

THE DEVELOPMENT AND CONSTRUCT
VALIDATION OF THE EPISTEMOLOGICAL
BELIEFS SURVEY FOR MATHEMATICS

By

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Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirements for
the Degree of
DOCTOR OF PHILOSOPHY
July 2007

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ACKNOWLEDGEMENTS

Delight yourself in the Lord and He will give you the desires of your heart.

Psalm 37:4

First and foremost, I would like to thank my committee, Dr. Laura Barnes, Dr. Diane Montgomery, Dr. Dale Fuqua, and Dr. Kayte Perry. I am so grateful to have had the opportunity to work with these faculty members over the last six years. They have each contributed in unique and significant ways to my development as a scholar and researcher.

I would like to thank my family and friends who provided physical, emotional, and spiritual support throughout this process. My husband, Kenneth, and my daughter, Rachel, have been extremely patient and supportive even when I had to miss family events in order to study. My parents have always supported my educational endeavors and provided assistance in every conceivable form. The camaraderie of fellow graduate students and friends provided continuous encouragement through challenging circumstances.

I would like to thank my Delta Kappa Gamma Society International sisters who demonstrated their commitment to members' professional development through very generous financial support. And finally, a special note of thanks to the late Dr. Elizabeth "Betty" Koball who first introduced me to educational research and encouraged me to pursue a doctoral degree.

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CHAPTER I

INTRODUCTION

The *Principles and Standards for School Mathematics* (NCTM, 2000), generally referred to as the *Standards*, delivered the following description of the outcome of effective mathematics education:

Students are flexible and resourceful problem solvers. Alone or in groups and with access to technology, they work productively and reflectively, with the skilled guidance of their teachers. Orally and in writing, students communicate their ideas and results effectively. They value mathematics and engage actively in learning it. (NCTM, 2000, p.5)

Although there is general consensus among mathematics educators regarding the vision offered by the *Standards*, the implementation of teaching practices and curriculum that reflect the reform movement has been divisive. Implementation of Standards-based curricula has been slow and has, at times, been met with significant opposition (Goldin, 1990; Schoenfeld, 2004). “Epistemologically, with its focus on process, the Standards could be seen as a challenge to the ‘content-oriented’ view of mathematics that predominated for more than a century” (Schoenfeld, 2004, p. 268).

Higher education has been sheltered for the most part from the *math wars* (Goldin, 2003; Schoenfeld, 2004), but there is a growing interest in implementing Standards-based curricula in college level courses (Prichard, 1995). Although the focus of the Standards is K-12 mathematics, the ideals expressed in the vision statement of the Standards apply equally well to college mathematics. A Standards-based instructional approach emphasizes conceptual understanding and reasoning which requires a pedagogical shift from direct instruction to more active engagement including collaborative work, multiple representations, discussion, and writing (Goldsmith & Mark, 1999). Mathematical literacy rather than skill acquisition is the goal of standards-based math instruction.

The publication of the *Standards* launched a research agenda that produced a number of studies reporting a variety of positive outcomes achieved with a standards-based curriculum (Riordan & Noyce, 2001). Senk and Thompson (2003) have edited an extensive review of research on Standards-based curricula implemented at elementary, middle, and high school levels, reporting that students utilizing standards-based curricula do as well as students using traditional curricula on standardized achievement tests but, more importantly, outperformed these students on measures of conceptual understanding and problem solving.

Interestingly, even in the face of extensive research evidence to support Standards-based curricula, a surprising number of parents and students resist attempts by school districts to reform mathematics instruction. Dillon (in McLeod, 1994) conducted an ethnographic study of elementary school mathematics teaching and found that one community felt so strongly about traditional computational mathematics that a reform-

oriented program was nearly terminated. More recently, Lubienski (2004) documented what happened when an affluent mid-western school district offered parents a choice of a traditional algebra course or an integrated mathematics curriculum that was reform-oriented. Of the 600 students enrolled, only 107 (18%) chose the integrated curriculum while 493 (82%) chose the traditional algebra course. These results are surprising for at least two reasons. First, the students had experienced a standards-based middle school mathematics curriculum and second, the majority of parents were college educated with more than 60% having a graduate degree. Goldin (2003) argues that “the chasm that has opened is in part attributable to the long fashionableness of certain epistemologies or theoretical ‘paradigms’ in mathematics education that dismiss or deny the integrity of fundamental aspects of mathematical and scientific knowledge” (p. 174). The epistemological differences that have contributed to the “math wars” (Schoenfeld, 2004) appear to influence parents and students as well as mathematics educators.

Implementation of reform-based curricula in higher education has lagged behind efforts in public education and research on its effects has produced seemingly inconsistent results. Hofer (1999) found that students enrolled in a reform-based calculus course had higher course grades and performed better on common final exam items than students enrolled in a traditional lecture section although large differences in sample size and potential differences in quality of instruction may have biased the results. Other researchers (Norwood, 1994; Windschitl & Andre, 1998) have documented interaction effects of learner characteristics with type of instruction concluding that a reform-based curriculum did not produce the desired outcome for some students. Specifically, Norwood (1994) found no statistically significant achievement differences between

community college students receiving traditional computation oriented instruction in developmental mathematics and relational instruction that focused more on conceptual development and understanding. Interestingly, students with elevated math anxiety preferred the highly structured learning environment of the traditional sections.

Fleener et al. (2002) studied the effects of a mathematics curriculum for elementary pre-service teachers designed to provide context and historical perspective for mathematical concepts. In spite of students' exposure to this curriculum in a sequence of courses taken over several semesters, the authors concluded that the curriculum did not have the desired effect of producing a less technical and more conceptual understanding of mathematics.

These studies suggest that a student's ability to benefit from a standards-based curriculum may be more complex than simply changing the curriculum or instructional environment. A number of researchers (Berenson et al., 1998; De Corte et al., 2002; Frank, 1988, 1990; Hofer, 1999; Kloosterman & Stage, 1992; Schoenfeld, 1989; Stodolsky et al., 1991) have shifted their focus to the effects of general epistemological and math specific beliefs on student engagement, motivation, and achievement. These two distinct areas of research have recently merged to form what is generally referred to as the study of domain-specific epistemological beliefs (Hofer & Pintrich, 2002; Muis, 2004)

Early findings from the mathematical beliefs research documented common perceptions of mathematics held by students. The findings were generally consistent and indicated that students at all levels of instruction viewed mathematics as the memorization of a variety of algorithms (De Corte et al. 2002). *Doing mathematics*

simply meant being able to access the correct algorithm for the problem (Kloosterman, 2002). A related belief that emerged in these studies, that occurs perhaps as a consequence of the belief that mathematics is collection of algorithms, is the idea that problems should be solved quickly. Students tend to believe that if they can not solve a problem in 5 to 10 minutes, the problem is beyond their range of knowledge or ability (Frank, 1988; Schoenfeld, 1989). Researchers consistently found it difficult for students to conceptualize mathematics apart from computation (Frank, 1988; Stodolsky et al., 1991).

A related area of research that emerged simultaneously was a multi-dimensional conceptualization of epistemological beliefs (Schommer, 1990) that synthesized previous research in epistemological development (Perry, 1970; Ryan, 1984), math beliefs (Schoenfeld, 1989), and goal orientation theory (Dweck & Leggett, 1988). Schommer (1990) was the first to hypothesize epistemological beliefs as a set of more or less independent dimensions and subsequent research has for the most part utilized similar dimensions.

Theoretical Framework

Schommer (1990) hypothesized a five dimensional structure of epistemological beliefs including three dimensions regarding the nature of knowledge and knowing and two beliefs related to the nature of learning and intelligence. The beliefs about the nature of knowledge and knowing are based on themes that emerged from developmental theories of personal epistemology (Baxter Magolda, 2004; King & Kitchener, 2004; Perry, 1970) and describe a continuum that ranges from a naïve view of knowledge as

absolute truth consisting of isolated bits of knowledge that are handed down by authority to a more sophisticated view that knowledge is tentative and evolving consisting of interrelated concepts that are constructed. Researchers empirically linked sophisticated epistemological beliefs with demographic variables like age and level of education (Chan, 2003; Jehng, Johnson, & Anderson, 1993; Schommer, 1998) as well as a number of desired learner outcomes including higher mastery test scores, text comprehension (Schommer, Crouse, & Rhodes, 1992), conceptual understanding (Qian & Alvermann, 1995), meta-cognitive study strategies (Chan, 2003), and GPA (Paulsen & Wells, 1998; Schommer, 1993a)

Beliefs about the nature of intelligence were derived from research in implicit-theories of intelligence (Dweck & Leggett, 1988; Dweck, 2000). The essence of this dimension is that people generally hold either a fixed or an incremental view of intelligence. A person with a fixed view generally takes a deterministic view of intelligence and would endorse the idea that you have only what you are born with and no more. The person with a more sophisticated or incremental view believes that intelligence functions more like a skill that can be improved with effort. Implicit theories of intelligence have been empirically linked with both demographic variables like age and gender (Paulsen & Wells, 1998) and academic variables such as reflective judgment (Bendixen, Dunkle, & Schraw, 1994) and meta-cognitive study strategies (Chan, 2003). This variable also effectively predicted whether teacher education students held a traditionalist or constructivist view of the teaching/learning process (Chan & Elliott, 2004a).

The dimension designed by Schommer (1990) to assess the nature of learning was based on research in math related beliefs and their influence on learning (Schoenfeld, 1988, 1989) and is generally referred to as the speed of knowledge acquisition. This belief ranges from a naïve view that learning happens quickly or not at all to a more sophisticated view that learning is a gradual process that requires continued effort and persistence. This belief has been linked to a number of positive learner outcomes including better text analysis, higher scores on mastery tests, and higher GPA (Schommer, 1990, 1993a).

Previous research in epistemological development had used extensive interviews as a method of data collection (Baxter Magolda, 2004.; Belenky, Clinchy, Goldberger, & Tarule, 1986; King & Kitchener, 2004; Perry, 1970) but with the multi-dimensional theory came the use of Likert-type scales beginning with the Epistemological Questionnaire (EQ, Schommer, 1990). The EQ was designed to measure five hypothetical dimensions of epistemological beliefs including beliefs about the stability, structure, and source of knowledge, the speed of learning, and the ability to learn. The data from the initial validation studies (Schommer, 1990, 1993, 1998) failed to produce factors corresponding to all five hypothesized dimensions but a fairly consistent four factor structure did emerge. Since the development of the Epistemological Questionnaire (EQ), numerous factor structure studies have been conducted using this instrument or some variation of the instrument (Braten & Stromso, 2005; Chan & Elliott, 2000; Clarebout, Elen, Luyten, & Bamps, 2001; Cole, 1996; Jehng et al., 1993; Qian & Alvermann, 1995; Schraw, Bendixen, & Dunkle, 2002; Wood & Kardash, 2002). All of these studies, utilizing item level factor analysis, have failed to consistently replicate

either the five-factor hypothesized structure or the four-factor structure supported in the initial validation study (Schommer, 1990). In addition, coefficient alpha measures of internal consistency reported in these studies range from .10 to .79 with most in the .50 to .60 range. One attempt at convergent validity of this construct utilizing two similar instruments, Schommer's Epistemological Questionnaire and the Epistemic Beliefs Inventory (Schraw et al., 2002), produced similar factor structures but the correlations between corresponding factors was small enough for the authors to conclude that "it is unclear what these two instruments measure and the extent to which they measure the same or unrelated constructs" (Schraw et al., 2002).

Statement of the Problem

In spite of the questionable psychometric properties of popular epistemological belief scales, researchers have explored the relationship among math related beliefs, epistemological beliefs, and achievement (Koller, 2001). A survey of college algebra students (Berenson et al., 1998) revealed significant differences in high and low achieving students with regard to math related beliefs. Low achieving students were more likely to have rigid beliefs, viewing mathematics simply as a collection of rules and procedures. High achieving students had a more flexible view, conceptualizing mathematics as a reasoning tool where any given procedure was viewed as one of many possible ways to solve a problem. A study conducted with middle-school students (Schommer-Aikins, Duell, & Hutter, 2005) found that the belief in Quick/Fixed Learning and the belief that math is useful significantly predicted scores on a mathematical problem solving task. A student who endorses the belief in Quick/Fixed Learning

believes that persons are generally born with a fixed quantity of a trait, math ability for example, and that students who are really good at math learn it quickly and do not have to work very hard.

The development of mathematics beliefs has also been related to learning environments (Carter & Norwood, 1997; Frank, 1988; Franke & Carey, 1997; Schoenfeld, 1988). At the conclusion of a year long observational study in a typical high school geometry class, Schoenfeld (1988) stated that, “The students developed perspectives regarding the nature of mathematics that . . . were likely to impede their acquisition and use of other mathematical knowledge” (p. 145). The student perspectives documented by Schoenfeld were produced by a learning context where the curriculum was driven by the text and by state mandated achievement tests. In fact, instructional effectiveness was measured by performance on a statewide achievement test. As a result, a number of topics were taught as step-by-step procedures that had to be memorized to ensure adequate performance on the exam. Mathematical practice consisted of textbook exercises where speed and efficiency were emphasized. One instructor commented to students that, “You’ll have to know all your constructions cold so you don’t spend a lot of time thinking about them” (Schoenfeld, 1988, p. 159).

If beliefs are formed as a result of the structure of instructional contexts, then it is important for beliefs to be addressed directly in mathematics classrooms, teacher education programs, and professional development programs. Teachers and students must be made aware of beliefs that may influence learning outcomes. It follows that in order for mathematics beliefs to be addressed, they must be assessed. One of the most efficient

methods of measuring student and/or teacher beliefs is the use of scales that can be quickly scored and analyzed to provide feedback to students and teachers.

One of the most frequently used instruments to measure student beliefs is a general measure of epistemological beliefs, the Epistemological Questionnaire (Schommer, 1990). Math-specific measures that are cited less frequently include the Indiana Mathematics Belief Scales (Kloosterman & Stage, 1992) and Mathematical World Views (Koller, 2001) which includes items from instruments developed by Schommer (1990) and Schoenfeld (1988). The scales listed above have failed to demonstrate adequate construct validity and all three have failed to produce adequate internal consistency reliabilities.

One compelling explanation for the weak psychometric performance of these instruments is an alternative conceptualization of personal epistemology as a collection of context sensitive cognitive resources, rather than a set of relatively stable, multidimensional beliefs (Elby & Hammer, 2001; Hammer & Elby, 2002; Louca, Elby, Hammer, & Kagey, 2004). A number of items on the most popular measures of epistemological beliefs could elicit either a naïve or sophisticated response from the same participant based on the context applied to the statement. For example, one statement from the Epistemic Beliefs Inventory (EBI) states, “What is true is a matter of opinion.” (Schraw et al., 2002). Relativistic thinking is generally considered more epistemologically sophisticated so that strong agreement with this statement would generate a higher score on the instrument. An epistemologically sophisticated person could, however, strongly disagree with the statement if interpreted in terms of certain elements of scientific or historic knowledge like water is made up of molecules

containing hydrogen and oxygen or millions of Jews perished during the Holocaust. The point is, a person's response to this statement cannot be adequately judged as naïve or sophisticated without understanding the contextual formation of the response.

Examination of the most popular measures of epistemological beliefs including Schommer's Epistemological Questionnaire (Schommer, 1990) and the Epistemic Beliefs Inventory (Schraw et al., 2002) reveal the use of vague and ambiguous language that, devoid of context, lends itself to multiple interpretations. This lack of consistency of interpretation may explain the psychometric inconsistencies across numerous factor structure studies that have failed to produce Schommer's hypothesized factor structure or replicate her results (Braten & Stromso, 2005; Chan & Elliott, 2000; Clarebout et al., 2001; Cole, 1996; Jehng et al., 1993; Qian & Alvermann, 1995; Schraw et al., 2002; Wood & Kardash, 2002).

More recently, researchers have begun to focus on domain or discipline specific epistemological beliefs (Buehl, Alexander, & Murphy, 2002; Hofer, 2000; Schommer & Walker, 1995; Stodolsky et al., 1991) and the results suggest that students' epistemological beliefs vary by domain. Specifically, researchers have documented distinct views of knowledge and learning between domains like mathematics and social studies (Buehl et al., 2002; Stodolsky et al., 1991). Research related to mathematics beliefs has documented that students generally view mathematics knowledge as static, believe the goal of problem solving is to produce the *right* answer, believe that mathematics knowledge is passively received from a teacher, and believe that mathematics skill is either something you have or you don't (Kloosterman, 2002; Lerch, 2004; Mtetwa & Garofalo, 1989; Schoenfeld, 1989). Additionally, mathematics beliefs

have been shown to influence how learners engage in the problem solving process and subsequent learner outcomes (Lerch, 2004; Schommer-Aikins et al., 2005). “Often students’ difficulties with mathematical tasks can be directly attributable to unhealthy beliefs about the nature of mathematics, school mathematical tasks, and mathematical behavior and such beliefs are not always readily identified nor are they always readily overcome” (Mtetwa & Garofalo, 1989, p. 611).

The psychometric inadequacies of the general epistemological belief instruments currently used in educational studies may be due to a lack of contextual reference for students to use in responding to statements. Domain specific instruments have simply inserted a word or phrase regarding a particular field of study into the generic instruments rather than to provide a richer discipline specific context. The purpose of the current study was to develop and evaluate a new scale, namely the Epistemological Beliefs Survey for Mathematics, designed to measure epistemological beliefs specific to the context of mathematical learning.

Research Questions

The following research questions were addressed in this study:

1. Is the Epistemological Beliefs Survey for Mathematics (EBSM) a reliable and valid measure of mathematics related epistemological beliefs?
2. What is the nature of the relationship between contextualized beliefs as measured by the EBSM and general epistemological beliefs measured by the Epistemic Beliefs Inventory?

3. What is the nature of the relationship between contextualized epistemological beliefs as measured by the EBSM and achievement goals as measured by the Achievement Goals Inventory?
4. What is the nature of the relationship between mathematics related epistemological beliefs as measured by the EBSM and implicit theories of intelligence as measured by the Theories of Intelligence Scale?

Significance of the Study

It appears that a person's epistemological orientation influences engagement, motivation, and academic performance. General epistemological beliefs have been empirically linked to a number of learner outcomes including study strategy use, text comprehension, achievement test performance, and GPA. Research also supports the notion that teachers directly influence the development of epistemological beliefs through instructional practice, which is influenced by their own epistemological beliefs. Epistemological beliefs of both students and teachers play a significant role in the successful implementation of standards-based curriculum in higher education and, therefore, meaningful measurement of mathematics related epistemological beliefs should provide an effective tool in implementing the vision of mathematics instruction provided in the *Standards*.

In addition, this study addresses issues recently identified as research areas in need of further study. Specifically, exploration of the relationship of EBSM and EBI scores and structure were identified as a direction for future research after an extensive review of literature related to personal epistemology and mathematics (Muis, 2004). The

EBSM fills a void, in that existing domain specific scales are based solely on general epistemological belief measures and suffer from similar psychometric inconsistencies. Existing mathematics beliefs scales have generally not been subjected to psychometric analysis leading DeCorte et al (2002) to state that “more comprehensive instruments have to be designed and validated” (p. 315), which is the major purpose of the current study.

CHAPTER II

REVIEW OF LITERATURE

In our most mundane encounters with new information and in our most sophisticated pursuits of knowledge, we are influenced by the beliefs we hold about knowledge and knowing.

Hofer, 2002, p. 3

Defining characteristics of personal epistemology vary based on the theoretical orientation of the researcher. The result is a lack of coherence regarding the definition of personal epistemology as a construct (Hofer & Pintrich, 1997). The purpose of this chapter is to explore the theoretical foundations of the construct including developmental, multidimensional, and integrated models of personal epistemology. Numerous psychometric studies have been conducted using variations of Schommer's (1990) Epistemological Questionnaire. A review of these studies is presented with emphasis on the psychometric properties, including dimensionality, reliability, and validity, of this widely used instrument. Studies utilizing domain-specific versions of the instrument are also reviewed with emphasis on reported psychometric properties. Two parallel lines of research that have recently been integrated with personal epistemology, implicit theories of self and domain-specific epistemological beliefs are reviewed. Finally, a definition of

mathematics related epistemological beliefs is presented and a review of scales developed to measure mathematics beliefs is presented.

Theories of Personal Epistemology

The following section presents the various theoretical models used to conceptualize personal epistemology. These include developmental models, cognitive models, multi-dimensional models, resource models, domain specific models, and finally, integrated models. Of particular interest were similarities and differences across models and the historical development of the construct.

Developmental Theories

The foundations of developmental theories of epistemological beliefs are a series of studies (Baxter Magolda, 2002; Belenky et al., 1986; Perry, 1970) based on longitudinal and cross-sectional interview data that documented a progression in students thinking through college and beyond. Although the theorists each use distinct language to describe the stages of this progression there is a great deal of similarity in the substance of the stages across models. Generally, these models describe a progression from an absolutist or received understanding of knowledge to an eventual understanding of knowledge as contextual and self-constructed.

William Perry's (1970) seminal work is identified throughout the literature as the foundation to personal epistemological research. In fact, "nearly all the existing psychological work on epistemological beliefs and theories can be traced to two longitudinal studies by Perry" (Hofer, 2000, p. 379). Perry used extensive longitudinal

interviews with male students at Harvard during the 1950s and 60s to document what he calls “an intellectual *Pilgrim’s Progress*”. This developmental progression of qualitative change in students’ views of knowledge and learning encompasses nine positions which move from a dualistic or absolutist view of knowledge to a more relativistic view culminating in commitment, the willingness to adopt a position while understanding that new information may cause one’s position to change. Perry’s ultimate contribution was that a student’s view of knowledge better explained student learning experiences and engagement than motivation, study skills, or ability (Moore, 2002).

As Perry’s ideas were generating interest, a group of women researchers at Harvard, influenced by Carol Gilligan (1982), asked whether Perry’s model applied equally well to female samples. Although Perry included female students in his original samples, his model was developed on transcripts from the male students. Belenky et al. (1986) used Perry’s model as a frame for analyzing the epistemological beliefs of an exclusively female sample that included university students as well as lesser educated social service clients. The result was a developmental stage theory similar to Perry’s in some respects, but utilized distinct language, as the focus of their interviews was on the woman’s conception of herself as knower rather than her view of knowledge (Clinchy, 2002). The underlying theme of movement from absolutist to relativistic thinking also emerges in this model which describes the process in terms of the knower. Belenky et al. (1986) use terms like received knowing to describe one end of the continuum that represents knowledge as absolute truth that is dispensed by an authority. The other end of the continuum is constructed knowing, a position where the knower expresses a constructivist view of knowledge and understands her involvement in the process.

Marcia Baxter Magolda (2002), building on the work of both Perry (1970) and Belenky et al. (1986), sought to explore a “gender-inclusive model of epistemological development” (p. 91). This theory was based on a longitudinal study beginning with a gender balanced sample of college freshmen that were followed into adulthood. The result was the Epistemological Reflection Model, a developmental model similar to those that preceded it in that the stages represent a general transition from *Absolute knowing* to *Contextual knowing*. Baxter Magolda was able to add to Perry (1970) and Belenky et al. (1986) in that although gender differences had been suggested after the publication of *Women’s Ways of Knowing*, Baxter Magolda was able to more directly explore gender differences in epistemological reasoning by using a gender balanced sample. Specifically, she was able to discern that both genders followed the same basic developmental sequence but found subtle gender differences within early developmental stages that seem to dissipate as students progress beyond college.

Cognitive Theories

Cognitive theories evolved from the developmental theories previously described and consequently share a common structure and language. Like developmental theories, these models describe a sequence of levels or stages that progress from absolutist to relativistic thinking reflected in responses to questions designed to assess a student’s reasoning process when presented with a problem (King & Kitchener, 2002; Kuhn, 2001; Kuhn & Weinstock, 2002). Major differences from previous models include attempts to validate the developmental sequence by using structured interviews with a standardized

rating process, incorporating paper-pencil evaluation tools, and focusing exclusively on cognitive processes.

The Reflective Judgment Model (King & Kitchener, 2002) uses *ill-structured* problems, written as opposing viewpoints about a controversial issue (Wood, Kitchener, & Jensen, 2002) to assess epistemological development. A standard interview protocol is used to explore how students evaluate the conflicting claims on a given issue. Three distinct levels, labeled pre-reflective, quasi-reflective, and reflective, have been observed to describe student reasoning. The three pre-reflective stages are characterized by thinking that is absolutist. Knowledge is certain and correct answers exist for all questions. The source of knowledge is authority figures. The two stages of quasi-reflective thinking are characterized by the recognition of uncertainty and the growing realization that knowledge is constructed. The student can see different approaches to a problem or question. Students in the final two stages of reflective thinking are able to place knowledge in context. They are willing to re-evaluate perspectives as new information is made available.

Kuhn (1999) has proposed a four-stage theory of epistemological understanding. Within each of the realist, absolutist, multiplist, or evaluativist stages is a distinct understanding of assertions, reality, knowledge, and critical thinking. Participants are evaluated with a standardized interview protocol and assigned to one of the four stages of reasoning based on their responses to an account of a fictional civil war written from two perspectives. Typically, students' reasoning moves from realist, characterized by inability to distinguish differences between accounts to conceptual evaluativist, where

differences are attributed to the different perspectives of the writers and acknowledgement that no *true* account can be determined.

