarding this research project:

- **Lori Steiner, Asst. Prof. of Mathematics, Newman University, 3100 McCormick Ave., Wichita, KS 67213, (316) 942-4291**
- **Rick Scheidt, Chair, Committee on Research Involving Human Subjects, 1 Fairchild Hall, Kansas State University, Manhattan, KS 66506, (785) 532-3224**

Your signature below indicates that you have read the above information and are willing to participate.

Name _____
(Print)

Signature _____

Appendix G
Personal Data Inventory (Spring 2006)

Please provide the following information. Thank you!

1. What is your gender? (circle one) Male Female

2. What is your age? (check one)
_____ 18-22
_____ 23-25
_____ 26-30
_____ 31-35
_____ 36-40
_____ 41-50
_____ 51+

3. What is your ethnic background? (check one)
_____ American Indian
_____ Asian or Pacific Islander
_____ Caucasian
_____ Hispanic
_____ African-American
_____ Other If other, what ethnicity? _____

4. What year did you graduate from high school or complete your GED? _____

5. What is your class standing? (check one)
_____ Freshman
_____ Sophomore
_____ Junior
_____ Senior

6. How many credit hours are you enrolled in this semester? _____

7. How many years has it been since you last took a mathematics class? (check one)
_____ 0 – 1 years
_____ 2 – 3 years
_____ 4 – 6 years
_____ 7 – 10 years
_____ More than 10 years

8. What is your highest level of high school mathematics? (Check one)
_____ Algebra 1
_____ Geometry
_____ Algebra 2
_____ Trigonometry
_____ Pre-calculus
_____ Calculus
_____ Other If other, what class? _____

Appendix G (Cont.)
Personal Data Inventory (Fall 2006)

Please provide the following information. Thank you!

1. What is your gender? (circle one) Male Female

2. What is your age? _____

3. What is your ethnic background? (check one)
_____ American Indian
_____ Asian or Pacific Islander
_____ Caucasian
_____ Hispanic
_____ African-American
_____ Interracial
_____ Other If other, what ethnicity? _____

4. What year did you graduate from high school or complete your GED? _____

5. What is your class standing? (check one)
_____ Freshman
_____ Sophomore
_____ Junior
_____ Senior

6. How many credit hours are you enrolled in this semester? _____

7. How many years has it been since you last took a mathematics class? (check one)
_____ 0 – 1 years
_____ 2 – 3 years
_____ 4 – 6 years
_____ 7 – 10 years
_____ More than 10 years

8. What is your highest level of high school mathematics? (Check one)
_____ Algebra 1
_____ Geometry
_____ Algebra 2
_____ Trigonometry
_____ Pre-calculus
_____ Calculus
_____ Other If other, what class? _____

Appendix H

Mathematics Belief Scales

Your answers to the following questions will help us to understand what students believe about mathematics. Your answers are completely anonymous. Please read each item carefully and circle the response which best describes your feeling for each item. Thanks for your help!

	Strongly Agree	Agree	Not Certain	Disagree	Strongly Disagree
1. Math problems can be solved without remembering formulas	1	2	3	4	5
2. Math problems should not take a long time to figure out	1	2	3	4	5
3. I have always done well in mathematics classes	1	2	3	4	5
4. Solving math problems may take a long time	1	2	3	4	5
5. Getting a right answer in math is more important than understanding why the answer works	1	2	3	4	5
6. Mathematics makes me feel inadequate	1	2	3	4	5
7. Studying mathematics is a waste of time	1	2	3	4	5
8. I have generally done better in mathematics courses than other courses	1	2	3	4	5
9. Understanding mathematics should not take a long time	1	2	3	4	5
10. Others come to me for help in mathematics	1	2	3	4	5
11. Learning to do math problems is mostly a matter of memorizing the right steps to follow	1	2	3	4	5
12. In addition to getting a right answer in mathematics, it is important to understand why the answer is correct	1	2	3	4	5
13. I never do well on tests that require mathematical reasoning	1	2	3	4	5
14. One must use step by step procedures to solve math problems	1	2	3	4	5
15. If a math problem can't be solved in a few minutes, it probably can't be solved	1	2	3	4	5