Multi-dimensional Theories

Schommer's (1990) multi-dimensional theory of epistemological beliefs represented a significant shift in epistemological research. Until the publication of her model, all existing models were represented as developmental sequences with substantial overlap in structure and language. Schommer's theory characterized epistemological beliefs as a set of "more or less" independent dimensions. Initially, her theory consisted of five epistemological dimensions based on previous research that address the certainty, structure, and source of knowledge, and the control and speed of knowledge acquisition.

The first of Schommer's (1990) hypothesized dimensions, certainty of knowledge, describes a continuum that ranges from a naïve view of knowledge as absolute truth to a more sophisticated view that knowledge is tentative and evolving. The foundation for this element of personal epistemology was the observation of developmental theorists (Baxter Magolda, 2004; King & Kitchener, 2004; Perry, 1970) that students tended to move from an absolutist to a relativistic understanding of knowledge as they progressed through higher education.

A second hypothesized dimension is the structure of knowledge which reflects a continuum ranging from understanding knowledge as isolated bits to an understanding of knowledge as interrelated concepts (Schommer, 1990). Other theorists (Hofer & Pintrich, 1997) conceptualize this dimension slightly differently, describing this continuum ranging from knowledge as a simple collection of discrete, concrete,

knowable facts progressing to a view of knowledge as integrated, complex, and contextual. Subsequent research has linked more sophisticated views on this factor with higher mastery test scores administered after brief learning scenarios (Schommer, Crouse, & Rhodes, 1992) indicating that students adopting a more sophisticated view approach learning as more complex than the memorization of facts.

The final dimension acquired from Perry's (1970) seminal work, is labeled source of knowledge. This dimension reflects a range of views regarding the role of an authority figure. The naïve view is the belief that knowledge is external to the learner and thus knowledge must be obtained from an authority. The more sophisticated view reflects a constructivist understanding of the learning process as an interactive event with the learner functioning as an active participant rather than a passive recipient. Interestingly, this is the only hypothesized dimension that has failed to emerge in factor analytic studies of Schommer's Epistemological Questionnaire (Schommer, 1990; Schraw et al., 2002; Wood & Kardash, 2002).

The fourth hypothesized dimension, control of knowledge acquisition, was derived from research in implicit-theories of intelligence (Dweck & Leggett, 1988; Dweck, 2000). The essence of this dimension is that people generally hold either a fixed or an incremental view of intelligence leading Schommer (1990) to name this dimension Innate Ability. A person with a fixed or naïve view of innate ability generally takes a deterministic view of intelligence and would endorse the idea that you have only what you are born with and no more. The person with a more sophisticated or incremental view of innate ability believes that intelligence functions more like a skill that can be improved with effort.

A fifth and final dimension, based on research in math related beliefs and their influence on learning (Schoenfeld, 1988, 1989), is speed of knowledge acquisition. This belief ranges from the naïve view that learning happens quickly or not at all to the more sophisticated view that learning is a gradual process that requires continued effort and persistence. This belief has been linked to a number of positive learner outcomes including better text analysis, higher scores on mastery tests, and higher GPA (Schommer, 1990, 1993a).

Prior research on epistemological theories had used qualitative interview techniques but Schommer (1990) decided to pursue a quantitative factor analytic approach to construct validity. Schommer's Epistemological Questionnaire (EQ) was constructed and subsequently factor analyzed using two or three item parcels for each hypothesized dimension. A total of 12 parcels were constructed with each parcel containing 2 to 11 items. The initial validation was conducted on a sample of 266 community college and university students. No internal consistency reliability estimates were reported. Principal axis factor analysis yielded four factors with eigenvalues greater than one and orthogonally rotated to a final solution. The four factors, Innate Ability, Simple Knowledge, Quick Learning, and Certain Knowledge, aligned with four of the hypothesized factors although not all parcels produced significant loadings nor did all parcels load on the theoretical factor they were constructed to represent (a more detailed critique of this instrument is provided later). In spite of its psychometric inadequacies the EQ has become the most popular measure of general epistemological beliefs currently in use.

Barbara Hofer (2000) produced a similar multi-dimensional theory from an extensive analysis of existing theories (Hofer & Pintrich, 1997). Hofer and Pintrich (1997) first posited a nested theory of epistemological beliefs with both certainty and simplicity of knowledge contained within a broader core construct labeled nature of knowledge. A second core construct, nature of knowing, encompasses an additional two dimensions, source of knowledge and justification for knowing. Definitions of the first three dimensions correspond with Schommer's theory. The unique element in Hofer's (2000) theory, justification for knowing, references "how individuals evaluate knowledge claims, including the use of evidence, the use they make of authority and expertise, and their evaluation of experts" (p. 381).

Hofer (2000) also used quantitative techniques to validate her multidimensional theory and developed a discipline-focused epistemological beliefs questionnaire. The items were similar to those included in Schommer's EQ with the exception that students were asked to consider a specific academic discipline (psychology or science) as they responded to items. A four-factor structure, similar to the structure of the EQ, emerged for both of the 18-item versions of the instrument, although, they varied somewhat from the hypothesized structure. The four factors were labeled; Certain/Simple Knowledge, Justification for Knowing: Personal, Source of Knowledge: Authority, and Attainability of Truth (a more complete psychometric review is provided in a subsequent section). Hofer concluded that although Certainty and Simplicity merged to form a single factor and Attainability of Truth emerged unexpectedly, there was sufficient evidence to support a multi-dimensional theory of epistemology.

Epistemological Resource Theory

Hammer and Elby (2002) have proposed epistemological resources as an alternate conceptualization of personal epistemology to both developmental and multi-dimensional theories. Epistemological resources are defined as “units of cognitive structure at a finer grain size than stages, beliefs, or theories” (Louca et al., 2004, p. 58). Consider Schommer’s hypothesized dimension, source of knowledge, which describes a continuum from understanding knowledge as handed down by authorities to learner constructed. Elby and Hammer (1999) would posit that it is more likely that a learner can hold both views simultaneously and engage one or the other depending on context. For example, an algebra student can quickly understand that an equation is simply a sequence of invented symbols (knowledge is constructed) yet also rely on teacher provided procedures for solving an equation (knowledge is handed down from authority). The same student may rely on instructor provided strategies for solving the equation but simultaneously believe that understanding will only come with experience in working problems independently. The complexity of this student’s epistemological framework could not be assessed with a generic question regarding the role of authority in transmitting knowledge.

A major contribution of epistemological resource theory is the questioning of consensus regarding what constitutes sophisticated epistemology. This consensus view, the term used for a view of knowledge represented across all existing developmental and multi-dimensional theories and models, proposes that a sophisticated personal epistemology views knowledge as tentative, evolving, and socially constructed rather than certain, unchanging, and discovered (Elby & Hammer, 2001). Hammer and Elby

(2002) propose a distinction between correctness and productivity of beliefs with attention to the interaction of beliefs and contextual elements. “It is hardly sophisticated, for example, to consider it ‘tentative’ that the earth is round, that the heart pumps blood, or that living organisms evolve” (p. 186).

Domain Specific Models

Researchers have also approached this construct as domain or discipline specific (Buehl et al., 2002; Hofer, 2000; Schommer & Walker, 1995; Stodolsky et al., 1991) and the results of empirical studies support this conceptualization, although, the methodological approaches used in these studies make comparisons difficult. For example, Schommer and Walker (1995) used a general measure of epistemological beliefs, asked participants to keep a particular academic domain in mind as they answered questions, and concluded that there was no support for substantive differences across domains after comparing mathematics focused responses to social science responses. Schommer-Aikins et al. (2003) repeated this study using the same general epistemological instrument and the Biglan (1973a, 1973b) classification system to refine the sample selection (Biglan’s model is more thoroughly discussed in a subsequent section). The study produced similar results and the researchers concluded “that epistemological beliefs of college undergraduates are moderately domain general” (p. 360). Jehng et al. (1993) however, administered a general measure of epistemological beliefs and looked at differences in response patterns across academic major. Differences were found in three of the five epistemological factors measured, leading to the conclusion that “students who study in soft fields have a stronger tendency to believe that

knowledge is uncertain, are more reliant on their independent reasoning ability, and have a stronger feeling that learning is not an orderly process” (p. 31).

Other researchers have developed domain specific measures of epistemological beliefs (Buehl et al., 2002; Hofer, 2000). Hofer (2000) constructed the Discipline-Focused Epistemological Beliefs Questionnaire to measure the four consensus dimensions of personal epistemology, certainty, simplicity, and source of knowledge and justification for knowing. Subsequent factor analysis on both psychology and science versions of the discipline-focused instruments, produced a four factor structure somewhat different than the hypothesized structure. The emergent factors were named, Certainty-Simplicity (contained items from both theoretical dimensions), Justification for Knowing, Source of Knowledge, and Attainment of Truth. Although the factor structure was similar across instruments the mean scores were significantly different with the science-focused instrument producing higher (less sophisticated) mean scores than the psychology-focused instrument.

Buehl et al. (2002) constructed the Domain-Specific Belief Questionnaire (DSBQ) based on Schommer’s Epistemological Questionnaire. Each item was included twice, once using the word history and one with the word mathematics. Initially a two factor solution emerged, one primarily consisting of history items and one with math items. Two subsequent confirmatory studies found improved fit in a four factor model and this model was adopted for subsequent analysis. Results of multivariate analysis of variance found significant mean differences by domain. Specifically, students believed that learning mathematics required more effort than learning history and believed

mathematics was integrated with other academic disciplines to a greater extent than history.

Integrated Models

Recently, perhaps as a result of the lack of a unified conceptualization of personal epistemology as a construct and inconsistencies across factor structure studies, several researchers representing various theoretical orientations have proposed integrated models that consist of dimensional, developmental, and contextual elements. Hofer (2001) first suggested that “We may be moving toward an integration of ideas from multiple models: *an identifiable set of dimensions of beliefs, organized as theories, progressing in reasonably predictable directions, activated in context, operating as epistemic cognition*” (p. 377). Since the publication of that statement, a number of integrated models have been proposed. Multi-dimensional theorists are suggesting that there are developmental components within various dimensions (Bendixen & Rule, 2004) and developmental theorists are suggesting that developmental sequences may vary by domain (Clinchy, 2002). In other words, students may function at one level in a humanities context but function at a different level in a science context. Schommer-Aikins and Easter (2006) recently examined the relationship between elements of ways of knowing (Belenky et al., 1986) and epistemological beliefs using two survey instruments. They found correlational evidence for a relationship between connected and separate knowing and various dimensions of epistemological beliefs. More detailed analysis is difficult to interpret due to psychometric inadequacies of the instrument used to measure general epistemological beliefs.

Several researchers (Bendixen & Rule, 2004; Hofer, 2004; Schommer-Aikins, 2004) now propose that personal epistemology is a function of metacognitive processes. The major difference in the theories is whether metacognition is viewed as an antecedent to epistemological beliefs (Bendixen & Rule, 2004; Hofer, 2004) or a consequent (Schommer-Aikins, 2004). Bendixen and Rule (2004) have generated a complex model that includes both developmental and multidimensional elements with cognitive abilities, epistemological beliefs, and beliefs change strategies all functioning under a metacognitive umbrella. Hofer (2004) posits a multidimensional theory of metacognitive processes that includes metacognitive knowledge and metacognitive judgments and monitoring. The model places beliefs about the nature of knowledge and beliefs about the self as a knower within metacognitive knowledge, while beliefs about the nature of knowing including the source of knowledge and justification for knowing are placed under metacognitive judgments and monitoring. These theories are similar in that metacognition is viewed as an antecedent of epistemological belief formation and change.

Schommer-Aikins (2004) has also produced a model that includes reciprocal relationships among beliefs about knowledge, beliefs about learning, classroom performance, and self-regulated learning similar to the previous models. Metacognition, however, is viewed as a category of self-regulated learning which is reciprocally influenced by epistemological beliefs and academic performance. In other words, epistemological beliefs exert a direct influence on and are influenced by metacognitive processes.

Little empirical testing of these models has been completed, but in one series of studies evaluating epistemic metacognition through student observation, Hofer (2004)

found evidence for each of the four previously discussed dimensions of personal epistemology, Simplicity, Certainty, Source of Knowledge and Justification for Knowing. Student strategies also varied by academic discipline providing support for domain differences.

Quantitative Measures of Epistemology

Although qualitative methodologies dominated epistemological research in the 1970s and 80s, there were attempts to develop a quantitative measure of personal epistemology (Perry, 1968; Ryan, 1984). Initially, the goal was to evaluate students' level of epistemological development on a dualistic – relativistic continuum (Ryan, 1984) therefore, the first instruments simply measured adherence to dualistic statements. There have been at least two attempts to transform the Reflective Judgement Interview (RJI) into a paper pencil-pencil measure (Martin, Silva, Newman, & Thayer, 1994; Wood et al., 2002), although neither instrument produced results entirely consistent with results obtained using the standardized interview protocol. It was Schommer's (1990) alternate conceptualization of personal epistemology as a multi-dimensional set of beliefs, however, that initiated a methodological shift toward quantitative measurement of the construct.

Epistemological Questionnaire (EQ)

The EQ (Schommer, 1990) was based on work by Ryan (1984), Schoenfeld (1989), and Dweck & Leggett (1988) and was validated in a sequence of studies (Schommer, 1990, 1993a; Schommer et al., 1992). Schommer (1990) initially wrote 63

items divided into 12 subsets to measure the five hypothesized dimensions of personal epistemology, which included structure, certainty, and source of knowledge and the control and speed of knowledge acquisition. The survey was administered to 263 students, primarily freshmen and sophomores. The results of factor analysis and orthogonal rotation using the 12 subsets as variables yielded four factors; Simple Knowledge, Certain Knowledge, Innate Ability, and Quick Learning, each named for the naïve view of epistemology it represents (see Table 1). The subsets of items that comprised the hypothesized Omniscient Authority factor produced low loadings across factors. For example, the sub-set, *don't criticize authority* produced loadings ranging from .26 to .33, and the subset, *depend on authority*, produced loadings ranging from -.20 to .27. In addition, some of the subsets did not load on the hypothesized factor. For example, the subset of items, *avoid ambiguity*, was hypothesized to measure an element of Certain Knowledge but produced a factor loading of .68 on Simple Knowledge. Two of the three subsets that were hypothesized to form the Quick Learning factor actually loaded on the first factor, Innate Ability, and one of these subsets, *learn the first time*, actually produced the largest loading (.62) on the Innate Ability factor.

No reliability information was provided but predictive validity was assessed using a subgroup of the initial sample ($n = 86$). Students read excerpts of texts from either psychology or nutrition and were asked to write a concluding paragraph for the passage, complete a mastery test, and rate their confidence in comprehending the passage. Multiple regression analysis was performed with background variables entered first (verbal ability, prior knowledge, and gender) followed by the four epistemological factors, Innate Ability, Simple Knowledge, Quick Learning, and Certain Knowledge.

The results indicated that students who expressed a belief in Quick Learning (learning happens quickly or not at all) tended to write oversimplified conclusions, performed poorly on the psychology mastery test and expressed overconfidence in their comprehension of the passage. Certain knowledge and prior knowledge, measured by the number of classes taken in the field related to the passage, predicted the tendency to write definitive conclusions. In other words, students with higher (less sophisticated) scores on Certain Knowledge were more likely to write absolute conclusions while students with more prior knowledge tended to write more tentative conclusions.

A second study (Schommer et al., 1992) was conducted to further establish the construct validity of the EQ. The sample for the factor replication study consisted of 412 introductory psychology students. Using the same procedures as the previous study, principal axis factor analysis followed by the orthogonal rotation of factors with eigenvalues larger than 1.0, three factors were generated that accounted for 46% of the total variance. The major structural difference from the first study was the merger of Innate Ability and Quick Learning into a single factor.

A re-examination of the eigenvalues generated from the factor analysis led to the decision to force a four-factor solution based on the size of the fourth eigenvalue (.96). The four factor solution was similar in structure to the initial validation study (see Table 1). Both three-factor and four-factor models were compared using confirmatory factor analysis and the four-factor model provided a significantly better fit to the data. As a result, the four factor model was used in subsequent analyses.

A subset of the initial sample ($n = 138$) participated in a subsequent validation study. Participants read a passage containing information from an elementary statistics

text and were asked to evaluate their confidence in understanding the passage. In addition, students provided information regarding their prior knowledge of mathematics and statistics, completed a study strategies inventory, and answered questions designed to evaluate their comprehension of the passages.

Regression analysis revealed that both prior knowledge and Simple Knowledge produced statistically significant increments in explained variance of comprehension scores. In other words, the more experience students had with mathematics or statistics the better they performed on the comprehension test. Additionally, the less they believed that knowledge is discrete, unambiguous, and handed down by authority, the better they performed on the test over and above the influence of prior knowledge. Simple Knowledge also proved to be a significant predictor of overconfidence in text comprehension. It should be noted that the correlations among prior knowledge and various epistemological belief dimensions was not reported, but significant correlations among regression predictors makes judgments about the relative influence of any single predictor impossible and may have masked the contribution of other epistemological factors.

A third factor replication study was conducted utilizing a sample of 1182 high school students (Schommer, 1993a). Minor wording changes were made to the original instrument written for college samples, based on suggestions from a pilot study. Principal axis factor analysis yielded a four-factor solution accounting for 53% of the variance (see Table 1). Internal consistency reliability estimates are reported for the first time and range from .51 to .78. These reliability estimates, however, were calculated after students judged to be “in transition” (i.e. students with mid-range raw scores) were

removed from the sample. A footnote states that the initial reliabilities calculated on the full sample ranged from .45 to .71. Statistically speaking, removing mid-range scores from a data set can result in over estimation of variable relationships. It is possible that mid-range scores were a function of the items rather than the epistemological status of the students.

Schommer (1993a) conducted a MANOVA using each of the four epistemological factors as dependent variables with classification (i.e. freshman, sophomore, junior, or senior) and gender as independent variables to assess developmental trends in epistemological beliefs. There were significant main effects reported for both gender and classification. Specifically, girls had more sophisticated beliefs on both the Fixed Ability and Quick Learning factors. Additionally, there was a linear trend noted with regard to three epistemological factors. Simple Knowledge, Quick Learning, and Certain Knowledge scores decreased as students progressed through high school. In other words, the epistemological beliefs of seniors were more sophisticated than those of freshmen. Regression analyses indicate that when GPA is regressed on Fixed Ability, Simple Knowledge, Quick Learning, and Certain Knowledge, all four epistemological factors made a small but statistically significant contribution to the prediction of GPA. In a second analysis, GPA was once again regressed the four epistemological factors after controlling for the effects of general intelligence. The results were similar in that, all five variables, IQ, Fixed Ability, Simple Knowledge, Quick Learning, and Certain Knowledge were significant predictors of GPA in the revised analysis indicating that the three epistemological factors accounted for significant GPA variance beyond that explained by IQ.

Using the same sample of high school students, Schommer and Dunnell (1994) examined the differences in epistemological beliefs between gifted and non-gifted students. Results of a series of four ANCOVAs, one for each of the four epistemological factors, and post hoc analyses indicate that “while gifted students change their beliefs in Simple Knowledge and Quick Learning over the high school years, the non-gifted students’ beliefs remain stable” (p. 210). Additionally, a gender difference was found for Quick Learning with boys holding a stronger belief in Quick Learning than girls.

The fourth, and final validation study (Schommer, 1998) was conducted with a sample of 418 working adults in a diverse range of occupations including, farmers, lawyers, homemakers, executives, and teachers. The sample was structured so that there was approximately equal representation with regard to educational experience. Exploratory factor analysis was conducted using the 12 item parcels previously described as variables (Schommer, 1990; 1993a; Schommer et al., 1992). The result was a four factor solution accounting for 53% of the variance and similar in structure to that described in previous studies (see Table 1). No reliability estimates were reported. The relationship of epistemological beliefs and two demographic variables (i.e. age and level of education) were explored using multiple regression. Specifically, each epistemological factor was regressed on age and education. The only epistemological factor predicted by age was Fixed Ability with older adults less likely to believe that ability to learn is innate. Level of education was related to two epistemological factors, Simple Knowledge and Certain Knowledge. Persons with higher levels of education were less likely to view knowledge as simple or certain.

After this initial sequence of validation studies, Schommer's research utilizing the EQ no longer employed factor structure analysis. The replication of the four factor structure across studies led Schommer to advocate the use of factor coefficients established during the initial validation studies, along with sample specific means and standard deviations, to compute factor scores for various statistical analyses (Schommer, 1993b; Schommer & Walker, 1995, 1997; Schommer-Aikins, Duell, & Barker, 2003). This practice seems questionable in light of the observation that four of the twelve item parcels loaded inconsistently or failed to load (see Table 1) and there has been no revision of these four parcels.

In the studies described in the following section, researchers have attempted to replicate the factor structure of the EQ. Two studies document the use of foreign language translations of the EQ (Chan & Elliott, 2000; Clarebout et al., 2001). Both studies attempted to replicate Schommer's findings using translations of the original 63 item instrument and replicating the factor analytic procedures used in the validation studies including the use of item parcels. Unfortunately, these efforts were not successful and the analysis of item parcels was ultimately abandoned for item level analysis and scale revision. Recent criticisms of the EQ (Schraw et al, 2002; Wood & Kardash, 2002) have focused specifically on the statistical analytic techniques used to explore the factor structure while supportive of the multidimensional conceptualization of the construct.

Table 1: A Comparison of Construct Validity Studies using the Epistemological Questionnaire with various samples.

Item Parcel	Schommer (1990)	Schommer et al. (1992)	Schommer (1993)	Schommer (1998)
	College Students <i>n</i> = 263	College Students <i>n</i> = 424	High School Students <i>n</i> = 1182	Working Adults <i>n</i> = 418
Learn first time	Innate Ability (.62)	Innate Ability (.44)	Fixed Ability (.45)	Fixed Ability (.46)
Can't learn how to learn	Innate Ability (.56)	Innate Ability (.61)	Fixed Ability (.64)	Fixed Ability (.85)
Success is unrelated to hard work	Innate Ability (.55)	Innate Ability (.51)	Fixed Ability (.51)	Fixed Ability (.38)
Ability to learn is innate	Innate Ability (.34)	DNL	Quick Learning (.49)	Simple Knowledge (.33)
Avoid ambiguity	Simple Knowledge (.68)	Simple Knowledge (.64)	Simple Knowledge (.55)	Simple Knowledge (.58)
Seek single answers	Simple Knowledge (.56)	Simple Knowledge (.46)	Simple Knowledge (.39)	Simple Knowledge (.60)
Avoid integration	Simple Knowledge (.54)	Simple Knowledge (.43)	Simple Knowledge (.41)	Simple Knowledge (.52)
Don't criticize authority	Simple Knowledge (.33)	Certain Knowledge (.39)	Fixed Ability (.40)	Quick Learning (.34)
Depend on authority	DNL	Simple Knowledge (.46)	DNL	DNL
Learning is quick	Quick Learning (.72)	Quick Learning (.63)	Quick Learning (.51) Fixed Ability (.45)	Quick Learning (.73)
Knowledge is certain	Certain Knowledge (.53)	Certain Knowledge (.38)	Certain Knowledge (.54)	Certain Knowledge (.62)
Concentrated effort is a waste of time	DNL	Innate Ability (.52)	Quick Learning (.32)	DNL

Notes: DNL indicates failure to load at > .30 on a factor. Structure coefficients are in parentheses. Innate Ability was changed to Fixed Ability to reflect the highest loading parcel of items.

Foreign Language Translations of Schommer's EQ

A Dutch translation of Schommer's (1990) Epistemological Questionnaire was administered to 250 sophomore students at three universities in Belgium and the Netherlands and 414 sophomore students at four different institutions of higher education in Belgium (Clarebout et al., 2001). Clarebout et al. conducted a series of factor analyses in an attempt to replicate the factor structure reported by Schommer (1990). In the first exploratory factor analysis, the same item parcels used by Schommer were analyzed. The result of this analysis was a four factor solution that explained 55% of the variance but failed to replicate the factor structure reported by Schommer. The first factor included the *learning is quick* and *ability to learn is innate* subsets. *Avoid ambiguity* and *depend on authority* defined the second factor. The third factor contained the sub-sets, *seek single answers*, *knowledge is certain*, and *don't criticize authority*. The fourth factor did not have any item parcels loading at .50 or above, therefore, no subsets were identified for this factor. The full results of the factor analysis were not reported. Five of the item sub-sets proposed by Schommer did not produce a significant factor loading including, *learn first time*, *can't learn how to learn*, *success is unrelated to hard work*, *concentrated effort is a waste of time*, and *avoid integration* (see Table 2). Exploratory factor analysis with the second sample also produced four factors with eigenvalues greater than one and explained 50% of the total variance yet only three sub-sets produced factor loadings of .50 or higher. Clarebout et al. (2001) reports that *avoid integration* and *avoid ambiguity* defined the first factor while *knowledge is certain* defined factor three. A full comparison of the factor structure reported in Schommer's (1990) initial

validation study and both of the analyses reported by Clarebout et al. are reported in Table 2.

A second exploratory factor analysis was conducted using the items rather than sub-sets as variables. For the data from the first sample, a principal components analysis identified two factors with eigenvalues larger than one. These two components accounted for 15% of the variance. Following varimax rotation of the two factors, items were removed that had factor loadings less than .40. The result was one factor named, For Most, Intelligence is Factual Knowledge, consisting of 8 items and internal consistency reliability equal to .68. The second factor, Scientists Know the Truth, contained 2 items, and produced a reliability estimate of .71.

Similar procedures were used to analyze data from a second sample. Principal components analysis resulted in four factors with eigenvalues greater than one that accounted for 21% of the variance. An iterative process was used to obtain a final solution that involved removing items that had a factor loading less than .40 and then reanalyzing the data. The final result was a three factor solution, each made up of two items. The factors were named, Scientists Know the Truth, Meaning is Contextually Constructed, and Effort Pays. The scales produced internal reliability coefficients of .59, .53 and .31 respectively. These disappointing results led Clarebout et al. (2001) to conclude that, “the failure in two subsequent studies both to replicate factor structures similar to the ones reported by Schommer and to construct reliable scales . . . puts further into question the usability of the instrument in research on epistemological beliefs” (p. 74).

Chan and Elliott (2000, 2002) conducted a series of studies to replicate the factor structure of Schommer's (1990) Epistemological Questionnaire with students at the Hong Kong Institute of Education using both the English version and a Chinese translation. Initially they used Schommer's 63 item instrument grouping the items into 12 subscales as Schommer had done in her original study. Exploratory factor analysis failed to replicate Schommer's factor structure (see Table 2). Chan and Elliott (2000) reported a three factor solution accounting for 46.5% of the variance. The authors explored a four factor solution but four factors did not improve interpretability of the factors. Only eight of the 12 subscales produced factor loadings of .40 or larger. The remaining four subscales produced factor loadings between .31 and .35. One interesting difference between Schommer's validation studies and the results reported by Chan and Elliott was the performance of the parcel, *don't criticize authority* that produced a loading of .80 in the Hong Kong sample.

These results, along with internal consistency reliability analysis on the 12 subscales that produced Cronbach alpha estimates ranging from .10 to .58, led Chan and Elliott (2002) to pursue a revision of Schommer's instrument. Utilizing an iterative process and feedback from students and faculty, they developed a 45 item instrument that was later reduced to 30 items based on results from both exploratory and confirmatory factor analyses. The 30-item instrument produced four factors with internal consistency reliability estimates ranging from .60 to .70 (Chan & Elliott, 2002). CFA analysis provided support for the four factor structure as GFI, AGFI, and RMSEA were all with acceptable limits for good fit. The following represents a brief description of each factor.

- Innate/Fixed Ability (alpha = .64) – measures the extent to which one believes ability to learn is fixed at birth or improvable.
- Learning Effort/Process (alpha = .77) – measures the extent to which one agrees that wisdom is a process and hard work and persistence are key to success
- Authority/Expert Knowledge (alpha = .52) – measures the extent to which one questions authority sources.
- Certainty Knowledge (alpha = .53) – measures the extent to which one agrees that scientists can ultimately find the truth.

In an attempt to provide depth to the understanding of this construct and potential cultural differences between North American students and Chinese students a qualitative component was included in the research design. As a result of the analysis of interview data, Chan and Elliott (2002) concluded that some of the responses were “at times inconsistent and occasionally contradictory” (p. 404). The interview data seemed to suggest that contradictory responses may have been due, in part, to domain and contextual differences.

Additional validation studies (Chan, 2003; Chan & Elliott, 2004a) with the revised 30 item Epistemological Beliefs Questionnaire (EBQ) were conducted with samples of Hong Kong teacher education students similar to participants in the previous studies. No factor analytic results were reported but internal consistency reliability estimates ranged from .52 to .77 on the four factors. More recently, Chan and Elliot (2004b) have proposed a hierarchical factor structure to represent the nature of epistemological beliefs. The structure describes epistemological beliefs initially divided into two categories, beliefs about knowledge and beliefs about knowing. Beliefs about

knowledge are then further divided into two beliefs pertaining to the structure of knowledge, Simple/Complex and Certain/Tentative. Beliefs about knowing are further divided in three factors, the source of knowing, speed of knowing and ability. These factors are labeled Authority/Justification, Effort/Process, and Innate/Acquired. This hierarchical structure has not been empirically tested but provides an interesting hypothesis that explains inconsistent factor structure.

Although Schommer (Duell & Schommer-Aikins, 2001) reported a consistent four-factor structure across studies, the studies just described failed to replicate this structure with international samples. Researchers (Clarebout et al., 2001; Chan & Elliott, 2002) ultimately abandoned analysis using item parcels and conducted item level factor analysis. The results in both cases were disappointing leading Clarebout et al. (2001) to abandon use of the instrument while Chan and Elliott (2002) revised poorly performing items and generated a more psychometrically sound scale for subsequent research. Table 2 presents a full comparison of factor results across studies.

Table 2: A comparison of factor structures across studies using item parcels as variables

Item Parcel	Schommer (1990)	Chan & Elliot (2000)	Clarebout et al. (2001) Sample 1	Clarebout et al. (2001) Sample 2
Learn first time	Innate Ability (.62)	Fixed/Innate Ability (.41)	DNL	DNL
Can't learn how to learn	Innate Ability (.56)	Fixed/Innate Ability (.69)	DNL	DNL
Success is unrelated to hard work	Innate Ability (.55)	Fixed/Innate Ability (.61)	DNL	DNL
Ability to learn in innate	Innate Ability (.34)	Certain Knowledge (.61)	Quick Learning (.54)	DNL
Avoid ambiguity	Simple Knowledge (.68)	Certain Knowledge (.48)	Simple Knowledge (.59)	Simple Knowledge (.56)
Seek single answers	Simple Knowledge (.56)	Certain Knowledge (.35)	Certain Knowledge (.51)	DNL
Avoid integration	Simple Knowledge (.54)	Fixed/Innate Ability (.35)	DNL	Simple Knowledge (.53)
Don't criticize authority	Simple Knowledge (.33)	Omniscient Authority (.80)	Certain Knowledge (.55)	DNL
Depend on authority	DNL	Certain Knowledge (.31)	Simple Knowledge (.50)	DNL
Learning is quick	Quick Learning (.72)	Omniscient Authority (.40)	Quick Learning (.52)	DNL
Knowledge is certain	Certain Knowledge (.53)	Omniscient Authority (.43)	Certain Knowledge (.51)	Certain Knowledge (.79)
Concentrated effort is a waste of time	DNL	Fixed/Innate Ability (.32)	DNL	DNL

Notes: All four studies used Varimax rotation for factor interpretation. Reported factor loadings are in parentheses. DNL indicates failure to load at >.30 on a factor for Schommer and >.50 for Clarebout et al.

Revised Epistemological Belief Questionnaire

A revised version of Schommer's Epistemological Questionnaire was administered to 212 high school science students (Qian & Alvermann, 1995). Qian and Alverman eliminated the 10 items that were hypothesized to load on the Omniscient Authority factor but had failed to produce a distinct factor in previous research. The revised 53 item Epistemological Belief Questionnaire was subjected to exploratory factor analysis to assess dimensionality. One distinct procedural difference from previous research with the EQ was that the items rather than item parcels were subjected to factor analysis (Schommer, 1990; Schommer et al., 1992). Thirty-two items produced factor loadings greater than .30. The remaining 21 items were deleted from subsequent analyses and the instrument was renamed the Revised Epistemological Belief Questionnaire.

The revised instrument was re-analyzed using exploratory factor analysis and two, three, four, and five factor solutions were compared. The three factor solution proved to produce the strongest statistical and theoretical fit to the data and was therefore used in subsequent analyses. The three factors were identified as Learning is Quick, consisting of 15 items with internal consistency reliability equal to .79; Knowledge is Simple and Certain containing 11 items with coefficient alpha equal to .68; and Ability to Learn is Innate containing 6 items with alpha equal to .62. The overall alpha for the full 32 item scale was .77. The authors conclude that "the modest internal consistency may be due to the nonconsensuality of the construct underlying belief systems. The nonconsensuality may suggest that the construct of underlying epistemological beliefs does not lend itself easily to empirical research" (Qian & Alverman, 1995, p. 290). In other words, students

may respond inconsistently to items because of the generic nature of the items or perhaps the lack of contextual structure makes it difficult to respond consistently to intra-dimensional items.

The validity of the scale was assessed using a variety of statistical analyses to explore the relationship among epistemological belief variables, learned helplessness, and achievement. The results of regressing learned helplessness scores on the three epistemological belief scores produced a statistically significant result that explained only 5% of the total variance, leading Qian and Alvermann (1995) to conclude that the relationship remained inconclusive. One contributing factor to the inconclusive result may have been due to the low internal consistency ($\alpha = .49$) of the Learned Helplessness Scale. A more comprehensive review of the relationships among epistemological beliefs and the achievement variables is provided in a later section.

Beliefs About Learning Questionnaire

Jehng et al. (1993) constructed an instrument based on a similar five-factor model of epistemological beliefs to that developed by Schommer (1990). The major difference between the two models was the replacement of the Simple Knowledge dimension with Orderly Process. Orderly Process reflects students' understanding of the learning process and is represented as a continuum ranging from *regular* to *irregular*. The construct is assessed with items such as, "I prefer classes in which students are told exactly what they are supposed to learn and what they have to do" (Jehng et al., 1993, p. 28). The instrument was developed using Schommer's EQ as a foundation, submitting the instrument to student and faculty groups for evaluation of item validity and clarity,

followed by item revision or deletion based on student and faculty feedback. The resulting 51-item instrument was thought to represent the five hypothesized dimensions, Certainty of Knowledge, Omniscient Authority, Orderly Process, Innate Ability, and Quick Learning.

The scale was administered to 386 students ranging from freshmen to graduate students and representing four diverse academic fields. Initial reliability analysis indicated that 10 items had very low correlations with the scale ($< .10$) and were subsequently deleted from the scale. After eliminating these items, the reliability of the full scale was .84 and the reliabilities of the subscales ranged from .42 to .59. Item discrimination was examined using item characteristic curves and seven statements judged to have low discrimination were eliminated from the scale. Confirmatory factor analysis was used to examine the structure of the final 34 item scale. Chi-square tests indicated that the five-factor model was a good fit to the data although alternate models were not tested.

Cole (1996) administered Jehng's (1993) original, 60 item Beliefs about Learning Questionnaire to a sample of academically under-prepared, freshmen enrolled in a study skills course. The instrument was used in a pre-post test design to measure change in epistemological beliefs during the course.

Due to small sample size ($n = 101$), item-level factor analysis was deemed inappropriate and items were grouped into subscales based on previous research by Jehng et al. (1993) and Schommer (1990). The subscales; Certain Knowledge, Innate Ability, Omniscient Authority, Quick Process (equivalent to Quick Learning), and Rigid Learning (equivalent to Orderly Process), were then subjected to factor analysis to assess

independence and structural stability across two administrations of the instrument. The results suggested that the factors were not independent, with correlations ranging from .06 to .59, which contradicted previous research (Jehng et al., 1993).

Initial reliability analysis on the full 60 item scale produced a coefficient alpha reliability of .74 with subscale alphas of .35, .21, .42, .26 and .44 for Certain Knowledge, Innate Ability, Omniscient Authority, Quick Process, and Rigid Learning respectively. Examination of the item-scale correlations, led Cole (1996) to eliminate the 23 items that produced low ($< .10$) or negative item-scale correlations. The resulting 37 item scale produced a Cronbach's alpha of .78 with subscale reliabilities of .44, .57, .50, .65, and .54. Exploratory factor analysis was used to evaluate the independence of the subscale scores. A two factor structure emerged for both pre and post test samples. Quick Process, Innate Ability, and Omniscient Authority loaded on the first factor and Certain Knowledge and Rigid Learning formed the second factor. Examination of the procedures used raise more questions than answers. Cole (1996) makes no mention of preliminary results that lead to a two factor solution such as eigenvalues, scree plot, or percent of variance explained. In addition, she did not report any information regarding extraction or rotation procedures used. She reported exploratory and confirmatory factor analyses as well as structural equation modeling procedures on a single sample of questionable size to establish and validate the two factor structure.

A repeated measures MANOVA revealed significant differences in pre and post-test scores on the Beliefs about Learning Questionnaire after completion of a study skills course. Subsequent univariate analyses indicated that there were significant differences in pre-post test scores on the Omniscient Authority, Quick Process, and Rigid Learning

Scales and no significant differences were found on the Certain Knowledge and Innate Ability Scales. Unlike previous studies, Cole (1996) found no relationship among academic success indicators including, high school rank, SAT Verbal and Math scores, college GPA, and epistemological beliefs.

Item Analysis of the EQ and the Beliefs About Learning Questionnaire

The psychometric properties of popular epistemological beliefs instruments like the EQ, as well as the factor analytic procedures used for structural analysis have been criticized (Wood & Kardash, 2002). In an attempt to clarify the dimensionality of the construct, Wood and Kardash (2002) submitted an 80 item epistemological instrument composed of 29 items from Shommer's (1990) Epistemological Questionnaire, 29 items shared by Schommer's and Jehng et al.'s instrument, and 22 additional items developed by Jehng et al. (1993) to more rigorous psychometric analysis. The instrument was administered to a diverse sample of 793 undergraduate and graduate students. Initial reliability analysis yielded an internal consistency reliability estimate of .83. Sixteen items, however, were subsequently eliminated from the instrument due to low or negative item-scale correlations. The resulting 64 item scale produced an internal consistency estimate of .86.

A variety of extraction and rotation procedures were used to analyze the structure of the remaining 64 items. Maximum likelihood, principal components, and generalized least squares extractions with both orthogonal and oblique rotations generated a similar pattern of factor loadings. Twenty-six items were eliminated because they had factor loadings less than .35 or cross loaded on more than one factor. Wood and Kardash

(2002) ultimately decided to report results on the final 38 item scale using principal axis factor analysis with Promax rotation. A combination of the size and pattern of eigenvalues and the scree plot led to a five-factor solution accounting for 22% of the variance and inter-factor correlations ranging from .00 to .49. Coefficient alpha estimates of internal consistency reliability ranged from .54 to .74 on the five subscales. Table 3 presents factors reported by Wood and Kardash (2002) including the number of items defining the factor, the contents of a defining item, and the internal consistency reliability estimate for the factor. Two additional columns provide corresponding information on the performance of the same items when analyzed by Schommer (1990) and Jehng et al. (1993). For example, the factor named Speed of Knowledge Acquisition was defined by eight items yet those same eight items were associated with four unique factors in Schommer's (1990) analysis and two distinct factors in analyses by Jehng et al. (1993). The most notable observation is the lack of consistency in factor structure across studies in spite of the use of similar items and analytic techniques.

Table 3: A comparison of factor structure across scales utilizing similar items assessing personal epistemological beliefs.

Wood and Kardash (2002) Factors	Schommer (1990)	Jehng et al. (1993)**	Alpha
Speed of Knowledge Acquisition (8) <i>“learning is a complex, gradual process requiring both time and effort” (p.250)</i>	Innate Ability (1) Simple Knowledge (2) Quick Learning (4) Certain Knowledge (1)	Certainty of Knowledge Quick Learning	.74
Structure of Knowledge (11) <i>“knowledge is often complex, interrelated, and ambiguous” (p. 250)</i>	Simple Knowledge (8)	Orderly Process	.72
Knowledge Construction and Modification (10) <i>“knowledge is constantly evolving, is actively and personally constructed and should be subjected to questioning” (p. 250)</i>	Innate Ability (1) Simple Knowledge (5) Certain Knowledge (1) *Don’t criticize authority (2)	Orderly Process Omniscient Authority	.66
Characteristics of Successful Students (5) <i>“ successful students are characterized by their recognition that learning takes time and effort” (p. 250)</i>	Innate Ability (1) Simple Knowledge (1) Quick Learning (1) *Ability to Learn is Innate (1)	Orderly Process Quick Learning Innate Ability	.58
Attainability of Objective Truth (3) <i>“skepticism concerning the veridicality of information that one reads” (p. 251)</i>	Certain Knowledge (2) *Don’t Criticize Authority (1)	Certainty of Knowledge Omniscient Authority	.54

Note: Number of items is in parentheses. The sophisticated view is presented in italics.

*Failed to load in Schommer’s analysis.

**Several items that produced significant factor loadings for Wood & Kardash were deleted by Jehng et al. for failure to load.

Epistemic Beliefs Inventory

The Epistemic Belief Inventory (EBI, Schraw et al.,2002) was developed based on Schommer's Epistemological Questionnaire (EQ) and represents another attempt to improve the psychometric characteristics of a general epistemological beliefs scale. The goal was to develop a shorter instrument that measured all five hypothesized beliefs with increased reliability and more consistent factor structure.

One hundred sixty undergraduate introductory psychology students completed the 63-item Epistemological Questionnaire (EQ), the 28-item Epistemic Beliefs Inventory (EBI), and a reading comprehension test. The EQ and EBI were administered a second time, one month later in order to evaluate test-retest reliability.

The EQ and EBI were subjected to principal factor analysis with both oblique and orthogonal rotation. Schraw et al. (2002) reported that both analyses led to highly similar solutions with minimal ($< .30$) inter-factor correlations; therefore the principal factor analysis with varimax rotation was reported. The EQ yielded 19 factors with eigenvalues greater than one but a five factor solution, representing 35% of the total variance, was selected for rotation based on the theoretical structure of the scale. The EBI generated five factors with eigenvalues greater than one, representing 60% of the total variance. The two instruments were administered to the same sample one month later. The structure of the EQ lacked stability as only two factors were fully replicated (Certain Knowledge 1 and 2) and one factor (Incremental Learning) was partially replicated. The remaining two factors were uninterpretable. Test-retest correlations for the two Certain Knowledge factors were .51 and .67.

In contrast, three of the EBI factors in the second sample were identical to those in the first and the two additional factors were nearly identical with the exception of one statement. The three replicated factors, Omniscient Authority, Certain Knowledge, and Quick Learning, had test-retest correlations of .66, .81, and .66 respectively. The two remaining factors, Simple Knowledge and Innate Ability, produced test-retest coefficients of .64 and .62. The factor structure, descriptions and reliability estimates are summarized in Table 4.

The relationship between the factors of the EQ and those of the EBI were examined via zero-order correlations. The correlations were surprisingly small, for example, the two Innate Ability factors produced a correlation of $r = .09$. The factors, Certain Knowledge 1 and Certain Knowledge produced the largest correlation ($r = .36$) reported. The lack of evidence of a relationship between the two instruments that were designed to measure the same construct led Schraw et al. (2002) to conclude, “it is unclear what these two instruments measure and the extent to which they measure the same or unrelated constructs” (p. 273).

To date, only one, unpublished study has attempted to validate the factor structure of the EBI (Huglin, 2003). The EBI was utilized as part of a larger study on the relationship between epistemological beliefs and learning styles. Because the EBI validation sample of college students differed from Huglin’s (2003) sample of adult learners, she conducted an analysis of the reliability and factor structure of the EBI. A 32-item version of the EBI was administered via the internet to 385 adult learners, over the age of 21, who had obtained at least a bachelor’s degree.

Table 4: A comparison of the factor structure of the EQ and EBI

	EQ	EBI
Factor 1	<p>Innate Ability</p> <p><i>Successful students understand things quickly.</i> $\alpha = .74$</p>	<p>Omniscient Authority</p> <p><i>People shouldn't question authority.</i> $\alpha = .68$</p>
Factor 2	<p>Certain Knowledge 1</p> <p><i>Scientists can ultimately get to the truth.</i> $\alpha = .74$</p>	<p>Certain Knowledge</p> <p><i>The moral rules I live by apply to everyone.</i> $\alpha = .62$</p>
Factor 3	<p>Incremental Learning</p> <p><i>The most successful people have discovered how to improve their ability to learn.</i> $\alpha = .64$</p>	<p>Quick Learning</p> <p><i>Working on a problem with no quick solution is a waste of time.</i> $\alpha = .58$</p>
Factor 4	<p>Certain Knowledge 2</p> <p><i>The only thing that is certain is uncertainty itself.</i> $\alpha = .53$</p>	<p>Simple Knowledge</p> <p><i>Instructors should focus on facts instead of theories.</i> $\alpha = .62$</p>
Factor 5	<p>Integrative Thinking</p> <p><i>If a person forgot details, and yet was able to come up with new ideas from a text, I would think they were bright.</i> $\alpha = .61$</p>	<p>Innate Ability</p> <p><i>How well you do in school depends on how smart you are.</i> $\alpha = .62$</p>

Note: Largest loading item on each factor is given in italics.

It should be noted that although Huglin (2003) cites Schraw et al. (2002) as the source of the EBI items, there are some differences between the scales used in the two studies. Huglin included four items not reported by Schraw et al. Specifically, these items were; *It bothers me when instructors don't tell students the answers to complicated problems, I like teachers who present several competing theories and let their students decide which is best, The moral rules I live by apply to everyone, and You can study something for years and still not really understand it.* In addition, three items were reworded. The motivation for these scale changes was not explained.

Principal factor analysis yielded 10 factors with eigenvalues greater than 1. Huglin decided to orthogonally rotate five factors that accounted for 38% of the total variance, in keeping with the scales hypothesized factor structure. These five factors were conceptually similar to factors reported by Schraw et al. (2002) and included; Fixed Ability, Quick Learning, Omniscient Authority, Certain Knowledge, and Simple Knowledge. Eighteen of the 32 items loaded on their corresponding hypothesized factor. The remaining 14 items either cross loaded or failed to load on a factor. Coefficient alpha reliabilities on the subscales ranged from .45 to .70. Huglin (2003) described reliability and validity issues related to the use of the EBI as “problematic” (p. 73).

Critical Review of General Epistemological Measures

Although general measures of personal epistemology have been widely used in numerous studies (see Buehl & Alexander, 2001) the nature of the construct appears to lack structural stability and consistency across studies. The decision regarding the number of factors to rotate is often based on a single criteria and the final factor solution

often accounts for very little total variance. In the studies examined using general epistemological scales, the range of explained variance was 15 to 60%. More specifically, analyses that used item parcels reported explained variance of 47 to 55% while item level analyses reported explained variance ranging from 15 to 38%. The only exception was the initial validation study of the EBI that reported 60% explained variance.

In addition, internal consistency reliability estimates, when reported, often failed to meet the widely accepted social science standard of .70. Internal consistency estimates typically ranged from .45 to .70. More specifically, the average alpha estimate for the Innate Ability factor was .64 ($n = 5$). The average estimate for Quick Learning was .69 ($n = 4$). Certain Knowledge produced an average of .59 ($n = 6$). The average for Simple Knowledge was .63 ($n = 5$) and the average reported alpha for a Source of Knowledge Factor was .59 ($n = 4$).

One line of research that offers a hypothetical explanation not only for the domain differences in epistemological beliefs previously described, but also for the psychometric inconsistencies in general epistemological belief measures has recently emerged in science education (Elby & Hammer, 2001; Louca et al., 2004). Elby and Hammer (2001) challenge the notion that the more sophisticated epistemological position is always the more relativistic view and contend that an epistemological position can only be understood as a function of the context of a response. For example, agreement with the following item on Schommer's Epistemological Questionnaire (1990), *Being a good student generally involves memorizing facts*, is considered a naïve response but an epistemologically sophisticated student may agree with the statement knowing that

memorization is an element of course assessment and higher grades may be achieved by using memory skills. “Assessment items such as this cannot distinguish between students’ expectations about that their teachers reward and their epistemological stance about what constitutes a deeper understanding” (Elby & Hammer, 2001, p. 560).

Epistemological Beliefs, Demographic, and Academic Variables

In spite of the psychometric inadequacies of the previously discussed measures, epistemological beliefs have been empirically linked to a number of demographic and academic achievement variables. The studies described below demonstrate that sophisticated epistemological beliefs consistently predict favorable academic outcomes lending support to the validity of the construct.

Demographic Variables

There are no consistent findings regarding gender differences and epistemological beliefs. Researchers have reported no effects, (Buehl et al., 2002; Chan & Elliott, 2002; Chan, 2003) effects on a single epistemological factor, (Schommer, 1993b; Schommer, Calvert, Gariglietti, & Bajaj, 1997) and effects on multiple factors (Hofer, 2000; Paulsen & Wells, 1998). Gender differences in Quick Learning have been documented in both cross-sectional and longitudinal studies of high school students (Hofer, 2000; Schommer, 1993b; Schommer et al., 1997). Females were less likely to believe learning occurs quickly or not at all with the gender gap widening from freshman to senior year. In a study of undergraduates (Hofer, 2000), men were found to view knowledge as more certain and unchanging and were more likely to rely on authority figures as the source of

knowledge. Finally, in a study of undergraduates and graduate students across six major academic areas, Paulsen and Wells (1998) observed more complex gender differences with women less likely to have naïve beliefs in Fixed Ability or Quick Learning while more likely to have naïve beliefs in Simple Knowledge.