	1	2	3	4	5
	Strongly Disagree	Disagree	Not Certain	Agree	Strongly Agree
16. I find many mathematical problems interesting	1	2	3	4	5
17. It's not important to understand why a mathematical procedure works as long as it gives a correct answer	1	2	3	4	5
18. Given enough time, hard math problems can be solved	1	2	3	4	5
19. I have hesitated to take courses that involve mathematics	1	2	3	4	5
20. Math problems can be solved without following a predetermined sequence of steps	1	2	3	4	5
21. I am quite good at mathematics	1	2	3	4	5
22. Math problems can be solved with logic and reason instead of learned rules and procedures	1	2	3	4	5
23. Understanding mathematics sometimes takes a long time	1	2	3	4	5
24. I study mathematics because I know how useful it is	1	2	3	4	5
25. I have never been very excited about mathematics	1	2	3	4	5
26. To solve math problems, you have to be taught the right procedures	1	2	3	4	5
27. I have trouble understanding anything that is based upon mathematics	1	2	3	4	5
28. Mathematics is a worthwhile and necessary subject	1	2	3	4	5
29. Mathematics is of no relevance to my life	1	2	3	4	5
30. Knowing mathematics will help me earn a living	1	2	3	4	5
31. Investigating why a solution to a math problem works is as important as getting the correct answer	1	2	3	4	5
32. Mathematics will not be important to me in my life's work	1	2	3	4	5
33. A person who doesn't understand why an answer to a math problem is correct hasn't really solved the problem	1	2	3	4	5

41. Do you think that students can discover mathematics on their own, or does all mathematics have to be shown to them? Please explain.
42. If you understand the material, how long should it take to solve a typical homework problem? What is a reasonable amount of time to work on a problem before you know it's impossible?
43. How can you know whether you understand something in math? What do you do to measure (test) yourself?
44. How important is memorizing in learning mathematics? If anything else is important, please explain how.
45. To what do you attribute your successful experiences in mathematics? (For example, effort, natural ability, or luck).

46. To what do you attribute your unsuccessful experiences in mathematics? (For example, lack of effort, lack of natural ability, or being unlucky).

Appendix I
Intermediate Algebra Course Objectives by School

<i>Newman Objectives include acquiring the following skills:</i>	<i>WSU Objectives include achieving the following outcomes:</i>	<i>Friends Objectives include the ability to do the following:</i>
Manipulating real numbers and algebraic expressions	Solves problems using operations and properties of the real numbers	Identify various subsets of the real number system; understand the properties of real numbers; add, subtract, multiply, and divide fractions and other real numbers
Factoring, adding, subtracting, multiplying, and dividing polynomials	Adds, subtracts and evaluates polynomials; uses multiplication of polynomials; uses division of polynomials	Add, subtract, multiply, and divide polynomials; factor polynomials
Adding, subtracting, multiplying, and dividing rational expressions	Solve problems involving rational expressions	Reduce, multiply, divide, add, and subtract rational expressions
Solving algebraic equations, inequalities, and applications problems	Solve problems using equations and inequalities	Solve linear equations; set up and solve application problems involving linear equations; solve linear inequalities
Graphing linear equations and inequalities, finding the slope of a line, and making geometric interpretation of algebraic data	Solve problems using graphical methods and information	Plot ordered pairs on a Cartesian coordinate system; graph linear functions
Evaluating, solving, and simplifying expressions and equations involving exponents, radicals, and complex numbers	Solve problems involving rational expressions; solve problems using roots and radicals	Solve equations with rational expressions
Solving, graphing, and applying quadratic equations	Solve problems relating to quadratics	Solve a quadratic equation using the Quadratic Formula
	Solve problems using functional relationships	Understand basic concepts of functions; graph linear functions
	Solve problems using system of equations and inequalities	

Appendix J

Intermediate Algebra Final Exam for WSU: Spring 2006

Spring 2006 Math 012 Final Exam

Name _____

You must show each step of your work in the space provided on the test paper.

Partial credit will be given for any correct work.

In numbers 1 – 6, simplify each expression.

1. $2 + 3 \cdot 2^2 + 3^2$

2. $x - 7[3x - (2 - x)]$

3. $\sqrt[3]{27a^{12}}$

4. $(\sqrt{3} + \sqrt{2})(3\sqrt{3} - \sqrt{2})$

5. $\frac{2}{5} + \frac{1}{15}$

6. $\frac{5x + 25}{x^2 - 25}$

7. Simplify $\frac{\frac{1}{x}}{1+\frac{1}{x}}$

8. Simplify $\frac{10x^2}{5y^2} \cdot \frac{15y^3}{2x^4}$

9. Simplify $\frac{7}{\sqrt{5}}$

10. Factor $18a^2 - 50$ completely.

11. Factor the perfect square trinomial
 $4y^4 - 12y^2 + 9$

12. Factor the greatest common factor from
 $6x^4y^2 + 24x^3y^3 - 18x^2y^4$

In numbers 13 – 17, solve each equation or inequality.