A more consistent pattern emerges with respect to the relationship of epistemological beliefs and age with at least three studies documenting a relationship between Fixed Ability and age (Bendixen et al., 1994; Paulsen & Wells, 1998; Schommer, 1998). In both college samples (Paulsen & Wells, 1994) and adult samples (Schommer, 1998) older persons were less like to believe that ability was fixed. Bendixen et al. (1994) found an indirect relationship between Fixed Ability and age as both Fixed Ability and age were positively related to lower levels of reflective judgment. The studies just mentioned utilized samples with a substantial range in participant age. Studies with a more restricted participant age range produce less consistent results. For example, using similar samples of 18 to 22 year old teacher education students, Chan and Elliott (2002) failed to find a significant relationship between age and epistemological beliefs while Chan (2003) found that age was a significant predictor of Authority/Expert Knowledge.

Educational Level

The relationship between educational level and epistemological beliefs has been researched with high school (Schommer et al., 1997), collegiate, (Jehng et al., 1993; Schommer, 1993b), and adult (Schommer, 1998) samples. Across all samples studied increased levels of education were associated with more sophisticated epistemological

beliefs. A longitudinal study (Schommer et al., 1997) measured the epistemological beliefs of high school students during their freshman and senior year and found a significant main effect for educational level using repeated measures MANOVA. Seniors had more sophisticated views in each of the four epistemological dimensions measured. In a study comparing Junior College and University students (Schommer, 1993b), Junior College students endorsed more naïve beliefs in Simple Knowledge, Certain Knowledge, and Quick Learning. The relationship between Quick Learning and educational level disappeared, however, when the effects of parental education were controlled. Jehng et al. (1993) reported that graduate students were less likely to endorse Certainty of Knowledge, Omniscient Authority, or Orderly Process beliefs but found no differences based on educational level in Innate Ability or Quick Process. Finally, regression analysis on a large sample of working adults led to the conclusion that more educated participants were less likely to view knowledge as simple or certain (Schommer, 1998).

GPA/Course Grade

The first evidence of a relationship between epistemological beliefs and academic performance was a study (Ryan, 1984) that utilized a short 7-item scale to classify students along a single dimension as either dualistic or relativistic. The more relativistic a student's epistemological beliefs the higher their course grade even after academic aptitude and experience were controlled. More recently, studies utilizing the EQ to assess epistemological beliefs have found Quick Learning (Schommer, 1993a) and Simple Knowledge (Paulsen & Wells, 1998) to be significant predictors of GPA. Hofer (2000) found that students' scores on the Certainty/Simplicity Scale of a revised general

epistemological beliefs questionnaire were significantly correlated with course grades in psychology and science as well as overall GPA.

Academic Achievement Variables

Epistemological beliefs have been linked to a variety of variables associated with academic achievement including reading comprehension (Ryan, 1984; Schommer, 1990; Schommer et al., 1992) and meta-cognitive study approaches (Chan, 2003). Specifically, naïve beliefs in Quick Learning and Certain Knowledge have been associated with drawing oversimplified, absolutist conclusions from text (Schommer, 1990) and a naïve view of Simple Knowledge was negatively associated with text comprehension and meta-comprehension (Schommer et al., 1992). Qian and Alvermann (1995) utilized canonical correlation to examine the relationship between epistemological beliefs and two achievement related variables, conceptual understanding and application reasoning. The single interpretable dimension, defined by Simple/Certain Knowledge (-.87) and Quick Learning (-.46) accounted for 23% of shared variance in the pair of comprehension variables. Chan (2003) examined bivariate correlations between epistemological beliefs and meta-cognitive study approaches and found that Surface Learning was related to Innate/Fixed Ability, Authority/Expert Knowledge, and Certainty Knowledge while Deep Process was negatively associated with Effort/Process and Authority/Expert knowledge.

Domain Specific Measures of Epistemological Beliefs

As previously mentioned, exploration of domain differences in epistemological beliefs developed simultaneously with the multidimensional conceptualization of the

construct (Jehng et al., 1993; Schommer & Walker, 1995). Initially, domain differences were explored using general epistemological belief instruments but more recently researchers have constructed domain specific measures. The following section describes studies utilizing these measures, their psychometric properties, and evidence of validity.

Hofer (2000) administered the revised epistemological beliefs questionnaire (Qian & Alvermann, 1995) and a discipline-focused epistemological beliefs questionnaire to 326 freshmen introductory college students. The 27 item discipline-focused epistemological beliefs questionnaire was adapted from existing instruments including Perry's Checklist of Educational Values and Schommer's Epistemological Questionnaire and contained new items generated by a team of researchers familiar with the epistemological belief literature. Each item in the discipline-focused instrument references a particular academic field (e.g. psychology or science) and students were asked to keep the particular discipline in mind as they answered questions.

Principal components analysis of the discipline-focused questionnaire yielded a four factor solution regardless of the discipline specified (psychology or science) that explained 46% and 53% of the variance for psychology and science respectively. The factors were named: (1) Certain/Simple Knowledge, defined by eight items that produced internal consistency reliability estimates of .74 for psychology and .81 for science; (2) Justification for Knowing: Personal, consisting of four items with reliability estimates of .56 for psychology and .61 for science; (3) Source of Knowledge: Authority, consisting of four items with reliability estimates of .51 for psychology and .64 for science; and (4) Attainability of Truth, defined by two items with reliability estimates of .60 for psychology and .75 for science.

Hofer (2000) factor analyzed the 32 item revised epistemological beliefs questionnaire, however, the results failed to replicate the one-factor solution reported by Qian and Alvermann (1995) and produced “no single factor that replicated those factors reported by Schommer and others when a factor analysis is conducted using subscales” (p. 392). In order to answer questions regarding construct validity of the new discipline-focused instrument, Hofer (2000) developed a Certainty/Simplicity of Knowledge scale using the same 11 items that emerged in Qian and Alvermann’s (1995) factor analysis. The scale produced an internal consistency reliability estimate of .66. The correlations of this scale with the corresponding factor of each of discipline-focused scales were .48 for psychology and .35 for science, indicating that the scales were measuring related but not identical constructs. A series of dependent *t* tests were used to evaluate mean differences between psychology and science scores and produced highly significant differences ($p < .001$) on all four epistemological factors. Specifically,

. . .students saw knowledge in science as more certain and unchanging than in psychology; were more likely to regard personal knowledge and firsthand experience as a basis for justification of knowing in psychology than in science; viewed authority and expertise as the source of knowledge more in science than in psychology; and perceived that in science, more than in psychology, truth is attainable by experts (Hofer, 2000, p. 394).

Buehl et al. (2002) also developed a domain specific measure of epistemological beliefs based on Schommer’s Epistemological Questionnaire and a preliminary study was conducted to explore the psychometric properties of the initial pool of 82 items. One

version of the instrument was written with items worded specific to mathematics and one version written specific to history.

One hundred eighty-two undergraduate students completed one of two parallel forms of the Preliminary Domain-Specific Beliefs Questionnaire (P-DSBQ). Each form of the instrument contained 41 items related to history and 41 items related to mathematics. Of the initial item pool consisting of 164 items (82 positive and negative item pairs), 76 items (38 pairs) were eliminated based on statistical analysis that indicated differential response patterns across the two parallel forms. Following elimination of these items, the scales produced statistically equivalent mean scores as measured by independent t tests.

The internal consistency reliability coefficients generated for the reduced scales were .89 for Form A and .88 for Form B. Reliability estimates were also generated for questions related to each academic domain. These internal consistency estimates were .84 on both Forms A and B for mathematics and .88 and .86 on Forms A and B respectively for history.

The factor structure of the revised 44 item scale was examined using exploratory factor analysis. Factors were extracted using principal axis factor analysis and two factors were retained accounting for 33% of the variance. Both orthogonal and oblique factor rotations were examined for interpretation. The factor structures were similar but the oblique rotation produced a substantial factor correlation and was, therefore, the factor solution used for interpretation.

The two-factor solution produced a *history* factor and a *mathematics* factor. Nine items failed to load on either factor. Further examination of the factor structure led Buehl

et al. (2002) to hypothesize that the small sample size in this study may have prevented the emergence of a four-factor solution. This hypothesis led to a second study with a larger sample and a more refined set of items.

The second study involved administering a 50 item version of the DBSQ to 633 undergraduate students. Additionally, some of the participants completed Shommer's original 63 item Epistemological Questionnaire. Both two-factor and four-factor models were tested using confirmatory factor analysis. Items were assigned to factors using a two-step process. First, items were divided by domain and second, items were then subdivided into groups based on whether the item represented a belief about the acquisition of knowledge or a belief about the nature of knowledge. Because the ratio of subjects to estimated parameters was less than 5 to 1, Buehl et al. (2002) decided to eliminate 12 items from the instrument so that the final instrument consisted of 38 items and produced a subject to parameter ratio of 6:1. The eliminated items represented the positively worded items in a sequence of 12 positive-negative item pairs so the negatively worded counterpart remained a part of the final instrument. The authors reported that the fit statistics for this model indicated a poor fit to the data.

Buehl et al. (2002) identified 31 scores that they considered outliers and eliminated these scores. In addition, one item (*If it takes a long time to learn a math concept, it is best to give up*) was eliminated due to extreme non-normality and was replaced by a counter item that had been eliminated earlier. The items were examined further and the recommendation of Hofer and Pintrich (1997) to separate beliefs about learning and intelligence from beliefs about knowledge was followed. The result was the elimination of items that referred to the speed of learning and innate ability. The final

scale, consisting of 22 items was then subjected to confirmatory analysis using maximum likelihood estimation. The Chi-Square and CFI estimates reflected significant improvements to model fit, but were not high enough to indicate a good fit to the data.

Final adjustments were made by allowing for correlated error terms among items with similar wording and, once again, model fit was significantly improved and the four-factor model was judged to produce a good fit. This model was compared to one- and two-factor domain-general models and two- and three-factor domain-specific models and all four comparisons resulted in a significant Chi-Square difference in favor of the four factor model. The factors of the final 22 item scale were:

- Need for Effort in Mathematics (alpha = .68)
- Integration of Information and Problem Solving in Mathematics (alpha = .70)
- Need for Effort in History (alpha = .61)
- Integration of Information and Problem Solving in History (alpha = .75).

The internal consistency reliability estimate for the full scale was .83.

Concurrent validity was assessed by comparing responses on Schommer's EQ to responses on the DSBQ using the correlations of the factor composite scores and the overall composite score for each instrument. The correlation between the EQ and the DSBQ was -.46 and the correlations among the sub-scales ranged from -.04 to -.35. EQ factors, Fixed Ability and Quick Learning, were significantly correlated with all four factors of the DSBQ and Simple Knowledge and Certain Knowledge were significantly correlated with both Integration of Information in Mathematics and Integration of Information in History.

A third study was conducted to provide additional support of the four-factor structure and to study gender differences. Undergraduate students ($n = 523$) were administered the 22-item DSBQ. After deletion of several cases that contributed to non-normality in the data the model fit was similar to that reported in the second study providing additional support for the four-factor domain specific structure of the DSBQ. The internal consistency reliability estimate for the full-scale was .82 with sub-scale estimates ranging from .58 to .72.

Domain Specific Outcomes

Studies that explore domain specific outcomes vary substantially in methodology making results difficult to compare. Some researchers (Jehng et al., 1993; Paulsen & Wells, 1998) explore differences by comparing students from different academic disciplines on general epistemological measures. Others (Hofer, 2000; Schommer & Walker, 1995) ask students to respond to general epistemological measures while keeping a particular academic domain in mind. At least one study mixed the two strategies (Schommer-Aikins et al., 2003). The review of studies presented in this section will reveal that very different conclusions result based on which approach is used.

Jehng et al. (1993) found significant differences in students' epistemological beliefs when grouped by academic discipline based on the results of a MANOVA. Specifically, significant differences were found on the Certainty of Knowledge, Omniscient Authority, and Orderly Process factors between students enrolled in engineering or business programs and those enrolled in arts/humanities or social science programs. Business and engineering students exhibited more naïve epistemological

beliefs than students in the humanities or social sciences. No significant differences were found in either Innate Ability or Quick Process scores across academic discipline.

Schommer and Walker (1995) took an entirely different approach to the exploration of domain specific epistemological beliefs and the result was just the opposite of that described by Jehng et al. (1993). Each participant in Schommer's and Walker's (1995) study completed the Epistemological Questionnaire (EQ) twice, once with the reminder to keep the social sciences such as psychology or sociology in mind as responses were made and once with the reminder to keep mathematics in mind. The study was completed with two undergraduate samples ($n = 94$ and 114) and the only difference in the design of the second study was the addition of a control group that was instructed to keep social sciences in mind both times the EQ was completed. In addition, the instrument used with the second sample was altered slightly to include more frequent domain reminders.

The results of both studies were very similar in that both provided support for the finding that epistemological beliefs are similar across domains. Each of the four epistemological factors, Fixed Learning, Simple Knowledge, Quick Learning, and Certain Knowledge were significantly correlated across domains with correlations ranging from .41 to .67. The results of regression analyses were also strikingly similar across domains with Certain Knowledge in both social science and mathematics functioning as the only significant predictor of Social Science performance. Likewise, Simple Knowledge for both social sciences and mathematics functioned as the only significant predictor of mathematics performance.

Additional studies (Paulsen & Wells, 1998; Schommer-Aikins et al., 2003) using the EQ to measure domain differences utilized the Biglan classification system to ensure better representation across various academic disciplines. Researches have found Biglan's scheme an efficient way to categorize academic disciplines and have documented discipline differences in teaching goals, evaluation and grading practices, knowledge validation processes, and graduate student characteristics. (Barnes, Bull, Campbell, & Perry, 2001; Donald, 1990; Hativa & Marincovich, 1996; Malaney, 1986).

Biglan (1973a) developed a multidimensional system to characterize various academic disciplines. The first dimension is generally labeled *hard-soft* because it distinguishes fields like engineering and the sciences from fields like humanities and the social sciences. Another way to characterize this dimension is that it distinguishes paradigmatic fields from those that are not. Paradigm, in this context, refers to "a body of theory which is subscribed to by all members of the field" (p. 201). Paradigmatic or *hard* disciplines have an agreed upon content and methodology that can foster absolutist thinking. In *soft* areas there is less theoretical consensus hence relativistic thinking is encouraged. This dimension has emerged as the most prominent in making group distinctions (Donald, 1990; Malaney, 1986)

The second dimension is generally referred to as *pure-applied* and distinguishes fields like education and agriculture that focus on practical application from fields like philosophy or history that are more abstract or theoretical. The third dimension, named *life-non life*, distinguishes fields that focus on living things like biology or psychology from fields that focus on inanimate objects such as computer science or economics.–

It is difficult to directly compare the results of the previously mentioned studies that utilize the Biglan scheme because the methodology and data analysis differed substantially leading to different conclusions. Paulsen and Wells (1998) focused on differences between various academic majors using a series of ANOVAs. They found that students enrolled in *pure* academic fields like humanities, social sciences, mathematics, or the natural sciences generally have more sophisticated beliefs than those enrolled in *applied* areas like education, business or engineering. The results of a multiple regression analysis indicated that students in *pure* fields had more sophisticated beliefs in Simple Knowledge, Certain Knowledge, and Quick Learning. Students in *soft* domains such as the humanities, social sciences, education, and business were more likely to have sophisticated beliefs regarding Certain Knowledge than those in *hard* domains like math, engineering, and the natural sciences. It is unfortunate that a factorial design was not utilized in the analysis as this may have provided more insightful information regarding the pattern of mean differences in epistemological beliefs.

Schommer-Aikins et al. (2003) asked students simply to keep a particular domain, mathematics, social sciences, or business, in mind as they answered a general epistemological beliefs scale. This study differed from Schommer's and Walker's (1995) previous study only in that Biglan's (1973a, 1973b) classification system was used to select disciplines that represented both *hard-soft* and *pure-applied* disciplines. A series of regression analyses demonstrated that math beliefs could be predicted from both social science and business beliefs and led to the conclusion that "epistemological beliefs of college students are moderately domain general" (Schommer-Aikins et al., 2003, p. 360). Manuscript reviewers encouraged the authors to re-analyze the data based on academic

experience. Bivariate correlations were used to assess similarities and differences in epistemological beliefs based on the number of courses completed in each academic area (i.e. mathematics, social science, and business). Schommer-Aikins et al. (2003) concluded that the pattern of correlations supported domain generality for students with either high or low exposure to the academic areas being compared. The pattern of correlations supported a domain specific view when exposure varied between disciplines (i.e. high exposure to one area and low exposure to another). These results appear tenuous at best based on the methodology used. A more sophisticated multivariate analysis may have been a more appropriate way to address the question of domain differences.

Hofer (2000) explored discipline specific epistemological beliefs in a similar manner by having undergraduates ($n = 326$) complete two versions of a discipline-focused epistemological beliefs questionnaire, one for psychology and one for science. The instruments were identical except for the insertion of the word psychology or science in the items. Results of a series of dependent t tests revealed significant differences by discipline. Hofer (2000) further explored discipline based differences by conducting a repeated measures MANOVA comparing science and social science majors on the four factors of each of the two discipline-focused epistemological instruments. No multivariate effects were found but there was a significant univariate effect of major for the attainability of truth factor, with science majors more likely to view truth as attainable.

Buehl et al. (2002) conducted a repeated measures MANOVA using academic discipline (mathematics and history) as the repeated measure and the four factors of the

DSBQ as the dependent variables. Buehl et al. (2002) reported a significant main effect for domain and further analysis revealed significant domain differences with regard to the effort required to gain knowledge and beliefs about the integration of knowledge.

“Specifically, students believed that the acquisition of mathematics knowledge required more effort than history knowledge . . . [and] students . . . believed that knowledge in mathematics was more integrated with other domains than history” (p. 438). These findings were replicated in a subsequent study that also examined gender differences.

It appears that students can hold both domain specific and domain general beliefs simultaneously. Students from different academic disciplines do seem to hold differing epistemological beliefs with students in mathematics and science programs holding less relativistic views of knowledge than students in the social science, arts, and humanities programs. Additionally, student’s beliefs appear to remain consistent across domains as responses of individual students change little even when prompted to consider a different domain. None of the previous studies attempted to generate a scale that included items contextually specific to a particular domain. In fact, Buehl et al. (2002) specifically eliminated items that would not work well across domains. For example, the item, “In math class, all you really need to know is how to use the formulas” (p. 423), was eliminated because replacing the word math with the word history would not have worked. To date, no contextually appropriate domain specific instrument has been tested.

The following sections describe two constructs related to general epistemological beliefs, implicit theories and math specific beliefs. When Schommer (1990) reconceptualized epistemological beliefs as a multidimensional construct, she utilized research regarding both implicit theories of intelligence and math beliefs to define two

dimensions later referred to as Innate Ability and Quick Learning. There has been subsequent debate (Hofer & Pintrich, 1997) as to whether these dimensions should be included with epistemological beliefs or whether they represent related but peripheral constructs. Both the general and mathematics related epistemological belief scales used in the current study include these dimensions. The following is a comprehensive description of the development of these constructs along with a review of a recent empirical study that explored the relationship between implicit theories and general epistemological beliefs.

Implicit Theories of Intelligence and Achievement Goals

Implicit theories of intelligence refer to a person's belief that intelligence is either flexible and adaptable or is fixed and unchanging (i.e. you have what you were born with and nothing more). The former view is referred to as an incremental theory of intelligence and the latter, an entity theory (Dweck, 2000). Implicit theories of intelligence have been empirically linked to learner response to challenging tasks via achievement goals.

Incrementalists believe that intelligence is malleable, that it can be increased with effort and practice, and tend to disagree with statements such as, "You can learn new things but you can't really change your basic intelligence" (Dweck, 2000, p. 21). Because incrementalists see intelligence as something under personal control, they are less threatened with failure and view hard work and persistence as a way to improve their skills. Students with an incremental view of intelligence tend to adopt learning goals in challenging situations as they are primarily concerned with mastering new skills. They

are likely to intensify their efforts at problem solving when challenged and they do not view difficulty or failure as a reflection on their intelligence.

Entity theorists view intelligence as a fixed trait that cannot really change much. With no personal control over their intelligence, failure becomes an indicator of personal inadequacies leading to an avoidance response in order to protect self-image. Dweck and Leggett (1988) reported that, in an experimental study with middle school children, students with an entity view tried to preserve self-image by demonstrating competence in other areas. She writes, “more than two thirds of the[se] . . . children (but virtually none of the mastery-oriented ones) engaged in task-irrelevant verbalizations, usually of diversionary or self-aggrandizing nature” (pp. 257-258). Further, students with an entity view of intelligence will tend to adopt performance goals when academically challenged. Students who adopt performance goals are primarily concerned with their standing in relation to others, “so when they do poorly they may condemn their intelligence and fall into a helpless response” (Dweck, 2000, p. 16).

To reiterate, students will generally perform equally well on tasks that are well within their ability regardless of their view of intelligence or their achievement goal orientation. The major behavioral and emotional differences are seen when students are confronted with difficult or challenging tasks. As long as confidence in one’s ability regarding any particular task is high, both performance and learning goals will produce mastery oriented behaviors and positive affect. It is only when confidence is low that a behavioral difference emerges. Students who adopt learning goals continue to persist and do not take failure personally, whereas students adopting performance goals take failure very personally, blaming their failure on intellectual inadequacy.

These behavioral responses have both situational and dispositional elements. Although people have a predisposition toward adoption of either learning or performance goals, Dweck (2000) has demonstrated in a variety of studies that situational elements can alter goal choice and subsequent behavioral responses to challenges. This theory provides a framework for assessing the dispositional tendencies of students and generating situational interventions when a maladaptive response interferes with cognitive or social skills.

A number of researchers are using Goal Orientation Theory in motivational research (Arias, 2002; Button, Mathieu, & Zajac, 1996; Kaplan & Maehr, 1999; Meece, Blumenfeld, & Hoyle, 1988; Midgley et al., 1998; Nicholls, Cobb, Wood, Yackel, & Patashnick, 1990; Seegers, van Putten, de Brabander, 2002; Strange, 1997; Wolters, 2004; Yorke & Knight, 2004) and, although the terminology changes somewhat, the defining characteristics of performance and learning goals remains consistent. Goals that focus on ability development are referred to as learning, mastery, and/or task involvement goals and goals that focus on the demonstration of ability are termed performance, ability, and/or ego involvement goals (Midgley et al., 1998).

The results of numerous studies consistently demonstrate that achievement goals are correlated with a number of cognitive and affective variables. Task or learning goals have been positively correlated with cognitive variables such as deep strategy use (Anderman & Young, 1994), active cognitive engagement (Meece et al., 1988), adaptive cognitive strategies in Math and English classes (Midgley et al., 1998), effort and persistence (Wolters, 2004), and the belief that success depends on interest, effort, and attempts to make sense of things (Nicholls et al., 1990). Performance or ego goals have

been associated with use of surface strategies (Anderman & Young, 1994), superficial engagement (Meece et al., 1988), maladaptive cognitive strategies in Math and English (Midgley et al., 1998), and the belief that success depends on superior ability and attempts to beat others (Nicholls et al., 1990). Kaplan and Maehr (1999) found task goals correlated negatively with disruptive classroom behavior and positively with impulse control and affect at school while ego goals were oppositely correlated with the same variables. Linnenbrink and Pintrich (2002) conducted an extensive review of the literature regarding the relationship between Achievement Goal Theory and affect concluding that mastery goals are positively correlated with positive affect and negatively correlated with negative affect while performance goals are positively correlated with negative affect.

Evidence of achievement goals appears under other names as well. For example, Joe Garofalo (1994) labeled students as meaning-oriented or number-oriented based on whether they focused on meaningful interpretation or mechanical computation as they solved problems. He found that meaning-oriented students were more willing to work complicated and non-routine problems while number-oriented students preferred short, simple problems that were similar to example problems.

Some researchers working with Achievement Goal Theory have proposed a revision to normative goal theory, a term used to describe the classic mastery-performance dichotomy (Arias, 2002; Harackiewicz, Barron, Pintrich, Elliot, & Thrash, 2002). The key element of this revised theory, called multiple goal perspective, is the division of performance goals into to sub-goals, performance approach (i.e. attain success) and performance avoidance (i.e. avoid failure). The basis for the revised theory

was an analysis of a number of goal theory studies that revealed significant performance approach effects on performance outcomes and significant mastery goal effects on interest outcomes leading to the conclusion that “mastery and performance-approach goals independently promoted different achievement outcomes: Students adopting both goals are optimally motivated. . .” (Harackiewicz et al., 2002, p. 642).

Recently, a four factor structure of achievement goals has been proposed (Grant & Dweck, 2003) consisting of Outcome, Ability, Normative, and Learning Goals. This represents a refinement of the extensively researched two factor model. Learning Goals, although still represented as a single factor, now contains items specific to learning as well as items that reference more general academic challenges. Performance Goals are divided into two factors, Ability Goals and Normative Goals. Ability Goals represent the importance of demonstrating or validating intelligence through academic activities. Normative Goals are similar to Ability Goals but are specifically focused on comparisons to other students. The fourth factor, Outcome Goals, taps students’ desire to do well on a particular task and is related to both Performance and Learning Goals. Learning Goals were empirically associated with a number of positive learner outcomes including higher intrinsic motivation, deeper processing, and higher grades compared to students who adopt Ability Goals (Grant & Dweck, 2003). In addition, students who adopt Ability Goals experience a loss of self-worth, tend to withdraw more quickly from challenges, and have a greater tendency to ruminate.

Schommer (1990) utilized research on implicit theories of intelligence (Dweck & Leggett, 1988) in the development of her original Epistemological Questionnaire, leading one to hypothesize that some relationship should exist between the constructs. A recent

study was designed specifically to test this hypothesis (Braten & Stomso, 2005). Interestingly, correlations between three of the four variables representing dimensions of epistemological beliefs (i.e. Speed of Knowledge Acquisition, Certainty of Knowledge, and Knowledge Construction and Modification) and the two variables measuring self-theories of intelligence (i.e. entity and incremental) were negligible, ranging from -.07 to .06 in a sample of 286 Norwegian business and education students. The fourth epistemological variable, Control of Knowledge Acquisition correlated moderately with the entity and incremental theory variables ($r = .26$ and $-.34$ respectively). This fourth factor, often named Innate Ability in other research using Schommer's (1990) EQ, contains items that are worded very similarly to the items in the Theories of Intelligence Scale (Dweck, 2000). Although these correlations are statistically significant, one would expect them to be much higher as they seem to measure the same construct. The authors conclude that although counterintuitive, "the dimensions of personal epistemology concerning the speed and control of knowledge acquisition represent constructs separate from the construct of implicit theories of intelligence" (Braten & Stromso, 2005, p. 558).

Mathematics Specific Epistemological Beliefs

"Students' mathematics-related beliefs are the implicitly or explicitly held subjective conceptions students hold to be true that influence their mathematical learning and problem solving" (Op'T Eynde, DeCorte, & Verschaffel, 2002, p. 24). Although there is no comprehensive theoretical model of mathematical beliefs, common themes are found across studies (Kloosterman, 2002; Lerch, 2004; Mtetwa & Garofalo, 1989; Schoenfeld, 1989) and include the following:

- Mathematics knowledge is static.
- The goal of problem solving is to produce the “right” answer.
- Mathematics knowledge is passively received from a teacher.
- Mathematics skill is either something you have or you don’t.

Mathematics beliefs have been shown to influence student engagement, effective strategy use in problem solving, and academic achievement (Lerch, 2004; Schommer-Aikins et al., 2005). Additionally, more sophisticated math beliefs have been associated with intrinsic motivation, self-efficacy, and self-regulation (Hofer, 1999).

A number of attempts have been made to quantitatively measure mathematics beliefs (Hofer, 1999; Kloosterman & Stage, 1992; Koller, 2001; Op’t Eynde & DeCorte, 2003; Schoenfeld, 1989). One of the first published scales (Schoenfeld, 1989) consisted of 60 Likert-style items, 10 demographic items, and 11 short answer questions and was administered to 230 high school geometry students. No formal psychometric analysis was reported as Schoenfeld simply used comparisons of sub-scale scores and item means as well as sub-scale correlations to explore particular aspects of student beliefs.

The instrument tapped a number of elements of student beliefs including attributions of success or failure, perceptions of mathematics, comparisons of student views of mathematics, English, and social studies, and student motivation. Schoenfeld (1989) reported that epistemological beliefs vary by discipline and that students were more likely to credit native ability for success in math than either English or social studies. Students believed that memorization was required to master content, believed that problems should take no more than five minutes to complete, and lacked an integrated view of mathematics because they didn’t make conceptual connections.

Schoenfeld concluded that even in the best educational environments (e.g. upper level courses with effective teachers and motivated college bound students) math instruction can result in an understanding of mathematics as a sequence of rules and procedures and a lack of integration of major concepts. In spite of a lack of psychometric information, most subsequently developed instruments, including Schommer's (1990) Epistemological Questionnaire have used elements of this initial instrument.

Kloosterman and Stage (1992) developed the Indiana Mathematics Belief Scale to measure beliefs regarding the problem solving process. The five beliefs that were included in the final version of the scale include:

- I can solve time-consuming mathematics problems.
- There are word problems that cannot be solved with simple, step-by-step procedures.
- Understanding concepts is important in mathematics.
- Word problems are important in mathematics.
- Effort can increase mathematical ability.

After refinement through pilot testing, the final 30-item instrument was administered to 517 college students with diverse experiences in mathematics including both those enrolled in developmental math courses and those who had successfully completed multiple college level mathematics courses. Cronbach's alpha estimates for the five scales ranged from .54 to .84. Inter-scale correlations ranged from -.02 to .29 reflecting relative independence of the five scales. Kloosterman and Stage (1992) did not report that any validity research was conducted as part of the development of this instrument. In view of the very limited information regarding the psychometric characteristics of the

scales and the lack of subsequent research utilizing the Indiana Mathematics Belief Scales, it is impossible to posit an evaluative judgment of this instrument.

The first scale to overtly combine personal epistemology theory and mathematics beliefs was a brief, six-item scale that measured two epistemological factors, Simple Beliefs and Isolated Beliefs (Hofer, 1999). Due to low internal consistency reliability estimates ($\alpha = .48$ and $.41$) the items were combined into a single math beliefs scale ($\alpha = .54$). Bivariate correlations among math beliefs and a variety of academic variables were analyzed and, in spite of low reliability estimates, math beliefs were significantly correlated with intrinsic motivation, self-efficacy, self-regulation, and course grades. This study represents a small psychometric step forward in that a brief description of factor analytic procedures was provided, reliability estimates were reported, and an attempt was made to establish the validity of the instrument through correlational associations with related variables.

A more recent attempt (Koller, 2001) was made to measure math specific epistemological beliefs using a combination of Schommer's (1990) multi-dimensional epistemological beliefs and Schoenfeld's (1983) cognitive requirements for success in mathematics, focusing on a specific category, belief systems. The measure was developed as part of a research project to test the effects of math beliefs on achievement via three mediator variables, interest, learning strategies, and course selection.

Eighteen items were developed measuring four aspects of mathematics related beliefs; constructive conception, certain knowledge, simple knowledge, and relevance of mathematics. The instrument was administered to 2138 German secondary students. Internal consistency reliability estimates ranged from $.47$ for Certain Knowledge to $.77$

on the Relevance scale. Small to moderate inter-scale correlations ranged from .03 to .28. In spite of low reliability estimates, all four dimensions proved to be significant predictors of student achievement in a subsequent path analysis.

In response to the lack of a comprehensive model of mathematics-related beliefs, the Student's Mathematics-Related Beliefs Questionnaire (MRBQ) was developed to validate the structure of mathematics-related beliefs systems (Op't Eynde & DeCorte, 2003). The MRBQ included items addressing beliefs about mathematics education, beliefs about the self as a learner of mathematics, and beliefs about the influence of the teacher. The initial item pool of 58 items was administered to 365 Flemish junior high school students. Principal components analysis yielded a four factor solution accounting for 38% of total variance. The factors were labeled; Beliefs about the role and functioning of the teacher, Beliefs about the significance of and competence in mathematics, Mathematics as a social activity, and Mathematics as a domain of excellence. The four scales produced internal consistency reliability estimates of .92, .89, .65 and .69 respectively. Inter-factor correlations ranged from .21 to .48 and may indicate the presence of a higher order factor, although this was not explored. No additional variables were included in the study and, therefore, additional evaluation of the validity of the MRBQ is not possible.

In a recent review of the status of the measurement of mathematics beliefs, DeCorte et al. (2002) indicate that a better understanding of mathematics beliefs is needed including the "relationship between mathematics-related beliefs and the more general epistemological beliefs" (p. 315). Existing instruments have little or no psychometric information with which to judge the reliability and validity, therefore,

“more comprehensive instruments have to be designed and validated” (DeCorte et al., 2002, p. 315).

Summary

Although psychometric inadequacies persist, epistemological beliefs have been linked to a number of desirable learner outcomes. It appears that epistemological beliefs function independently of other variables related to learner outcomes like motivation and ability. It is currently unclear whether mathematics related beliefs are simply a domain-specific variation of general epistemological beliefs or represent a unique but related construct. The current study represents the first attempt to explore these relationships utilizing a contextualized mathematics beliefs instrument and a general measure of epistemological beliefs as well as measures of related peripheral constructs about the nature of learning and the nature of intelligence. A need has been expressed (Muis, 2004) for a better understanding of the relationship between student beliefs, learning environments, and the influence of teacher’s beliefs on student beliefs. These questions cannot be effectively answered without a reliable and valid measure of mathematics related epistemological beliefs.

CHAPTER III

METHODOLOGY

Researchers need better instrumentation and methodology to construct a better theoretical and applied understanding of epistemic beliefs.

(Schraw, Bendixen, & Dunkle, 2002, p.273)

The purpose of the current chapter is to describe various methodological elements of the study including sample characteristics, instruments used to measure constructs of interest, data collection procedures, and statistical analyses.

Participants

The sample included students at a large Midwestern university and a small Midwestern community college. Attempts were made to achieve heterogeneity of age, academic classification, and field of study to the greatest extent possible, as these variables have been associated with differences in epistemological beliefs. Various course instructors were asked to allow a regularly scheduled class session to be used for data collection. Data collection began in November 2006 and concluded in February 2007 when the minimum required sample of 300 completed questionnaires was achieved (Tabachnick & Fidell, 2001).

The final sample consisted of 316 participants from four campus locations. Participants ranged in age from 18 to 55 with a mean age of 25.3 years. The majority (70%) of participants were female and 67% were White. The desired heterogeneity was achieved with regard to academic classification and to a lesser extent with regard to academic major. Specifically, the community college sample was fairly balanced across both the *hard/soft* and *pure/applied* dimensions of the Biglan (1973a) classification system while the *soft* and *applied* dimensions dominated the university sample. A more detailed description of participant demographics is provided in Table 5.

Instruments

The following section provides a detailed description of each of the instruments used to measure constructs of interest in the current study. Item development for the EBSM is detailed including the theoretical basis for each of the hypothesized factors. In addition, descriptions of each of the scales included for validation are provided. These descriptions include information related to the development and validation of the scales as well as previously published psychometric properties including factor structure and reliability estimates.

Demographic Information

A brief demographic questionnaire that included age, gender, ethnicity, academic classification, college major, career goal, international student status, and the number of mathematics courses completed in high school or college was presented in the participant's packets. In addition, participants could choose to endorse any number of a

variety of statements that reflect common attitudes toward mathematics or write their own statement (see Appendix F).

Table 5: Frequencies and Corresponding Percentages for Demographic Variables

Demographic Categories	Community College <i>n</i> = 186	University <i>n</i> = 130	Total <i>n</i> = 316
Gender			
Male	45 (24.2)	48 (36.9)	93 (29.4)
Female	141 (75.8)	81 (62.3)	222 (70.3)
No Response	0 (0.0)	1 (0.8)	1 (0.3)
Ethnicity			
Hispanic	1 (0.5)	5 (3.8)	6 (1.9)
Native American	45 (24.2)	12 (9.2)	57 (18.0)
Asian American	1 (0.5)	4 (3.1)	5 (1.6)
African American	16 (8.6)	4 (3.1)	20 (6.3)
White	116 (62.4)	95 (73.1)	211 (66.8)
Multi-Racial	2 (1.1)	5 (3.8)	7 (2.2)
Other	2 (1.1)	4 (3.1)	6 (1.9)
No Response	3 (1.6)	1 (0.8)	4 (1.3)
Biglan classification by major			
Pure & Hard	34 (18.3)	1 (0.8)	35 (11.1)
Pure & Soft	43 (23.1)	17 (13.1)	60 (19.0)
Applied & Hard	54 (29.0)	7 (5.4)	61 (19.3)
Applied & Soft	55 (29.6)	104 (80.0)	159 (50.3)
No Response	0 (0.0)	1 (0.8)	1 (0.3)
Classification			
Freshman	40 (21.5)	1 (0.8)	41 (13.0)
Sophomore	122 (65.6)	0 (0.0)	122 (38.6)
Junior	17 (9.1)	24 (18.5)	41 (13.0)
Senior	7 (3.8)	73 (56.1)	80 (25.3)
Graduate	0 (0.0)	29 (22.3)	29 (9.2)
No Response	0 (0.0)	3 (2.3)	3 (0.9)

Note: Percent of column total in parentheses.

Epistemological Beliefs Survey for Mathematics

The Epistemological Beliefs Survey for Mathematics (EBSM, see Appendix A) was developed for this study using literature from both general epistemological beliefs and mathematics related beliefs. Seven distinct dimensions were identified and labeled, Source of Knowledge, Certainty of Knowledge, Structure of Knowledge, Speed of Knowledge Acquisition, Innate Ability- General, Innate Ability-Personal, and Real-World Applicability, based on previously published research (Schoenfeld, 1989; Schommer, 1990). Ten to twelve statements were written for each dimension using a variety of previously published epistemological and mathematical belief instruments (Buehl, 2003; Elby, 2001; Koller, 2001; Op't Eynde & DeCorte, 2003; Schoenfeld, 1989; Schommer, 1990) and revising as necessary for the current study. Some statements were reworded to reflect beliefs specific to mathematics and some of the language was changed to reflect the perspective of the student rather than a judgment. For example, an EQ item that measures Ability to Learn, *Everyone needs to learn how to learn*, was revised to read, *Learning good study skills can improve my math ability*.

Epistemic Beliefs Inventory

The Epistemic Beliefs Inventory (EBI) consists of 28 items measuring five dimensions of general epistemological beliefs (see Appendix B). Coefficient alpha reliability estimates reported for the validation sample of 160 undergraduate university students ranged from .58 to .68. Test-retest correlations were reported to range from .62 to .81. Although these reliability estimates are less than optimal, they are typical of reliability estimates reported in psychometric studies of general epistemological beliefs.

Schraw et al. (2002) developed the Epistemic Beliefs Inventory (EBI) as a response to many of the psychometric inadequacies of Schommer's (1990) Epistemological Questionnaire. Items were developed and refined to measure the same five dimensions first hypothesized by Schommer including, Certain Knowledge, Simple Knowledge, Quick Learning, Omniscient Authority, and Innate Ability. Although the only additional validation study of the EBI is an unpublished doctoral dissertation (Huglin, 2003), it remains the most psychometrically sound measure of general epistemological beliefs currently available. The purpose of including it in the current study is to assess the relationship between domain-specific epistemological beliefs as measured by the Epistemological Beliefs Survey for Mathematics and general epistemological beliefs. In addition, inclusion of the instrument provided an opportunity to explore the structural validity of the EBI through exploratory factor analysis.

Achievement Goal Inventory

The Achievement Goal Inventory (Grant & Dweck, 2003) represents the most recent refinement in Achievement Goal Theory research (see Appendix C). The instrument is based on previous research by Dweck (2000) and other Achievement Goal Orientation researchers (Midgley et al., 1998; Nicholls et al., 1990). The instrument measures four distinct but related goal orientation factors, Outcome Goals, Ability Goals, Normative Goals (including both normative outcome and normative ability goals), and Learning Goals (including both learning and challenge-mastery goals). The instrument was developed and validated through a sequence of studies including a preliminary pilot study followed by a sequence of five validation studies.

Grant and Dweck (2003) constructed the final 18 item version of the instrument by selecting the three items on each of the six preliminary scales that produced the highest internal consistency reliability estimates for the 560 participant pilot sample. Subsequent factor analysis produced four factors and the coefficient alpha reliability estimates for each of the final four scales were: Outcome goals, .85; Ability goals, .81; Normative goals (outcome and ability), .92; and Learning goals (learning and challenge-mastery), .86. Confirmatory factor analysis provided support for the hierarchical four factor model. Test-retest reliability was evaluated on an independent sample of 54 participants and correlations between the two sets of scores ranged from .69 to .88 with an average correlation of .79 (Grant & Dweck, 2003).

The Achievement Goal Inventory appears to be both a reliable and valid measure of achievement goals. This measure also reflects the latest developments in Achievement Goal Theory with the refinement of the former two factor model that included only performance and learning goals into a four factor hierarchical model that better reflects subtle variations within both performance and learning goals.

Implicit Theories of Intelligence Scale

The Implicit Theories of Intelligence Scale (see Appendix D) is an eight item, Likert-type scale designed to measure one's implicit theory of intelligence. This is a unidimensional construct that ranges from fixed to malleable, termed entity and incremental respectively. The scale originally consisted of three items reflecting only an entity view, as the incremental items produced universal endorsement. The scale has been revised (Dweck, 2000) by designing incremental items that do not generate over-

endorsement. Entity and incremental items have a strong negative correlation, providing additional support for the unidimensionality of the construct.

Published validation studies (Dweck, Chiu, & Hong, 1995) were conducted using a shorter scale that consisted of three entity items. The scale was evaluated in a series of six studies with sample sizes ranging from 32 to 184. The coefficient alpha estimates of internal consistency ranged from .94 to .98. Test-retest reliability was evaluated in one of the validation studies and produced a correlation coefficient equal to .80. In a discussion of the scales validity, the authors demonstrate discriminant validity through a factor analysis of three implicit theory scales, implicit theory of morality, implicit theory of intelligence, and implicit theory of the world. In five separate factor analyses three distinct factors emerged with identical structure across studies and factor loadings ranging from .74 to .96. These studies provided support for the conceptualization of one's implicit theory of intelligence as distinct from one's implicit theory of morality or the world. Additional analysis revealed that implicit theories are unrelated to demographic variables such as gender and age as well as political or religious affiliation. Additionally, there was no evidence for confounding with either self-presentation or social desirability and the scales were unrelated to cognitive ability, intellectual self-efficacy, or self-esteem.

The Implicit Theories of Intelligence Scale appears to be a reliable and valid measure of one's implicit theory of intelligence. Although published psychometric analysis of the newer eight-item version of the scale is not available, the use of the instrument provides opportunity to examine the psychometric properties of the longer

instrument and, if needed, the well established and frequently used subset of entity items can be used in subsequent analysis.

Procedures

Participants were informed of their rights, provided an explanation of the purpose of the study, and provided a copy of the IRB approved informed consent. Those who chose to participate were given a packet that included, a brief demographic survey, the Epistemological Beliefs Survey for Mathematics (EBSM), the Epistemic Beliefs Inventory (EBI), the Achievement Goal Inventory (AGI), and the Implicit Theories of Intelligence Scale (TIS). A random arrangement of the EBSM items was presented first, followed by a random presentation of items from the EBI, AGI, and TIS. All scales were measured using a six-point Likert type scale ranging from 1 (*very strongly disagree*) to 6 (*very strongly agree*). In addition, three brief scenarios (see Appendix F), modified from the Epistemological Beliefs Inventory for Physics (EBAPS, Elby, 2001), were inserted into the scale. One scenario was placed in the midst of the EBSM and the other two were equally spaced in the midst of the remaining scales. These scenarios served two purposes. First, they functioned to improve the validity of participant response by interrupting the flow of the Likert-type items. Second, the scenarios were used to evaluate how participant responses to briefer scale stems correspond to more contextualized scenarios designed to evaluate the same construct.

Analysis

All analyses were conducted using SPSS 14.0. Traditional psychometric analysis of the EBSM, EBI, AGI, and TIS included exploratory factor analysis to assess the dimensional structure of each scale followed by reliability analysis. Exploratory factor analysis included an assessment of each inter-item matrix for factorability. This assessment consisted of visual inspection of the inter-item correlation matrix followed by statistical tests to evaluate the factorability of the correlation matrix including Bartlett's test of sphericity and the Kaiser-Meyer-Olkin (KMO) test of sampling adequacy. The Kaiser-Meyer-Olkin test of sampling adequacy is a ratio of shared inter-item variance to total variance. A general rule of thumb is that KMO should be at least .60 to consider factor analysis appropriate for the data. Bartlett's test of sphericity is a statistical test of the null hypothesis that the correlation matrix is an identity matrix. A significant value indicates that the correlation matrix differs significantly from identity.

These diagnostic procedures were followed by exploratory factor analysis. Factor extraction procedures included principal axis factor analysis (PAF) and, in some cases, principal components analysis (PCA). Gorsuch (1983) provides several reasons that he prefers factor analysis over components analysis. One argument is that the assumption of error free measurement in components analysis is untenable and, therefore, factor analysis provides a better fit to the data. Another argument is that if the component model is truly appropriate then common factor analysis will produce the same solution. In the current study, PAF was used for structural analysis of the various scales.

Decisions regarding the number of factors to rotate to a final solution were made using three criteria, the Kaiser criterion (1960), Cattell's scree plot (1966), and Horn's

parallel analysis (1965). The Kaiser criterion, which is the default option in SPSS, extracts any factor that has an eigenvalue greater than 1.0. Cattell's scree test is actually a graphical representation of the eigenvalues presented in order of size. Interpretation of a scree plot involves identification of the number of factors that occur prior to the leveling off or scree. Horn's parallel analysis, now regarded as possibly the best method for determining the number of factors to extract (Thompson, 2004), compares the actual eigenvalues generated by the data to eigenvalues of a random data matrix of the same size. The argument is that any factor producing an eigenvalue greater than the corresponding random data eigenvalue should be extracted.

Discriminant and convergent validity were examined by exploring the nature of the relationships among scores on the EBSM, EBI, AGI, TIS, the three revised EBAPS scenarios, and the endorsement of the six mathematics attitude statements. Initially, a correlation matrix of these variables was generated and examined for significant relationships. A series of multiple regression analyses were conducted using the EBSM score as the dependent variable, first with various demographic variables as independent variables, followed by analyses with other math related variables, and scores on the EBI subscales, AGI subscales the TIS as independent variables. ANOVA and MANOVA were used to evaluate domain-based EBSM score differences.

CHAPTER IV

RESULTS

There are more than one and less than ten independent dimensions that are necessary to define an individual's personal epistemology.

(Pintrich, 2002, p.394)

The purpose of the current chapter is to provide the results of statistical analyses that addressed the following research questions:

1. Is the Epistemological Beliefs Survey for Mathematics (EBSM) a reliable and valid measure of mathematics related epistemological beliefs?
2. What is the nature of the relationship between contextualized beliefs as measured by the EBSM and general epistemological beliefs measured by the Epistemological Beliefs Inventory (EBI)?
3. What is the nature of the relationship between contextualized epistemological beliefs as measured by the EBSM and achievement goals as measured by the Achievement Goals Inventory (AGI)?

4. What is the nature of the relationship between mathematics related epistemological beliefs as measured by the EBSM and implicit theories of intelligence as measured by the Theories of Intelligence Scale (TIS)?

The first question was addressed using an iterative process consisting of principal factor analysis followed by item deletion to assess dimensionality and item functioning. The identified factors were interpreted using oblique factor rotation. This process was followed by internal consistency reliability analysis that was used iteratively to identify and delete items that did not produce sufficient item-total correlations with the scale. To answer the remaining three research questions, the EBI, AGI, and TIS were each initially subjected to psychometric analyses to examine the relationship of previously reported factor structure and internal consistency estimates to those of the current sample. Specifically, principal factor analysis and principal components analysis followed by oblique and/or orthogonal rotation was used to examine scale structure. Once the psychometric properties of the scales were established, multiple regression analysis was used to regress the factors of the EBSM on scale scores from the EBI, AGI, and TIS as well as epistemological scenarios and mathematical belief statements.

Structural Analysis of Instruments

The following section details the results of structural analyses of each of the scales used in the current study. Included are results of principal axis factor analysis and internal consistency reliability analysis. Also included is a description of the resulting scales that were formed and used in subsequent analyses.

Epistemological Beliefs Survey for Mathematics (EBSM)

Initially, all 75 items were subjected to factor analysis. The inter-item correlation matrix was visually inspected and most values were in the low to moderate range. Statistical assessment of the correlation matrix for factor analysis of the 75 items was performed using both KMO and Bartlett's test of sphericity. KMO was equal to .84 and Bartlett's Test [$\chi^2(2775) = 9922.12; p < .001$] was significant, indicating that the inter-item correlation matrix was suitable for factor analysis.

The data were analyzed using principal axis factor analysis (PAF). Three criteria, the Kaiser criterion, scree plot, and parallel analysis, were used to estimate the number of factors to extract. There were 19 eigenvalues greater than one that accounted for 67% of the total variance. The scree plot appeared to support a five factor solution. Parallel analysis was computed for both PAF and PCA. PAF supported the extraction of 14 factors while PCA supported seven factors. Since a seven factor solution was supported by the theoretical structure of the scale, seven factors were extracted and obliquely rotated for interpretation. The first factor represented 20% of the total variance ($\lambda = 14.92$) and appeared to be a mixture of elements from several of the hypothetical factors. In fact, all seven theoretical factors had at least one item loading on the first factor. These analyses were repeated after removing 17 items that had factor loadings less than .40 on all factors. The remaining 58 items were subjected to principal factor analysis followed by oblique rotation. The results were very similar to the first set of analyses. There were 13 eigenvalues greater than one accounting for 64.3% of the total variance. The first eigenvalue ($\lambda = 13.77$) accounted for 23.7% of the total variance. Once again the scree plot supported a five factor solution while parallel analysis supported 12 and 7

factors for PAF and PCA respectively. The presence of a single factor that accounted for a substantial amount of the total variance led to hypothesis that the data may be characterized by a general factor.