13. $\sqrt{3y-1} = 2$

14. $|x+1| = 2$

15. $(2y-1)^2 = 25$

16. $x^2 - 5x > 6$

17. $\frac{1}{x} = \frac{1}{3} - \frac{2}{3x}$

18. Solve $PV = nRT$ for T

19. Find the next two numbers in the arithmetic sequence 10, 16, 22, 28, ...
20. Write the equation of the circle with center (3, -1) and radius $r = 5$.
21. Use the quadratic formula or completing the square to solve the equation
 $x^2 - 5x - 3 = 0$
22. The length of a rectangle is 1 foot more than twice the width. The perimeter is 20 feet. Find the dimensions of the rectangle by setting up an equation and solving it.
23. Find the slope-intercept form of the equation of the line through the point (-1, -5) with slope $m = 2$.

24. Find the inverse $f^{-1}(x)$ of the one-to-one function $f(x) = \frac{x-3}{4}$.

25. Solve the system of equations $\begin{cases} x + y = 5 \\ 3x - y = 3 \end{cases}$

26. If tickets for a show cost \$2.00 for adults and \$1.50 for children, how many of each kind of ticket were sold if a total of 300 tickets were sold for \$525? Find out by setting up a system of equations and solving it.

27. Find the coordinates of the vertex of the parabola with the equation

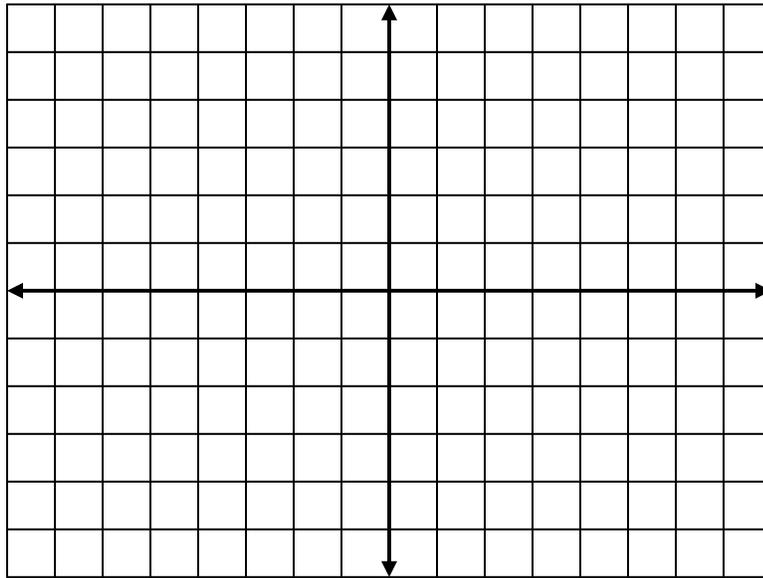
$$y = -x^2 + 6x - 5$$

28. Let $g(x) = x^2 + 3x + 4$. Evaluate $g(2)$.

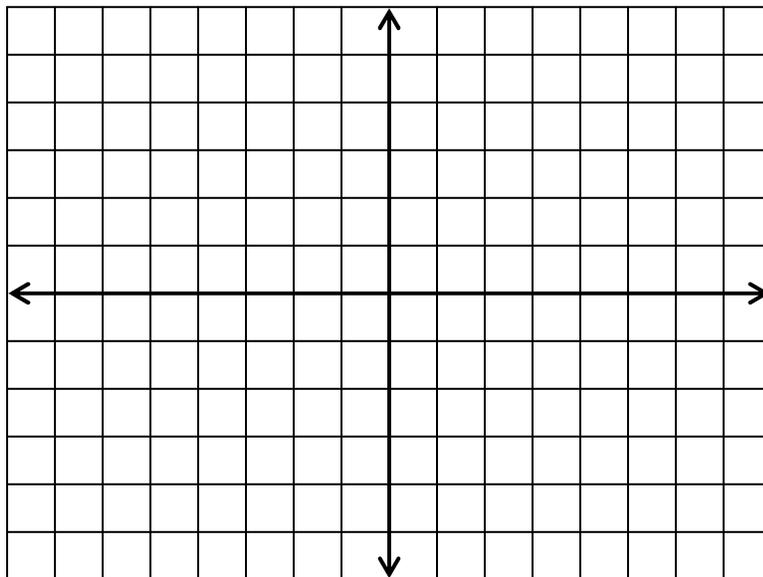
29. Use the properties of logarithms to expand $\log_{10} x^2 y^4$ as much as possible.