The data were reanalyzed by applying PAF to each scale individually. An iterative process was used to refine each theoretical set of items to a uni-dimensional scale (see Tables 6 through 12). Uni-dimensionality was further evaluated through reliability analysis. Specifically, item-total correlations were examined and items deleted when the result was an improvement in coefficient alpha estimates. The following tables provide factor analytic and reliability information for each of the seven EBSM subscales that were subjected to higher-order factor analysis.

Table 6: EBSM Factor Loadings and Communalities for Source of Knowledge

Items	Factor Loading	h^2
1. To solve math problems you have to be taught the right procedure.	.71	.51
2. I learn math best when watching the teacher work example problems.	.53	.28
3. Math is something I could never learn on my own.	.52	.27
4. Learning math depends most on having a good teacher.	.45	.20
5. The quality of a math class is determined entirely by the instructor.	.42	.18

Note: $\lambda = 2.12$, 42.4% of total variance represented, $\alpha = .65$.

Table 7: EBSM Factor Loadings and Communalities for Certainty of Knowledge

Items	Factor Loading	h^2
1. In math, answers are always either right or wrong.	.58	.34
2. Truth is unchanging in mathematics.	.58	.34
3. All mathematics professors would probably come up with the same answers to questions in their field.	.57	.32
4. Creativity has no place in a math class.	.46	.21

Note: $\lambda = 1.90$, 47.5% of total variance represented, $\alpha = .63$.

Table 8: EBSM Factor Loadings and Communalities for Structure of Knowledge

Items	Factor Loading	h^2
1. It is a waste of time to work on problems that have no solution.	.62	.38
2. I don't care about <i>why</i> something works, just show me how to work the problem.	.61	.38
3. Understanding how math is used in other disciplines helps me to comprehend the concepts.	-.53	.28
4. I like to find different ways to work problems.	-.51	.26

Note: $\lambda = 1.96$, 49.1% of total variance represented, $\alpha = .65$. Items with negative loadings were reverse scored prior to reliability analysis.

Table 9: EBSM Factor Loadings and Communalities for Speed of Knowledge Acquisition

Items	Factor Loading	h^2
1. If I can't solve a problem quickly, I get frustrated and tend to give up.	.63	.39
2. If you can't solve a problem in a few minutes, you're not going to solve it without help.	.62	.38
3. It takes a lot of time to learn math.	.54	.29
4. When it comes to math, most students either <i>get it</i> quickly or not at all.	.51	.26
5. It is frustrating to read a problem and not know immediately how to begin to solve it.	.49	.24
6. If you know what you're doing, you shouldn't have to spend more than a few minutes to complete a homework problem.	.48	.23
7. When I encounter a difficult math problem, I stick with it until I solve it.	-.45	.20

Note: $\lambda = 2.69$, 38.4% of total variance represented, $\alpha = .73$.

Table 10: EBSM Factor Loadings and Communalities for Innate Ability-Personal

Items	Factor Loading	h^2
1. Math is like a foreign language to me and even if I work hard, I'll never really <i>get it</i> .	.86	.74
2. I'm just not a math person.	.79	.62
3. If math were easy for me, I wouldn't have to spend so much time on homework.	.66	.43
4. It is frustrating when I have to work hard to understand a problem.	.60	.36
5. I can learn new things, but I can't really change the math ability I was born with.	.55	.30
6. I'm confident I could learn difficult material like calculus if I put in enough effort.	-.54	.29

Note: $\lambda = 3.24$, 54.0% of total variance represented, $\alpha = .83$.

Table 11: EBSM Factor Loadings and Communalities for Innate Ability-General

Items	Factor Loading	h^2
1. Math ability is really just something you're born with.	.71	.51
2. You can learn new things, but you can't really change the math ability you were born with.	.69	.48
3. Most people know at an early age whether they are good at math or not.	.56	.31
4. The smartest math students don't have to do many problems because they just <i>get it</i> .	.56	.31
5. Some people are born with great math ability and some aren't.	.53	.28

Note: $\lambda = 2.49$, 49.8% of total variance represented, $\alpha = .75$.

Table 12: EBSM Factor Loadings and Communalities for Real-world Applicability

Items	Factor Loading	h^2
1. I'm rarely able to use the math I've learned in other subjects.	-.74	.55
2. I can apply what I learn in mathematics to other subjects.	.72	.51
3. It is easy to see the connections between the math I learn in class and real world applications.	.66	.44
4. Mathematics helps us better understand the world we live in.	.65	.42
5. I will rarely use algebra in real life.	-.64	.41
6. I need to learn math for my future work.	.60	.36
7. Understanding mathematics is important for mathematicians, economists, and scientists, but not for most people.	-.56	.31
8. Mathematics provides the foundation for most of the principles used in science and business.	.47	.22

Note: $\lambda = 3.79$, 47.4% of total variance represented, $\alpha = .84$.

The seven scales, representing the seven theoretical factors, were then subjected to PAF analysis. As in previous analyses, the inter-scale correlation matrix was inspected and the correlations ranged in absolute magnitude from .32 to .68. All bivariate correlations were significant at $p < .001$. KMO was equal to .86 and Bartlett's test [$\chi^2 (21) = 919.47$; $p < .001$] was significant. Both the Kaiser criterion and the scree plot supported a single factor ($\lambda = 4.023$) that accounted for 57.5% of the total variance (see

Table 13). Factor loadings ranged in magnitude from .63 to .89 and communalities ranged from .39 to .80.

The hierarchical factor was interpreted as General Beliefs about Learning Mathematics. The factor can be described in terms of its composite factors as a spectrum that ranges from a naive or non-availing view (Muis, 2004) characterized as follows: Math is something you are born with or not. Math is something that can be mastered quickly if it going to be mastered at all. It has little real-life application for the average person. Students endorsing this view believe mathematics consists of a set body of knowledge. In addition, these students view the teacher as the key to mathematics learning, are generally uninterested in conceptual explanations, and see themselves as passive recipients in the learning process. Students typically just want to know how to work the problems. At the opposite end of the spectrum is a more sophisticated or availing view of learning mathematics. This view is characterized by a belief that hard work, persistence, and continued practice can improve one’s math skills. These students are not satisfied with instruction that focuses on mechanics. They prefer big-picture, conceptual explanations that connect to real-world applications. Although these students rely on the teacher and see her as a critical component in the learning process, they also see themselves as active participants.

Table 13: EBSM Second-Order Factor Structure

Scale	Factor Loading	h^2
Leaning is Innate -Personal	.89	.80
Speed of Knowledge Acquisition	.80	.65
Learning is Innate - General	.72	.52
Real World Applicability	-.66	.44
Structure of Knowledge	-.65	.43
Certainty of Knowledge	.63	.39
Source of Knowledge	.59	.35

A scale was constructed that contained the 39 items from the various uni-dimensional subscales and was subjected to reliability analysis. Items that produced negative item-scale correlations were reverse scored. The coefficient alpha estimate of internal consistency was .93. The bivariate correlation between the factor score generated in PAF analysis and the scale score computed by summing raw scores for each item was .99. Scale scores were used in subsequent analyses.

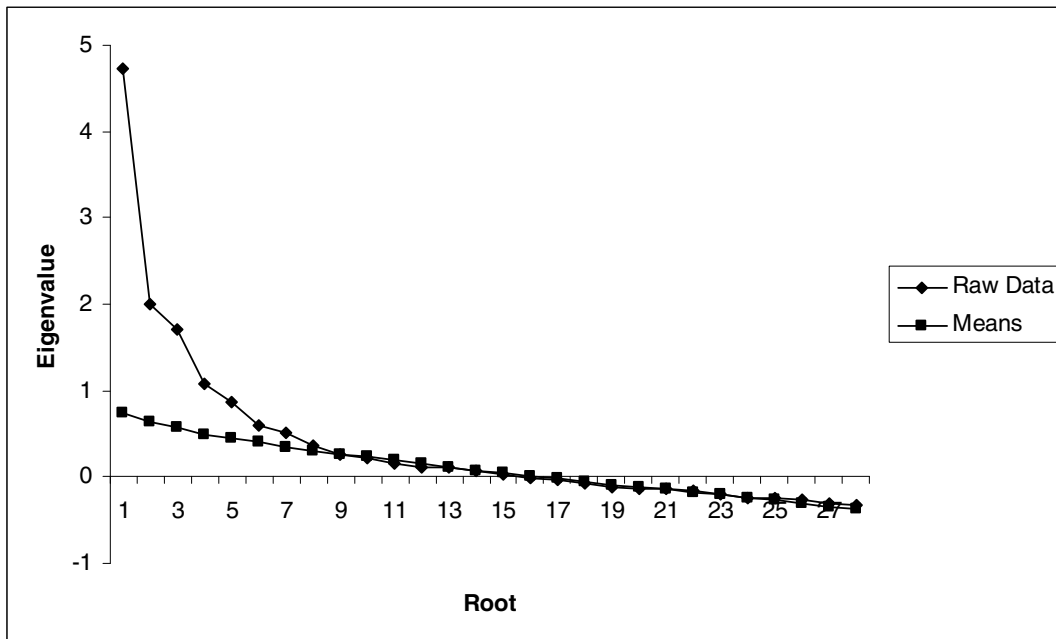
Epistemic Beliefs Inventory (EBI)

Analysis of the EBI began with a structural analysis of the scale. Visual inspection of the inter-item correlation matrix revealed a pattern of low to moderate correlations. Of the 378 unique off-diagonal elements only thirteen correlations exceeded .04. The vast majority of correlations were in the .01 to .03 range. Statistical assessment of the correlation matrix for factor analysis of the 28 items was performed using both the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy and Bartlett's test of sphericity. KMO was equal to .79 and Bartlett's Test [$\chi^2(378) = 2273.20; p < .001$] was significant, indicating that the inter-item correlation matrix was suitable for factor analysis.

The EBI items were analyzed using principal axis factor analysis (PAF). Three criteria, the Kaiser criterion, scree plot, and parallel analysis, were used to determine the number of factors to extract. Although there were eight components with eigenvalues greater than one, the scree plot suggested a five factor solution, and parallel analysis indicated that seven factors should be extracted (see Figure 1). Existing theory regarding the development of the EBI (Scraw, Bendixen, & Dunkle, 2002), supports a five factor

solution. Since the consequences of over-extraction are less severe than under-extraction, a seven factor solution, which accounted for 57% of the total variance, was initially explored using oblique rotation for interpretation. Analysis of the structure matrix found two factors that contained no substantial loadings. The data was reanalyzed, rotating five factors to final solution using oblique rotation.

Figure 1: Parallel Analysis for EBI



Following oblique rotation using direct oblimin, 27 out of 28 items produced a factor loading of at least .30. One item, *What is true today, will be true tomorrow*, failed to produce a significant loading on any factor. The inter-factor correlations were small, ranging in absolute magnitude from .02 to .33. The analysis was again repeated using Varimax rotation. One additional item, *Sometimes there are no right answers to life's big problems*, failed to produce a significant loading under orthogonal rotation. This item had produced a small loading (.32) under oblique rotation. These two items were deleted

and the final 26 items were factor analyzed a third time. Only three of the five factors were interpretable. The first factor was a combination of items theoretically linked to three different scales. Closer examination of the item distributions revealed that these items were heavily endorsed by participants thus the first factor appeared to be a statistical factor based on item distribution similarities. The fifth factor also appears to be a statistical factor. The four items that formed this factor all had responses very tightly clustered around the center of the distribution meaning that the scale as a whole was leptokurtic. Factors 2, 3 and 4, however, appear to be valid factors that are interpretable and consistent with existing theory (see Table 14). These scales were named, Innate Ability ($\lambda = 2.56$, 9.8% of variance), Simple Knowledge ($\lambda = 2.17$, 8.3% of variance), and Omniscient Authority ($\lambda = 1.66$, 6.4% of variance), based on previous theory. The two factors that failed to emerge in the current analysis, but were documented in the initial scale development, are Certain Knowledge and Quick Learning. Most of the items that formed these two scales loaded on Factors 1 or 5.

It is important to note that Schraw et al. (2002) did not fully report the factor structure of the 28-item EBI. Specifically, three example items were provided for each factor and unfortunately, one of these items (the largest loading item on Certain Knowledge factor) was, for unknown reasons, not included in the full-scale. This leaves 14 items not specifically identified with a factor. In the current study these items were identified with a factor based on previous theory. As a result, it is unclear to what extent the three interpretable factors reported in the current study replicate factors reported by Schraw et al. (2002).

Table 14: EBI structure coefficients and communalities based on PAF and Varimax rotation.

Item	Factor 1	Innate Ability	Simple Knowledge	Omniscient Authority	Factor 5	h^2
1. If you don't learn something quickly you won't ever learn it..	.66					.56
2. If you haven't understood a chapter the first time through, going back over it won't help.	.63					.55
3. Some people are born with special gifts and talents.	-.61					.58
4. People's intellectual potential is fixed at birth.	.55	.51				.56
5. If two people are arguing about something, at least one of them must be wrong.	.55					.36
6. Working on a problem with no quick solution is a waste of time.	.50					.50
7. The more you know about a topic, the more there is to know.	-.49					.34
8. Smart people are born that way.		.67				.55
9. Students who learn things quickly are the most successful		.66				.49
10. Really smart students don't have to work as hard to do well in school.		.64				.45
11. How well you do in school depends on how smart you are.		.51				.39
12. Some people just have a knack for learning and others don't.		.44				.36
13. If a person tries too hard to understand a problem they will most likely end up being confused.			.66			.52
14. Instructors should focus on facts instead of theories.			.53			.49
15. Too many theories just complicates things.			.50			.37
16. The best ideas are often the most simple.			.49			.35
17. When someone in authority tells me what to do, I usually do it.				.61		.43
18. People should always obey the law.				.61		.43
19. People shouldn't question authority.				.50		.32
20. Children should be allowed to question their parent's authority.				-.44		.23
21. Parents should teach their children all there is to know about life.				.37		.18
22. Absolute moral truth does not exist.				-.31		.11
23. Things are simpler than most professors would have you believe.					.48	.25
24. Most things worth knowing are easy to understand.	.43				.46	.45
25. What is true is a matter of opinion.					.39	.16
26. Science is easy to understand because it contains so many facts.					.32	.15

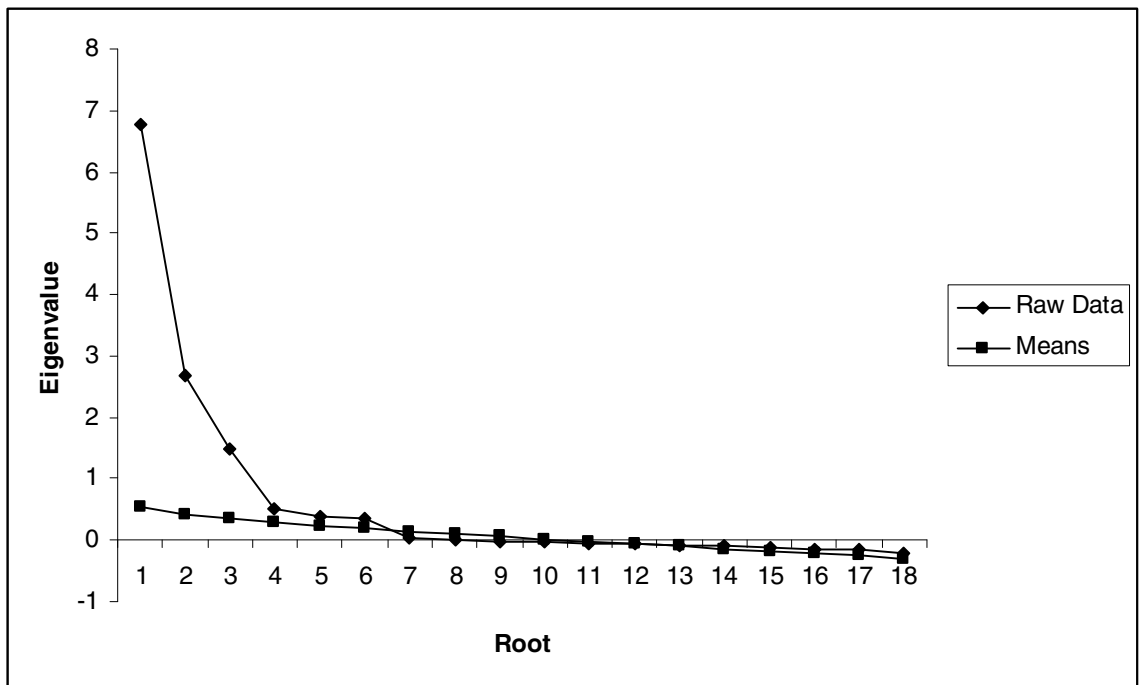
Scales were formed from the items that loaded on the three factors, Innate Ability, Omniscient Authority, and Simple Knowledge, and these scales were then subjected to reliability analysis. The coefficient alpha estimate for the five items that formed the Innate Ability scale was .75. One item associated with the Omniscient Authority scale, *Absolute moral truth does not exist*, produced low item-total correlations and was deleted from the scale. The resulting 5 item scale had an internal consistency reliability estimate of .61. The four-item, Simple Knowledge scale produced a coefficient alpha estimate of .66. These values are very similar to those reported in previous research (Schraw et al., 2002).

Achievement Goals Inventory (AGI)

Analysis of the AGI began with a structural analysis of the scale. Initial inspection of the bivariate correlations for the 18-item AGI revealed a pattern of correlations ranging from small to large with the majority in the moderate range. Examination of the frequency distributions for the items revealed three items that comprise the Outcome Goal scale were heavily endorsed by students, creating an extremely skewed scale distribution. Statistical assessment of the correlation matrix for factor analysis of the 18 items was performed using both the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy and Bartlett's test of sphericity. Bartlett's Test [$\chi^2(153) = 3598.7; p < .001$] was significant and KMO was equal to .89, indicating that the inter-item correlation matrix was suitable for factor analysis. The data was analyzed using both principal axis factor analysis (PAF) and principal components analysis (PCA) and three criteria were used to determine the number of factors to extract; the Kaiser criterion,

Scree Plot, and parallel analysis (see Figure 2). Both the Kaiser criterion and the scree plot converged on a three factor solution. Parallel analysis, however, seemed to suggest that a four factor solution might be more appropriate.

Figure 2: Parallel Analysis for AGI



The statistical procedures documented by Grant and Dweck (2003) were repeated with the current sample for comparative purposes. Specifically, four factors were extracted using PCA, followed by varimax rotation. The result was an identical factor solution to that reported by Grant and Dweck (2003). In addition, the percentage of total variance explained was 72%, identical to that previously reported. Factor loadings were similar in magnitude and one item crossloaded on the same two scales in both samples.

Since the inter-factor correlations reported by Grant and Dweck (2003) were substantial, ranging from .17 to .53 and because of the tendency for the *Little Jiffy*

(Gorsuch, 1983), PCA with varimax rotation, to impose structure on even random data, additional analyses were conducted using PAF and oblique rotation to explore alternative factor solutions. Four factors were extracted that accounted for 72% of the total variance. The factor structure was basically similar to the PCA solution reported by Grant and Dweck (2003), however, the inter-factor correlations were substantial, ranging in absolute magnitude from .10 to .52, suggesting the presence of a higher order factor. A second order factor analysis was conducted using the factor scores from the first order factors as variables. Two factors were extracted that accounted for 78.1% of the total variance. The factors were obliquely rotated to a final solution (see Table 16).

Two scales were formed from the items that comprised the higher-order factors and subjected to reliability analysis. The first scale consisted of 15 items from the Ability Goals, Normative Outcome Goals, Learning Goals, and Outcome Goals factors. All of the items that comprise the first-order factors pertained to various aspects of course performance and therefore, the second-order factor was named Course Outcome Goals. Outcome goals assess the importance of getting good grades and doing well in class. Ability goals emphasize the confirmation of intelligence through course performance. Learning Goals reflect value in the learning process. The Normative Goals items, which formed a single factor under PCA with orthogonal rotation (Grant & Dweck, 2003), split into two factors under PAF analysis. Normative Outcome Goals combined with Ability Goals to form the first factor, although all three items cross loaded with the three items that formed the Normative Ability factor. Normative outcome goals focus on course performance in comparison to others while Normative Ability goals emphasize validating intelligence through comparison with others. The second higher order factor was formed

from the three items related to Normative Ability and, therefore, retained this name (see Table 16). Coefficient alpha internal consistency estimates for the two scales were .90 and .94 for Course Outcome and Normative Ability scales respectively.

Table 15: AGI Structure Coefficients and Communalities

Item	Ability with Normative Outcome	Normative Goals	Learning Goals	Outcome Goals	h^2
One of my important goals is to validate my intelligence through my schoolwork.	.84	-.45			.71
In school I am focused on demonstrating my intellectual ability.	.77	-.40	.40	.43	.61
A major goal I have in my courses is to get higher grades than the other students.	.72	-.72			.71
It is very important to me to do well in my courses compared to others.	.65	-.52		.49	.54
It is important to me to confirm my intelligence through my schoolwork.	.64			.41	.43
I try to do better in my classes than other students.	.59	-.52		.41	.46
When I take a course in school it is very important for me to validate that I am smarter than other students.	.42	-.94			.88
It is very important to me to confirm that I am more intelligent than other students.	.45	-.88			.78
In school I am focused on demonstrating that I am smarter than other students.	.42	-.87			.78
I really enjoy facing challenges, and I seek out opportunities to do so in my courses.	.40		.81		.68
I seek out courses that I will find challenging			.76		.60
In school I am always seeking opportunities to develop new skills and acquire knowledge.	.46		.76	.43	.63
It is very important to me to feel that my coursework offers me real challenges.			.75		.57
In my classes I focus on developing my abilities and acquiring new ones.	.45		.74	.53	.64
A major goal I have in my courses is to perform really well.	.59			.85	.75
I really want to get good grades in my classes	.42			.82	.68
It is very important for me to do well in my courses.				.72	.52
I strive to constantly learn and improve in my courses.	.53		.62	.64	.63

Table 16: Second order PAF for AGI factors

First-order Factors	Factor 1 $\alpha = .90$	Factor 2 $\alpha = .94$
Ability and Normative Outcome Goals	.82	
Normative Ability Goals	.81	-.73
Learning Goals	.51	
Outcome Goals		.73

Note: Inter-factor correlation, $r = -.37$.

Theories of Intelligence Scale (TIS)

Analysis of the TIS began with structural analysis. Initial inspection of the inter-item correlations revealed moderate to large correlations ranging from .27 to .71.

Bartlett's test [$\chi^2 (28) = 1262.4; p < .001$] was highly significant and the Kaiser-Meyer-Olkin Measure of Sampling Adequacy (KMO) was .87, indicating that the items were sufficiently related to warrant factor analysis. The data was analyzed using both principal axis factor analysis (PAF) and principal components analysis (PCA) and three criteria were used to determine the number of factors to extract; the Kaiser criterion, scree plot, and parallel analysis. All three criteria seemed to converge on a two factor solution.

There were two eigenvalues greater than 1.0 and both the scree plot and parallel analysis supported the extraction of two factors (see Figure 3). Two factors were extracted that represented 70% of the total variance and obliquely rotated using direct oblimin. The two factors were highly correlated ($r = -.67$). One factor represented the negatively worded items and the other positively worded items.

Since previous research found this scale to be uni-dimensional (Dweck, Chiu, & Hong, 1995), the data were reanalyzed to force a single factor to be extracted. The one factor solution accounted for approximately 57% of the total variance. All eight items produced strong factor loadings ranging in magnitude from .59 to .80. Communalities

ranged from .35 to .64 (see Table 17). Interestingly, parallel analysis produced using PCA supports a one-factor solution and produced similar factor loadings and communalities to the PAF solution (see Figure 4).

Figure 3: PAF Parallel Analysis of TIS Items

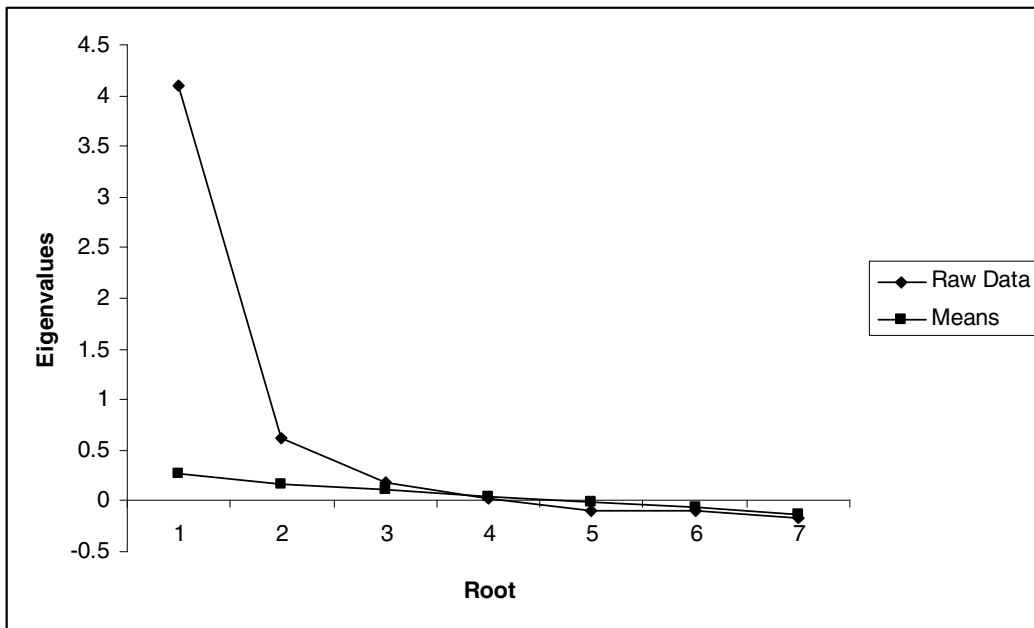


Figure 4: PCA Parallel Analysis of TIS Items

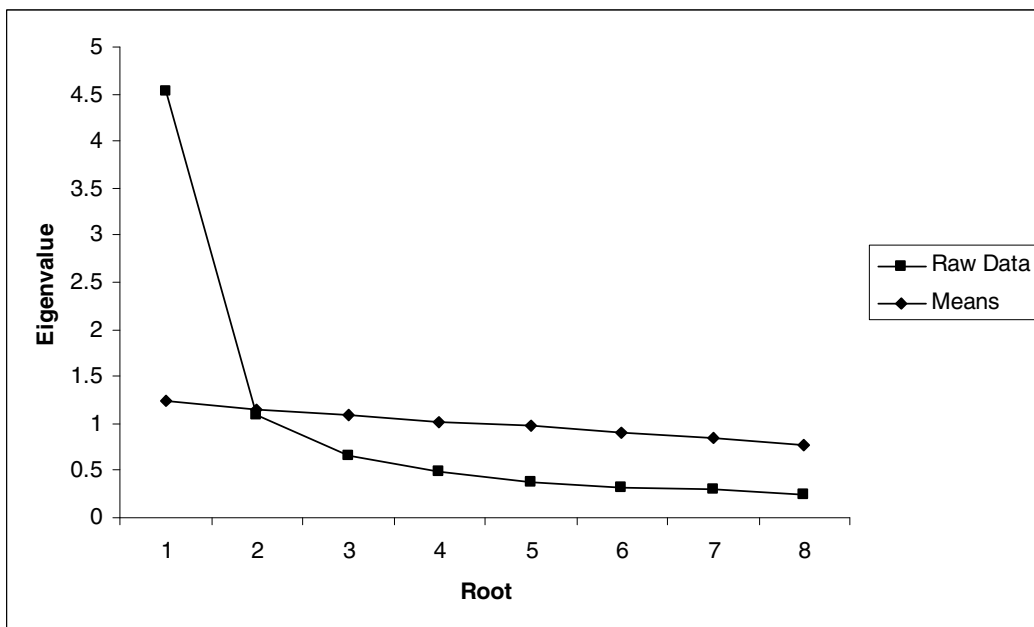


Table 17: Structure coefficients and communalities for TIS items

Item	Factor Loading	h^2
1. You can change even your basic intelligence level considerably.	.80	.64
2. You can learn new things, but you can't really change your basic intelligence.	-.78	.61
3. No matter who you are, you can significantly change your intelligence level.	.75	.57
4. You can always substantially change how intelligent you are.	.71	.50
5. No matter how much intelligence you have, you can always change it quite a bit.	.70	.49
6. Your intelligence is something about you that can't change very much.	-.69	.47
7. To be honest, you can't really change how intelligent you are.	-.66	.43
8. You have a certain amount of intelligence, and you can't really do much to change it.	-.59	.35

Once the uni-dimensionality of the scale was established, the negative loading items were reverse scored prior to reliability analysis. Coefficient alpha internal consistency reliability estimate was equal to .89. Both the factor structure and reliability estimates are very similar to those reported in previous studies (Dweck, Chiu, & Hong, 1995).

Construct Validity of the EBSM

Construct validity of the EBSM was explored through the analysis of relationships with demographic variables including age, gender, and academic classification, student's mathematical experience, endorsement of math related attitude statements, and through the analysis of relationships with other constructs including scores on the EBI, AGI and TIS.

Following structural analysis of the EBSM, EBI, AGI and TIS, scales were formed by summing the items associated with each substantive factor. Various scale characteristics including means, standard deviations, and coefficient alpha internal consistency estimates are presented in Table 18.

Table 18: Scale Means, Standard Deviations, and Inter-scale correlations

Scale	\bar{X}	s	EBSM	EBI-I	EBI-S	EBI-A	AGI-CP	AGI-NA	TIS
EBSM	137.0	24.0	.93						
EBI – Innate	17.1	4.1	.53*	.75					
EBI – Simple	14.6	3.0	.57*	.39*	.66				
EBI – Authority	19.6	3.5	.11	.15*	.16*	.61			
AGI – Course Performance	65.4	10.1	-.07	.04	.03	.30*	.90		
AGI – Normative Ability	9.6	3.4	.07	.30*	.15*	.17*	.42*	.94	
TIS	33.1	6.5	-.35*	-.56*	-.27*	.09	.17*	-.25*	.89

Note: Internal consistency estimates on main diagonal, * $p < .01$.

Demographic and Mathematics Variables

As described in Chapter II, epistemological beliefs have been linked to particular demographic variables. To test the assumption that mathematics related epistemological beliefs, as measured by the EBSM, varied demographically, EBSM scores were regressed on age, gender, and academic classification. The result was a statistically significant relationship ($F(3,265) = 4.369, p = .005$) with little practical significance, however, as only 5% of the variance in EBSM was accounted for by these demographic variables. Academic classification was the only significant predictor. The results seem to indicate that upperclassmen are more likely to endorse availing beliefs while underclassmen are more likely to endorse naïve beliefs.

Participants were provided a series of six statements that reflect commonly voiced mathematics experiences. The statements ranged from positive to negative (see Appendix F). EBSM scores were regressed on the six statements and the result was a highly significant relationship ($F(6,266) = 25.087, p < .001$) that accounted for 36% of the variance in EBSM scores with all six statements producing statistically significant regression coefficients. As predicted, the three negative statements produced positive regression coefficients and the reverse was true for the three positive statements. This indicates that higher scores on the EBSM (representing a naïve epistemology) are associated with more negative attitudes toward mathematics and lower scores (associated with an availing or more sophisticated epistemology) are related to positive attitudes.

Participants responded to three contextualized scenarios that measured various aspects of mathematical beliefs. EBSM scores were regressed on the three scenario scores and the result was highly significant ($F(2,2270) = 40.487, p < .001$) and accounted for 32% of the variance in EBSM scores. Only the first two scenarios, which measured Structure of Knowledge and Innate Ability, proved to be useful predictors. The third scenario was extremely skewed, as the vast majority of participants responded similarly. Once again, an availing epistemology was associated with lower EBSM scores and a naïve view was associated with higher scores.

Participants were asked to provide the number of mathematics courses completed in high school or college. This variable was to function as a proxy for mathematical competency. When EBSM scores were regressed on the number of courses completed the result was ($F(1,270) = 31.678, p < .001$) and indicated the proportion of variance shared between these variables was 11%. The regression coefficient was negative

indicating that more sophisticated or availing mathematics beliefs are associated with students who have completed more mathematics courses. This relationship may have been attenuated based on the observation that a large number of participants had completed a basic, three course algebra sequence.

Domain Specificity

It was hypothesized that students with majors in different quadrants of the Biglan (1973a) classification system would differ in their mathematics beliefs. Only the community college sample ($n = 186$) was used in this analysis because the university sample was not balanced across domains. The vast majority of university participants included education or business majors and were classified in a single quadrant, *soft-applied*, of the Biglan scheme.

A two (*pure-applied*) by two (*hard-soft*) between-subjects factorial ANOVA was used to assess mean differences in EBSM scores. Neither the interaction ($F(1, 156) = 2.987, p = .09$), nor the main effects ($F_{Pure/Applied}(1,156) = 2.631, p = .11$ and $F_{Hard/Soft}(1,156) = 1.537, p = .22$) were significant. It was hypothesized that perhaps mean differences among community college students are not as pronounced as they may be for upperclassmen and graduate students. Community college students are engaged in general education curriculum and have not experienced more focused upper division coursework in a declared major.

In order to examine more subtle mean differences, a factorial MANOVA was employed to assess mean differences on the seven uni-dimensional scales rather than the full EBSM scale. As was the case in the previous analysis, there was no significant

interaction ($\lambda(7, 150) = .951, p = .367$). The main effect for the *pure-applied* dimension was also not statistically significant ($\lambda(7, 150) = .954, p = .415$). The main effect for the *hard-soft* dimension was statistically significant ($\lambda(7, 150) = .880, p = .007$) and produced a partial η^2 equal to .12. Follow-up univariate tests indicated that two variables, Real World Applicability ($F(1, 156) = 9.464, p = .002, \text{partial } \eta^2 = .06$) and Innate Ability-General ($F(1, 156) = 3.952, p = .049, \text{partial } \eta^2 = .03$) had statistically significant mean differences. Specifically, students with academic majors classified as *hard* ($\bar{X} = 31.9$) were more likely to see the applicability of mathematical education than those with *soft* ($\bar{X} = 29.5$) majors. Interestingly, the students majoring in *hard* ($\bar{X} = 18.5$) areas were also slightly more likely to endorse a naïve view of innate ability than those majoring in *soft* ($\bar{X} = 18.1$) areas.

General Epistemological Beliefs

The relationship among various dimensions of general epistemological beliefs and math specific beliefs was assessed by regressing EBSM scores on the three EBI subscale scores. The result was a highly significant relationship ($F(3, 258) = 64.77, p < .001$) that accounted for 43% of the EBSM score variance. The Innate Ability and Simple Knowledge scales proved to be significant predictors while Omniscient Authority was not. It did not appear that multicollinearity was responsible for the lack of relationship between the Omniscient Authority and EBSM scores, as the Omniscient Authority scale was not highly correlated with either the Innate Ability ($r = .15$) or the Simple Knowledge ($r = .16$) scales. A scatterplot of the two variables, EBSM and EBI-

Authority, revealed a random pattern indicating no significant relationship between the two variables.

Bivariate correlations were computed for corresponding EBI and EBSM scales. The EBI Innate Ability scale produced a significant correlation with both the EBSM Innate-Personal ($r = .46, p < .01$) and General ($r = .65, p < .01$) scales. The correlation between EBI Simple and EBSM Structure scales was $.49 (p < .01)$ and the correlation between EBI and EBSM authority scales was $.24 (p < .01)$.

Achievement Goals and Theories of Intelligence

The relationship among achievement goals, theories of intelligence, and math beliefs was assessed by regressing EBSM scores onto the AGI subscale scores and the TIS scores. The result of regressing the EBSM on two subscales of the AGI, Course Performance and Learning- Ability, was not statistically significant ($F(2, 260) = 2.015, p = .135$) and accounted for a mere 1.5% of the variance. The result of the regression of EBSM scores on TIS scores was significant ($F(1, 264) = 36.73, p < .001$) and accounted for 12% of the total variance. The Innate Ability dimension of general epistemological measures is based on implicit theories of intelligence. To assess the nature of this relationship in the current study, the bivariate correlations between the TIS and EBSM subscales, Innate Ability-Personal and Innate Ability-General were computed. The results indicate that the TIS is significantly related to both the EBSM Innate Ability Personal ($r = -.32, p < .01$) and EBSM Innate Ability-General ($r = -.49, p < .01$) scales.

Summary

The first research question sought to assess the reliability and validity of the EBSM. Item level factor analysis of the EBSM indicated that the data might be characterized by a general factor. Subsequent analysis was conducted by submitting seven uni-dimensional scales to PAF analysis. The result was a single higher order factor. The internal consistency reliability estimate for the items that comprised this general epistemological factor was .93. The construct validity of the EBSM was evaluated through regression analysis. The EBSM scores were regressed onto a number of variables that represent a range of mathematics attitudes, beliefs, and experience. Statistically significant results that supported hypothesized relationships were documented. Initial results indicate that the EBSM is a reliable and valid measure of mathematics related epistemological beliefs.

Analysis of mean differences based on demographic variables was conducted and both gender and age seemed to be generally unrelated to epistemological beliefs while academic classification has a small, but statistically significant relationship with beliefs. Mean differences based on academic major were analyzed using both univariate ANOVA and MANOVA. Results indicate that differences exist between *hard* and *soft* majors but not *pure* and *applied*. The Real World Applicability and Innate Ability-General subscales appeared to be primarily responsible for the mean differences.

The second research question sought to assess the relationship among mathematics beliefs as measured by the EBSM and general epistemological beliefs measured by the EBI. EBSM scores were regressed onto the three EBI subscale scores and a statistically significant relationship emerged. In addition, bivariate correlations

among the three EBI subscales and corresponding EBSM subscales were examined. The results indicated a significant relationship between EBI Innate Ability and both EBSM Innate Personal and Innate General scales. There was also a significant relationship between the EBI Simple Knowledge and EBSM Structure of Knowledge scales. No significant relationship was found between the EBI Omniscient Authority and EBSM Source of Knowledge scales.

The third research question sought to address the relationship among mathematics beliefs and achievement goals as measured by the AGI. The structure of the AGI was first analyzed using PAF analysis and oblique rotation. The four first order factors were significantly correlated leading to higher order factor analysis. Two higher order factors emerged and were named, Course Performance and Learning Ability, and produced internal consistency reliability estimates of .90 and .94 respectively. No statistically significant relationship was found when EBSM scores were regressed onto the subscales of the AGI.

The fourth research question sought to address the relationship between mathematics beliefs and implicit theories of intelligence as measured by the TIS. The structure of the TIS was first analyzed using PAF analysis. The result confirmed previous research regarding the uni-dimensionality of the TIS. The coefficient alpha estimate of internal consistency was .89. The EBSM was regressed on the TIS and a statistically significant relationship was found. Bivariate correlations among the EBSM, AGI, and TIS indicate that implicit theories of intelligence are related to both achievement goals and math beliefs.

CHAPTER V

DISCUSSION

The important thing to note here is that the investigator is not finished once the scale is developed. There is always more to know . . .

Andrew Comrey

The purpose of the current study was to assess the psychometric properties of a scale developed to measure mathematics related epistemological beliefs. Factor analysis revealed that this construct may differ in structure from general measures of epistemological beliefs, and specifically the EBI. General epistemological beliefs have been found to be multidimensional (Jehng et al., 1993; Schommer, 1990; Wood & Kardash, 2002), although the exact nature of the dimensions has not converged in number or form. In contrast, the various theoretical dimensions of the EBSM were highly correlated and it appears that this construct is best represented by a hierarchical factor structure.

The EBSM was found to be related in expected ways to a number of mathematics related variables including, the number of mathematics courses completed in high school and/or college, endorsement of any number of six common mathematics attitude statements, and responses to contextualized epistemological beliefs scenarios. In spite of the structural differences between the general measure of epistemological beliefs

and the EBSM, the two constructs were highly correlated. Participants' EBSM scores were found to be moderately related to personal theories of intelligence but were not significantly related to achievement goals. The following discussion addresses each of the stated research questions, followed by limitations of the current study, and finally, implications for further research, theory, and practice.

Structure, Reliability and Validity of the EBSM

The initial item pool for the EBSM was comprised of 75 items corresponding to seven hypothesized dimensions; Source of Knowledge, Certainty of Knowledge, Structure of Knowledge, Speed of Knowledge Acquisition, Innate Ability – Personal, Innate Ability – General, and Real-world Applicability. The first research question asked: *Is the EBSM a reliable and valid measure of mathematics related epistemological beliefs?* This question was addressed through an iterative process of factor analysis and item deletion. The results of PAF analysis with the full 75 items resulted in a large first factor that accounted for nearly 24% of the total variance and was characterized by items from all seven hypothesized dimensions. To better understand the psychometric dynamics of the scale, items for each of the hypothesized dimensions were analyzed separately. Uni-dimensional scales were formed through an iterative process involving PAF analysis, internal consistency reliability analysis, and item deletion. The seven uni-dimensional scales were then subjected to PAF analysis and the result was a single factor that accounted for nearly 58% of the total variance. The 39 items that comprised this scale produced an internal consistency reliability coefficient of .93.

The emergence of highly correlated scales that ultimately produced a single higher-order factor was certainly an unexpected, although not unprecedented result. It is unclear to what extent students' general attitudes about mathematics may have masked the more subtle distinctions among items across dimensions. A similar result was reported previously (Buehl et al., 2002) during the development of a domain specific instrument that assessed beliefs about mathematics and history. All mathematics related items loaded on a single factor as did all history-based beliefs. Hofer (1999) also found support for a one-dimensional mathematics beliefs scale. Two factors initially emerged when six items were subjected to EFA and orthogonal rotation. The items were subsequently combined into a single scale based on internal consistency reliability analysis. Hofer (1999) indicated that the scale seemed to measure "acceptance of typical, relatively unsophisticated views about the nature of mathematics" (p. 77). In the present study this naïve view could be characterized as follows: Students view mathematics as a collection of mechanical skills, learned passively from a teacher, with little application to their everyday lives. At the opposite end of the continuum is a more sophisticated or availing view of mathematics, characterized by a belief that the student is an active participant in the learning process and hard work and persistence can improve one's math ability. These students frequently prefer conceptual explanations that link concepts to real-world applications.

The EBSM appears to be a consistent measure of mathematics related beliefs based on reliability analysis. The coefficient alpha estimate for the EBSM exceeds reliability estimates reported in previous studies of both general and domain specific instruments. Internal consistency reliability estimates on general measures of personal

epistemology are somewhat inconsistent and typically range from .45 to .70. Hofer (1999) reported a coefficient alpha estimate of .54 on a six-item math beliefs scale and Buehl et al. (2002) reported alpha estimates of .84 for each of two parallel forms of the 22-item mathematics portion of the Preliminary-Domain Specific Beliefs Questionnaire (P-DSBQ). One might argue that the larger number of items ($n = 39$) comprising the EBSM may have contributed to a larger internal consistency estimate. It should be noted, however, that even the smaller set of 24 items that comprised the first factor during the initial factor analysis, also produced a coefficient alpha estimate equal to .93.

It was hypothesized that students would be able to respond more consistently to domain specific items than to general epistemological beliefs items. This hypothesis appears to be supported in the current study. General measures of personal epistemology have been plagued by structural and psychometric inconsistency. General epistemological measures typically contain items that are difficult to answer devoid of context (e.g. *What is true today will be true tomorrow* or *What is true is a matter of opinion*). Elby and Hammer (2001) questioned that students could meaningfully and consistently respond to such general items. They suggested that items must be contextualized to elicit a meaningful response. In the current study, items were written that are specific to the learning and teaching of mathematics. Initial results indicate that students were able to respond more consistently to the mathematics items than the general items.

Differences in EBSM scores based on various demographic characteristics were examined via regression analysis. The result was statistically significant, but only a small proportion of the variance (5%) was accounted for. Gender and age appeared to be

unrelated to EBSM scores. Although reports of differences based on gender have been inconsistent, a number of studies have found no gender related effects on general measures of personal epistemology (Buehl et al., 2002; Chan & Elliott, 2002; Chan, 2003). A more consistent pattern of differences is documented with respect to age. The differences appear to be factor specific, however, with most researchers noting age differences on the innate ability factor (Bendixen et al., 1994; Paulsen & Wells, 1998; Schommer, 1998) and one study noting differences on the Authority/Expert Knowledge factor (Chan, 2003). One explanation for the findings in the current study may be found in the age distribution of participants. Although the age range of participants was 18 to 55 years, the distribution was extremely positively skewed with a mean participant age of 25 years. Studies with a restricted age range tend to produce less consistent results with respect to the relationship between age and epistemological beliefs. The fact that the data in the present study was clustered in the low 20s may have prevented the detection of differences with regard to age.

Academic classification (i.e. freshman, sophomore, etc.) was found to have a statistically significant relationship to EBSM scores with upperclassmen and graduate students endorsing more sophisticated beliefs than underclassmen. Similar findings have been documented in previous studies. Academic experience has consistently been associated with epistemological beliefs in high school (Schommer et al., 1997), collegiate (Jehng et al., 1993; Schommer, 1993b), and adult (Schommer, 1998) samples. As in the current study, higher levels of education were associated with more sophisticated epistemological beliefs. It is unclear whether longer exposure to educational experiences

influences one's beliefs, whether persons with more sophisticated beliefs are more likely to continue to engage in educational processes, or whether the two work synergistically.

It should be noted that the results of analyses using academic classification could be confounded with the effects of academic major. Upperclassmen in the current sample were generally university students who were primarily enrolled in education and business programs. As discussed in a subsequent section, education and business majors, both classified as *soft* disciplines in Biglan's scheme, have been associated with more sophisticated epistemological beliefs (Paulsen & Wells, 1998) and *hard* disciplines such as physics or engineering. The results of statistical differences based on academic classification should, therefore, be interpreted with caution.

Construct validity for the EBSM was evaluated in three ways. Participants were asked to endorse any number of six statements commonly expressed by students with regard to mathematics. The statements ranged from positive, *Math has always been easy for me*, to negative, *I have never had good experiences in a math class*. Participants were also asked to provide information regarding the number of mathematics classes they had taken during high school and college. This variable was to serve as a proxy for mathematics ability. Participants were also asked to respond to three brief scenarios that measured epistemological beliefs in the context of a typical learning situation. All three variables were significantly related in expected ways to EBSM scores. Specifically, students who endorsed more negative attitude statements, took fewer math courses in high school or college, and endorsed naïve beliefs on the contextualized scenarios also had more naïve mathematics related epistemological beliefs. These results indicate that

EBSM scores are related to students' attitudes about math and math experiences lending validity to the construct.

Domain specificity was analyzed using the Biglan (1973a, 1973b) classification system to organize academic majors across two domains, *pure-applied* and *hard-soft*. Neither the interaction effect nor the main effects were significant when using the total EBSM score as the dependent variable. Further analyses were conducted using the seven uni-dimensional scales as the dependent variables in a factorial MANOVA design. As before, there was no significant interaction, but unlike previous results the main effect for the *hard-soft* dimension was statistically significant. Univariate tests revealed that the source of the mean differences were the Real-World Applicability scale and the Innate Ability-General scale. Jehng et al. (1993) also found significant epistemological differences across a *hard-soft* classification system; with students in *soft* fields reflecting more sophisticated beliefs on three dimensions, Certainty, Structure, and Authority. There were, however, some differences between the system used by Jehng et al. and Biglan's system. For example, only four academic fields (i.e. engineering, business, arts/humanities, and social science) were studied and business majors were classified as *hard* while Biglan (1973a) classifies business majors as *soft*. Paulsen and Wells (1998) found significant differences across both the *hard-soft* and *pure-applied* dimensions using a series of univariate ANOVAs. Specifically, mean scores were higher (i.e. less sophisticated) on Certain Knowledge, Simple Knowledge, and Quick Learning scales in the *applied* fields and scores were also higher on Certain Knowledge in the *hard* domains. In the current study, although students in *hard* domains were able to more clearly see real-world applicability of mathematics, they were more likely to take a naïve

view of innate ability. Perhaps students in *hard* fields have always found mathematics relatively easy leading to their adoption of a more naïve perspective. If these same students were to complete an epistemological survey specific to a discipline like foreign language or literature would their responses change?

Although additional research is needed, the *hard-soft* dimension may best distinguish group differences. In Biglan's (1973a) initial study, the *hard-soft* dimension accounted for more variance among groups than the other two dimensions. Subsequent research has confirmed the explanatory power of the *hard-soft* dimension (Donald, 1990; Malaney, 1986). Donald (1990) documented that faculty differences in knowledge validation criteria were accounted for only by the *hard-soft* dimension and Malaney (1986) found the *hard-soft* dimension accounted for more than 60% of the variance among graduate students in a discriminant analysis. Donald (1990) concluded that perhaps the first dimension of Biglan's model best characterizes domain differences similar to *The Two Cultures* observed by Snow (1964).

Relationship to Other Constructs

The relationship of the EBSM to various constructs including general epistemological beliefs, achievement goals, and implicit theories of intelligence was explored through regression analyses. The results of these analyses provides evidence for convergent and discriminant validity of the EBSM. These results are detailed in the following section.