30. Solve the exponential equation $3^{2x+1} = 2$. Leave your answer in logarithmic form.

31. Graph the line $-3x + y = -2$ on the axes below.



32. Graph the solution set of the inequality $-x + 2y > -4$ on the axes below.



Appendix K

Intermediate Algebra Final Exam for WSU: Fall 2006

Fall 2006 Math 012 Final Exam

Name: _____

You **must show each step of your work in the space provided on the test paper.**

Partial credit will be given for any correct work.

In numbers 1 – 6, simplify each expression.

1. $4^2 + 5 \cdot 2^2 - 3^2$

2. $\log_5 \frac{1}{125}$

3. $\sqrt[4]{16x^{24}}$

4. $(2\sqrt{5} - \sqrt{3})(\sqrt{5} + 2\sqrt{3})$

5. $\frac{3}{7} + \frac{5}{21}$

6. $\frac{6x - 36}{x^2 - 12x + 36}$

7. Simplify $\frac{1 + \frac{2}{x}}{1 + \frac{5}{x}}$

8. Simplify $\frac{y^2 - 16}{2y + 6} \cdot \frac{y + 3}{y - 4}$

9. Simplify $\frac{6}{\sqrt{8}}$

10. Factor $4x^2 + 2x - 6$ completely.

11. Factor $x + x^2 - 90$

12. Factor the greatest common factor from $6x^3y + 9x^2y^2 + 12xy^3$

In numbers 13 – 17, solve each equation or inequality.

13. $\sqrt{5x+1} = 6$

14. $|x-4| = 5$

15. $(3y-1)^2 = 64$

16. $x^2 - 8 < -2x$

17. $\frac{2}{5} - \frac{1}{x} = \frac{3}{5x}$

18. Solve $A = \frac{a+b}{2}$ for a .

19. The sum of the numbers on two adjacent post-office boxes is 487. What are the numbers?
20. Write the equation of the circle with center $(-2, 4)$ and radius $r = 6$.
21. Use the quadratic formula or completing the square to solve the equation $x^2 + 7x + 3 = 0$.
22. The length of a rectangle is 2 feet more than three times the width. The perimeter is 44 feet. Find the dimensions of the rectangle by setting up an equation and solving it.
23. Find the slope-intercept form of the equation of the line through the point $(2, 5)$ with slope $m = 4$.

24. Find the inverse $f^{-1}(x)$ of the one-to-one function $f(x) = 3x + 7$

25. Solve the system of equations $\begin{cases} 2x + 3y = 4 \\ 4x - 3y = -10 \end{cases}$

26. A train leaves Wichita and travels north at a speed of 40 mph. Three hours later, a second train leaves on a parallel track and travels north at 60 mph. How far from the station will they meet?

27. Find the coordinates of the vertex of the parabola with the equation

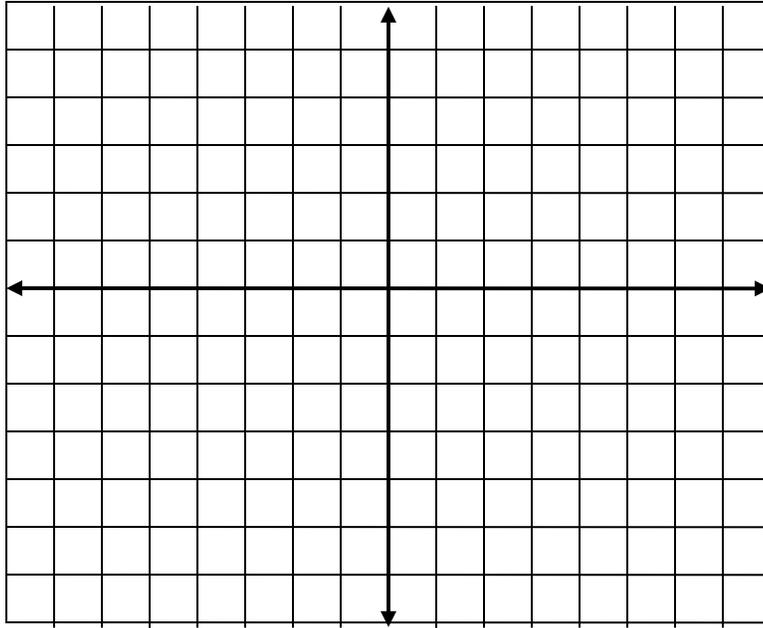
$$y = 3x^2 + 12x - 4.$$

28. Let $f(x) = x^2 - 5x + 3$. Evaluate $f(3)$.

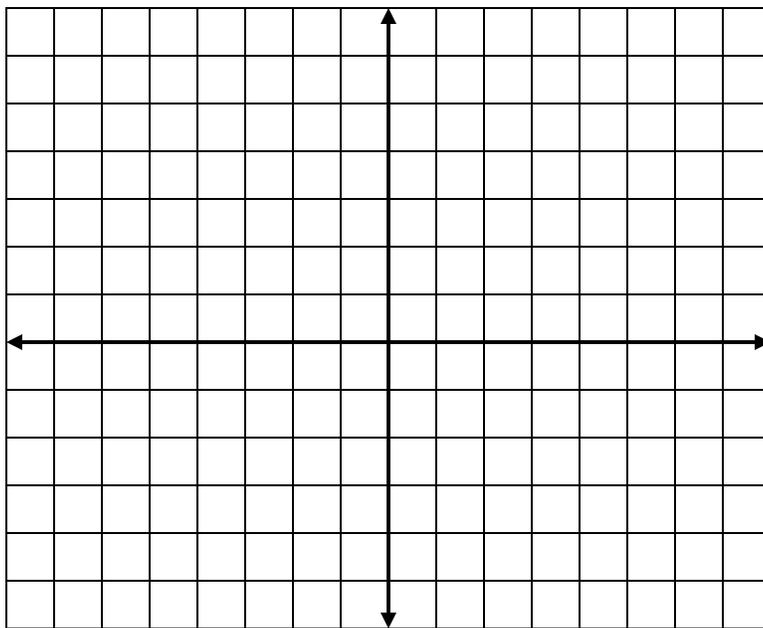
29. Use the properties of logarithms to expand $\log_6 \frac{x^3}{y^2}$ as much as possible.

30. Solve the logarithmic equation $\log_3(2x+1) = 2$.

31. Graph the line $4x + 2y = 6$ on the axes below.

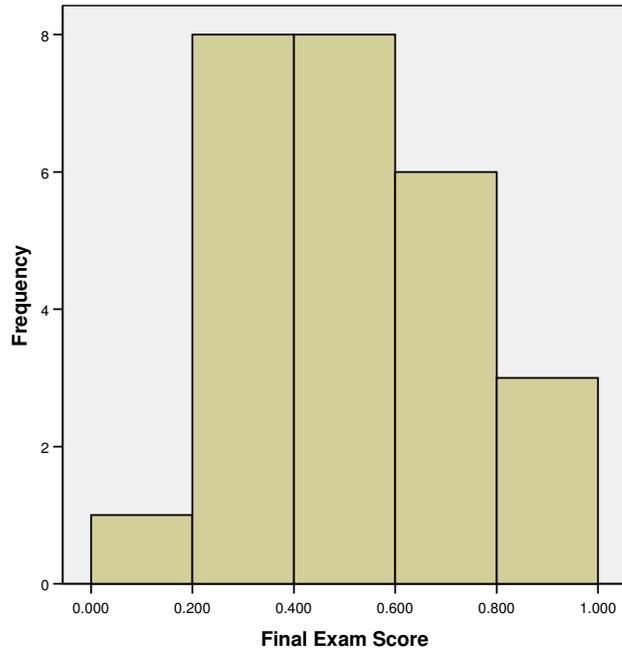


32. Graph the solution set of the inequality $x - 2y < 8$ on the axes below.

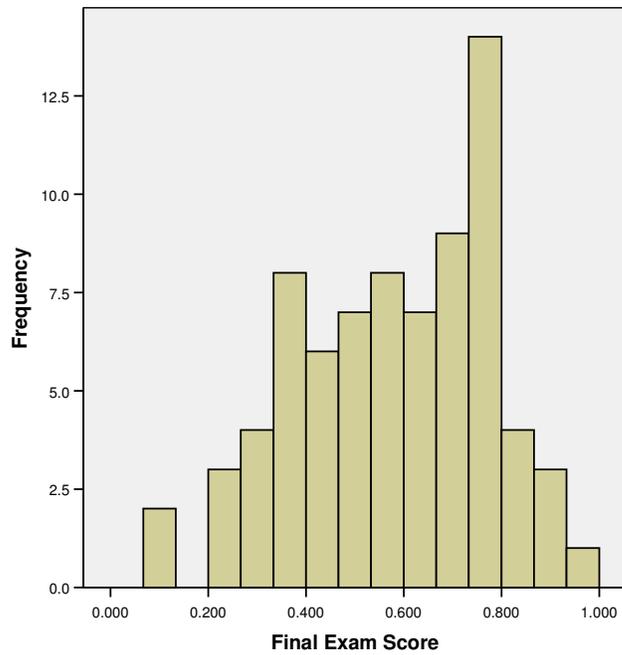


Appendix L

Histogram of Spring 2006 Final Exam Scores



Histogram of Fall 2006 Final Exam Scores



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