Relationship of EBSM to EBI

The second research question, *What is the nature of the relationship between mathematics beliefs measured by the EBSM and more general epistemological beliefs measured by the EBI?*, was first addressed through a structural analysis of the Epistemic Beliefs Inventory (EBI). Procedures similar to those described in previous studies (Schraw et al., 2002; Huglin, 2003) were followed with somewhat similar results. The current study replicated only three of the five factors documented in the initial validation study, namely Innate Ability, Simple Knowledge, and Omniscient Authority. Internal consistency reliability estimates in the current study ranged from .61 to .75, similar to estimates reported by Schraw et al. (2002). One unpublished validation study of the EBI (Huglin, 2003) reported somewhat lower coefficient alpha estimates on the three EBI factors interpreted in the current study. It seems that the measure of general epistemological beliefs continues to produce psychometric inconsistencies. One contribution of the current study is the documentation that some items tend to be over-endorsed. These consensus items formed a single factor that was not interpretable. It seems that these items should be revised and or replaced in subsequent studies using the EBI.

To evaluate the relationship between general epistemological beliefs and math specific beliefs, the EBSM scores were regressed on the three EBI scale scores and the result was statistically significant. Specifically, the analysis indicated that EBI scales accounted for approximately 43% of the variance in EBSM scores. These results indicate that there is considerable overlap between general epistemological beliefs and mathematics specific beliefs.

Bivariate correlations between corresponding scales of the EBI and EBSM ranged from .24 to .65 indicating that these scales measure related but not redundant constructs. The strongest correlation was between the EBI Innate Ability scale and the EBSM Innate-General scale. Shared variance between these scales was approximately 42%. Examination of specific items from these scales reveals an epistemological belief that to some extent transcends a specific academic domain. For example, the two largest loading items on the EBI Innate Ability and the EBSM Innate-General scales were, *Smart people are born that way* and *Math ability is really just something you're born with*, respectively. One would intuitively expect similarities in student responses to these items

The EBI Simple Knowledge and EBSM Structure scales share a moderate amount of variance (24%). Items representing the EBSM Structure factor have a distinct focus on a desire for conceptual understanding rather than computational efficiency. This factor distinguishes students who seek to understand *why* from those who just want to know *how*. The EBI Simple Knowledge factor is much more general, characterized by items such as, *If a person tries too hard to understand a problem, they will most likely end up being confused* and *Instructors should focus on facts instead of theories*.

The weakest observed relationship was between the Authority scales of the EBI and EBSM ($r^2 = .06$). It is possible that these two scales assess different constructs. The EBI Authority scale includes statements regarding authority in general. For example, *People shouldn't question authority* and *People should always obey the law*. Alternatively, the EBSM Authority scale focuses on the role of the teacher. This scale includes statements such as: *To solve math problems you have to be taught the right*

procedure. Beliefs about the role of the teacher may be independent of one's general view of authority.

Relationship of EBSM to AGI

The third research question, *What is the nature of the relationship between mathematics beliefs measured by the EBSM and achievement goals?*, was initially addressed through structural analysis of the Achievement Goals Inventory (AGI).

Although PCA and varimax rotation produced identical factor structure to that reported by Grant and Dweck (2003), Gorshuch's (1983) warnings about this procedure led to the use of principal axis factor analysis and oblique rotation in the current study. The inter-factor correlations following oblique rotation were substantial and lead to higher order factor analysis. Two correlated higher order factors were formed, the first labeled Course Outcome Goals ($\alpha = .90$) and the second, Normative Ability Goals ($\alpha = .94$).

Dweck (2000) initially conceptualized learning and performance goals as a uni-dimensional construct. She indicated that students will tend to endorse both learning and ability goals in benign situations. The distinction is manifest only under situations of forced choice or when students are observed in learning situations that challenge their knowledge or skills. For reasons just stated, students may have endorsed both learning and ability goals in the present study contributing to substantial inter-factor correlation.

EBSM scores were regressed on the AGI subscale scores and the result was not statistically significant. Bivariate correlations among AGI scale scores and EBI scale scores were negligible, ranging from .03 to .30. Epistemological beliefs appear to represent a construct distinct from achievement goals. This is an interesting finding as

both constructs are based in part on implicit theories of intelligence. The implications of this finding are explored further in the following section.

Relationship of EBSM to TIS

The fourth research question, *What is the nature of the relationship between mathematics beliefs measured by the EBSM and implicit theories of intelligence?*, was first addressed through structural analysis of the Theories of Intelligence Scale (TIS). Structural analysis of the TIS resulted in a unidimensional scale that produced an internal consistency reliability estimate of .89. The foundation of the general epistemological factor, Innate Ability, which is included in general epistemological beliefs measures and included as part of the hypothesized structure of the EBSM, is found in research regarding fixed and malleable beliefs about intelligence (Dweck & Leggett, 1988). It seems intuitive to assume that these constructs would be related, although a recent study designed to test this hypothesis found a moderate relationship between the Innate Ability factor of a measure of general epistemological beliefs and theories of intelligence ($r = .26$ for fixed intelligence and $r = -.34$ for malleable intelligence). The results of the current study produced similar results. A moderate correlation was found between the TIS and the EBSM ($r = -.35, p < .01$), indicating that more naïve mathematics related beliefs were associated with a fixed view of intelligence. When the relationship between the EBSM subscales relating to Innate Ability and the TIS was examined the result was a substantially stronger relationship particularly between the general form of the EBSM Innate Ability scale ($r = -.49, p < .01$).

Interestingly, although both epistemological beliefs and achievement goals are related to implicit theories of intelligence, they are unrelated to each other, each seemingly tapping an independent portion of the implicit theories construct. These observations prompt a number of currently unanswered questions including the following: Is one's theory of intelligence an antecedent to both one's epistemological beliefs and one's adoption of particular achievement goals? What is the nature of the relationship of all three constructs to academic outcome variables like achievement? Would an intervention directed at changing student's fixed beliefs to malleable ones (Dweck, 2000) ultimately influence both achievement goals and epistemological beliefs? These questions warrant further research to explore the nature of the relationship among these constructs.

Limitations

The results of the current study may be subject to the following limitations: First, the sample was non-random and may not be representative of the population. The sample was predominately white (67%) and female (70%) and these sample characteristics should be considered when interpreting the findings of the current study.

Second, only the community college sample could be used when analyzing mean differences based on Biglan's classification system. Nearly 80% of the university sample included education or business majors. Both of these fields are classified as *soft-applied* in the Biglan scheme, rendering group comparisons dubious. In addition, domain differences may have been masked in the community college sample, in that students are not yet fully engaged in courses in their major field of study. Community college

coursework consists primarily of general education courses. Domain differences may be more pronounced in samples including upper division and graduate students.

Third, the instrument was quite lengthy and completion required 40 to 45 minutes for most participants. Fatigue may have been a factor and a shorter version of the instrument will be used in subsequent studies. The length of the instrument may have affected responses on the EBI, AGI and or TIS as these items were delivered in random order after the EBSM items.

Fourth, although feedback regarding content validity was solicited from mathematics education specialists, none was returned. It is unclear to what extent the items could have been improved based on requested feedback.

Fifth, mathematics ability was assessed using the number of mathematics courses taken in high school or college as a proxy variable. It is unclear to what extent this variable is able to approximate mathematics ability. The distribution for this variable was leptokurtic, as a large number of participants had taken the basic algebra sequence including college algebra leading to a severely peaked distribution. Applying a transformation (e.g. a square root transformation) to the data may improve the validity of statistical analyses using this variable. A measure of mathematical thinking or problem solving may produce more meaningful results.

Sixth, the sample size was not large enough to allow for cross validation of results. Additional research will be needed to validate the results of the current study. And finally, factor analytic results are inherently subjective in nature, as the numerous decisions regarding factor extraction, rotation, and interpretation can lead to different outcomes.

Implications for Further Research

The results of the current study have generated a number of recommendations for further research. First, previous research (Buehl et al., 2002) found that confirmatory and exploratory factor analytic techniques produced different structural interpretations of the construct. In light of these results, confirmatory factor analysis should be used in subsequent validation studies. Specifically, a series of nested models can be compared and model fit analyzed. Second, if the uni-dimensional nature of the EBSM remains stable then the construct is a candidate for analysis via Item Response Theory. Rasch analysis of the scale may assist with further item refinement and scale development. Early indications are that a shorter, version of the instrument produced equivalent internal consistency reliability estimates and should be tested in subsequent studies. Third, predictive validity should be explored using an established measure of mathematical reasoning or problem solving. Fourth, structural equation modeling techniques should be used to explore a number of issues that emerged in the current study including, the synergistic relationship between exposure to education and epistemological beliefs, further exploration of the finding that the AGI and EBSM seem to tap independent portions of implicit theories of intelligence as measured by the TIS, and finally, a pre-post test design with an intervention directed at eliciting more sophisticated epistemological beliefs. Finally, the measure of general epistemological beliefs used in the current study did not prove to be a psychometrically sound measure of the construct. Item refinement and perhaps additional item construction followed by psychometric and structural analyses need to continue. In addition, further structural analysis of the AGI is warranted. The emergence of a higher order factor in the current study has not been

previously explored in achievement goal literature. This may open the door to new interpretations of this construct.

Implications for Theory and Practice

There is currently no comprehensive theoretical model of mathematics beliefs. The basis for the development of the EBSM was common themes that emerged in mathematics beliefs and general epistemological beliefs literature. The finding in the current study that mathematics related epistemological beliefs may be characterized by a hierarchical factor structure appears to be supported in previous studies of mathematics beliefs. Previous research indicates that students tend to believe mathematics knowledge is static, that the goal of problem solving is to produce the *right* answer, that mathematics knowledge is passively received from a teacher, and mathematics skill is either something you have or you don't (Kloosterman, 2002; Lerch, 2004; Mtetwa & Garofalo, 1989; Schoenfeld, 1989). Although these beliefs represent independent dimensions of general beliefs (i.e. Certain Knowledge, Simple Knowledge, Omniscient Authority, and Innate Ability), they appear to form a more coherent cluster of beliefs when focused specifically on mathematics.

Two independent evaluations of research in mathematics beliefs concluded that an important step in the advancement of the understanding of this construct is the development of psychometrically sound instruments (DeCorte et al., 2002, Muis, 2004). The current study represents an initial step in the process of producing a reliable and valid measure of mathematics related epistemological beliefs. The ultimate focus of research with both general and domain specific epistemological beliefs is to transform

naïve beliefs into more sophisticated or availing beliefs. Constructivist curriculum and learning environments are not well received when imposed on students with non-availing beliefs. In order for teachers to embrace conceptual, integrated instruction and for students to benefit from reform-based instruction, mathematics related epistemological beliefs must be evaluated and addressed as part of classroom practice. Experimental studies have shown that both achievement goals and implicit theories of intelligence are subject to manipulation through intervention (Dweck, 2000). Empirical research is needed to explore the effects of interventions aimed at influencing student beliefs.

Conclusions

Initial results seem to indicate that the EBSM is both a reliable and valid measure of mathematics related beliefs. The EBSM characterized mathematics-related epistemological beliefs as uni-dimensional based on factor analytic results. EBSM scores were related in expected ways to mathematics experience, mathematics attitudes, and math-based epistemological scenarios. Additionally, EBSM scores were related to general epistemological beliefs and implicit theories of intelligence, while unrelated to achievement goals.

The psychometric properties of the EBSM were superior to those of the EBI and may indicate that students are able to respond in more consistent ways to domain specific items. The result is a more consistent instrument in terms of structural and psychometric properties. Some of the items on domain general instruments like the EBI may be too general to elicit a consistent response on conceptually similar items leading to unstable factor structure and low estimates of internal consistency reliability. Qian and Alverman

(1995) noted that “modest internal consistency may be due to the nonconsensuality of the construct underlying belief systems” (p. 290).

It appears that general and domain specific epistemological beliefs are related but not redundant constructs. The present study supports a previous finding that students can hold both domain specific and domain general beliefs simultaneously (Buehl et al., 2002). The relationships among the EBSM, the AGI, and the TIS warrant further analysis through structural equation modeling. The results presented indicate that epistemological beliefs and achievement goals are independently related to theories of intelligence.

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APPENDIX A

EPISTEMOLOGICAL BELIEFS SURVEY FOR MATHEMATICS (EBSM)

Epistemological Beliefs Survey for Mathematics (EBSM)

I. Source of Knowledge

1. Learning math depends most on having a good teacher.
2. I learn math best when watching the teacher work example problems.
3. I learn math best by working practice problems.
4. A teacher said, "I don't *really* understand something until I teach it." But actually, teaching doesn't help a teacher understand the material better, it just reminds her of how much she already knows.
5. If math teachers gave *really clear* lectures with plenty of good example problems, I wouldn't have to practice so much on my own.
6. The quality of a math class is determined entirely by the instructor.
7. What I get from a math class depends mostly on the effort I invest.
8. Sometimes you have to accept answers from math teachers even if you don't understand them.
9. Math is something I could never learn on my own.
10. To solve math problems you have to be taught the right procedure.
11. In mathematics you can be creative and discover things on your own.

II. Certainty of Knowledge

1. Most of what is true in mathematics is already known.
2. Math is really just knowing the right formula for the problem.
3. I prefer a math teacher who shows students lots of different ways to look at the same problem.
4. Mathematics is like a game that uses numbers, symbols and formulas.
5. Mathematical theories are the product of creativity.
6. There is usually one *best* way to solve a math problem.
7. In math, the answers are always either right or wrong.
8. Creativity has no place in a math class.
9. All mathematics professors would probably come up with the same answers to questions in their field.
10. Truth is unchanging in mathematics.
11. Answers to questions in mathematics change as experts gather more information.

III. Structure of Knowledge

1. It is important to know why something works rather than memorize a formula
2. When learning math, I can understand the material better if I relate it to the *real world*.
3. When solving problems, the key is knowing the best method for each type of problem.
4. Math is mostly facts and procedures that have to be memorized.

5. I learn best when the *big picture* is presented before the specific steps for working a problem.
6. I like to find different ways to work problems.
7. I find it confusing when the teacher shows more than one way to work a problem.
8. If there weren't answers in the back of the book, I would have no idea whether I had worked the problem correctly or not.
9. I don't care about *why* something works, just show me *how* to work the problem.
10. It is a waste of time to work on problems that have no solution.
11. Understanding how math is used in other disciplines helps me to comprehend the concepts.
12. I often learn the most from my mistakes.

IV. Speed of Knowledge Acquisition

1. When it comes to math, most students either *get it* quickly or not at all.
2. It takes a lot of time to learn math.
3. If I can't solve a problem quickly I get frustrated and tend to give up.
4. When I encounter a difficult math problem, I stick with it until I solve it.
5. Given enough time, almost everyone could learn algebra if they really tried.
6. If you don't understand something presented in class, going back over it later isn't going to help.
7. If you can't solve a problem in a few minutes you're not going to solve it without help.
8. If you know what you're doing, you shouldn't have to spend more than a few minutes to complete a homework problem.
9. It is frustrating to read a problem and not know immediately how to begin to solve it.
10. In classes I've taken, I could have done better if I'd had more time to learn the concepts.

V. Innate Ability

Personal

1. When I'm having trouble in math class, better study habits can make a big difference.
2. I'm confident I could learn calculus if I put in enough effort.
3. When I don't understand something I keep asking questions.
4. Learning good study skills can improve my math ability.
5. Math is like a foreign language to me and even if I work hard I'll never really *get it*.
6. I knew at an early age what my math ability was.

7. If math were easy for me, then I wouldn't have to spend so much time on homework.
8. It is frustrating when I have to work hard to understand a problem.
9. I can learn new things, but I can't really change the math ability I was born with.
10. I'm just not a math person.

General

11. Better study habits are the key to success for persons who struggle in math.
12. Someone who doesn't have high natural ability is still capable of learning difficult material like calculus.
13. When you don't understand something you should keep asking questions.
14. Learning good study skills can improve a person's math ability.
15. Some people are born with great math ability and some aren't.
16. Math ability is really just something you're born with.
17. The smartest math students don't have to do many problems because they just *get it*.
18. It is frustrating for students to have to work hard to understand a problem.
19. You can learn new things, but you can't really change the math ability you were born with.
20. Most people know at an early age whether they are good at math or not.

VI. Real-world Applicability

1. I will rarely use algebra in real life.
2. Understanding mathematics is important for mathematicians, economists, and scientists but not for most people.
3. The only reason I would take a math class is because it is a requirement.
4. I would rather work on *real-life* problems than those in the textbook.
5. I need to learn math for my future work.
6. I can apply what I learn in mathematics to other subjects.
7. It is easy to see the connections between the math I learn in class and real world applications.
8. I'm rarely able to use the math I've learned in other subjects.
9. I will probably take more math than is required for my degree.
10. Mathematics provides the foundation for most of the principles used in science and business.
11. Mathematics helps us better understand the world we live in.

APPENDIX B
EPISTEMIC BELIEFS INVENTORY (EBI)

Epistemic Beliefs Inventory (EBI, Schraw et al., 2002)

1. Most things worth knowing are easy to understand.
2. What is true is a matter of opinion.
3. Students who learn things quickly are the most successful.
4. People should always obey the law.
5. People's intellectual potential is fixed at birth.
6. Absolute moral truth does not exist.
7. Parents should teach their children all there is to know about life.
8. Really smart students don't have to work as hard to do well in school.
9. If a person tries too hard to understand a problem, they will most likely end up being confused.
10. Too many theories just complicate things.
11. The best ideas are often the most simple.
12. Instructors should focus on facts instead of theories.
13. Some people are born with special gifts and talents.
14. How well you do in school depends on how smart you are.
15. If you don't learn something quickly, you won't ever learn it.
16. Some people just have a knack for learning and others don't.
17. Things are simpler than most professors would have you believe.
18. If two people are arguing about something, at least one of them must be wrong.
19. Children should be allowed to question their parents' authority.
20. If you haven't understood a chapter the first time through, going back over it won't help.
21. Science is easy to understand because it contains so many facts.
22. The more you know about a topic, the more there is to know.
23. What is true today will be true tomorrow.
24. Smart people are born that way.
25. When someone in authority tells me what to do, I usually do it.
26. People shouldn't question authority.
27. Working on a problem with no quick solution is a waste of time.
28. Sometimes there are no right answers to life's big problems.

APPENDIX C

ACHIEVEMENT GOAL INVENTORY (AGI)

Achievement Goal Inventory (Grant & Dweck, 2003)

1. It is very important to me to do well in my courses.
2. I really want to get good grades in my classes.
3. A major goal I have in my courses is to perform really well.
4. It is important to me to confirm my intelligence through my schoolwork.
5. In school I am focused on demonstrating my intellectual ability.
6. One of my important goals is to validate my intelligence through my schoolwork.
7. It is very important to me to do well in my courses compared to others.
8. I try to do better in my classes than other students.
9. A major goal I have in my courses is to get higher grades than the other students.
10. It is very important to me to confirm that I am more intelligent than other students.
11. When I take a course in school it is very important for me to validate that I am smarter than other students.
12. In school I am focused on demonstrating that I am smarter than other students.
13. I strive to constantly learn and improve in my courses.
14. In school I am always seeking opportunities to develop new skills and acquire knowledge.
15. In my classes I focus on developing my abilities and acquiring new ones.
16. I seek out courses that I will find challenging.
17. I really enjoy facing challenges, and I seek out opportunities to do so in my courses.
18. It is very important to me to feel that my coursework offers me real challenges.

APPENDIX D
THEORIES OF INTELLIGENCE SCALE (TIS)

Theories of Intelligence Scale (Dweck, 2000)

1. You have a certain amount of intelligence, and you can't really do much to change it.
2. Your intelligence is something about you that can't change very much.
3. No matter who you are, you can significantly change your intelligence level.
4. To be honest, you can't really change how intelligent you are.
5. You can always substantially change how intelligent you are.
6. You can learn new things, but you can't really change your basic intelligence.
7. No matter how much intelligence you have, you can always change it quite a bit.
8. You can change even your basic intelligence level considerably.

APPENDIX E

EDITED SCENARIOS FROM THE EPISTEMOLOGICAL
BELIEFS ASSESSMENT FOR PHYSICAL SCIENCE

Edited Scenarios from the Epistemological
Beliefs Assessment for Physical Science (EBAPS, Elby, 2001)

Directions: In each of the following items you will read a short discussion between two students who disagree about some issue. Then you'll indicate whether you agree with one student or the other.

1. **Brandon:** A good math textbook should show how the material in one chapter relates to the material in other chapters. It shouldn't treat each topic as a separate unit because they're not really separate.

Jamal: But most of the time, each chapter is about a different topic, and those different topics don't always have much to do with each other. The textbook should keep everything separate, instead of blending it all together.

With whom do you agree? Read all the choices before circling one.

- (a) I agree almost entirely with Brandon.
- (b) Although I agree more with Brandon, I think Jamal makes some good points.
- (c) I agree (or disagree) equally with Jamal and Brandon.
- (d) Although I agree more with Jamal, I think Brandon makes some good points.
- (e) I agree almost entirely with Jamal.

2. **Anna:** I just read about Elizabeth Perry, the economist. She sounds naturally brilliant.

Emily: Maybe she is. But when it comes to being a good at math, hard work is more important than natural ability. I bet Dr. Perry does well because she has worked really hard.

Anna: Well, maybe she did. But let's face it, some people are just smarter at math than other people. Without natural ability, hard work won't get you anywhere in math!

- (a) I agree almost entirely with Anna.
- (b) Although I agree more with Anna, I think Emily makes some good points.
- (c) I agree (or disagree) equally with Anna and Emily.
- (d) Although I agree more with Emily, I think Anna makes some good points.
- (e) I agree almost entirely with Emily.

3. Jessica and Mia are working on a homework assignment together. . .

Jessica: O.K., we just got problem #1. I think we should go on to problem #2.

Mia: No, wait. I don't really understand how we got that answer.

Jessica: Mia, we know it's the right answer from the back of the book, so what are you worried about? If we didn't understand it, we wouldn't have gotten the right answer.

Mia: No, I think it's possible to get the right answer without really understanding what it means.

- (a) I agree almost entirely with Jessica
- (b) Although I agree more with Jessica, I think Mia makes some good points.
- (c) I agree (or disagree) equally with Mia and Jessica.
- (d) Although I agree more with Mia, I think Jessica makes some good points.
- (e) I agree almost entirely with Mia.

APPENDIX F
DEMOGRAPHIC SURVEY

DEMOGRAPHIC SURVEY

GENDER Male
 Female

AGE: years

ETHNICITY (check one): Hispanic African American or black
 Native American White
 Asian American Multi Ethnic/Racial
 Other

What math courses have you have completed in high school and/or college?
(check all that apply)

Algebra I or Elementary Algebra
 Algebra II or Intermediate Algebra
 Geometry
 Math Structures
 College Algebra
 Trigonometry
 Pre-Calculus
 Calculus
 Other(s) _____

Are you an international student? (circle one): yes no

What is your classification? (check one): Freshman
 Sophomore
 Junior
 Senior
 Graduate Student

What is your College Major: _____

What is your Career Goal: _____

Which statements best describe your experiences in mathematics (Check all that apply):

Math has always been easy for me.
 Math is one of my favorite subjects.
 Math is not my favorite subject but I don't hate it.
 Math isn't easy for me. I have to work really hard to learn math.
 I have never had good experiences in a math class.
 I hate math.

 Other _____

APPENDIX G

SCRIPT

SCRIPT

I am conducting a study to examine student beliefs about learning. The responses you provide will help educators better understand student's beliefs about knowledge and learning. If you choose to participate in this study you will be asked to complete a questionnaire that asks to what degree you agree or disagree with a number of statements about beliefs specific to learning mathematics, general beliefs about knowledge and learning, beliefs about intelligence, and motivation.

Participation is strictly voluntary. If you choose not to participate or withdraw from the study at any time, there will be no penalty. The answers you provide are strictly confidential and no identifying information will be collected. It is estimated that the survey will take approximately 30 minutes to complete. Your participation is greatly appreciated.

APPENDIX H
IRB APPROVAL FORM

Oklahoma State University Institutional Review Board

Date: Tuesday, October 17, 2006
IRB Application No ED06189
Proposal Title: The Development and Construct Validation of the Epistemological Beliefs Survey for mathematics

Reviewed and Exempt
Processed as:

Status Recommended by Reviewer(s): Approved Protocol Expires: 10/16/2007

Principal Investigator(s)

Denna Wheeler	Laura Barnes
427 South 13th St.	700 N. Greenwood
Muskogee, OK 74401	Tulsa, OK 74016

The IRB application referenced above has been approved. It is the judgment of the reviewers that the rights and welfare of individuals who may be asked to participate in this study will be respected, and that the research will be conducted in a manner consistent with the IRB requirements as outlined in section 45 CFR 46.

The final versions of any printed recruitment, consent and assent documents bearing the IRB approval stamp are attached to this letter. These are the versions that must be used during the study.

As Principal Investigator, it is your responsibility to do the following:

1. Conduct this study exactly as it has been approved. Any modifications to the research protocol must be submitted with the appropriate signatures for IRB approval.
2. Submit a request for continuation if the study extends beyond the approval period of one calendar year. This continuation must receive IRB review and approval before the research can continue.
3. Report any adverse events to the IRB Chair promptly. Adverse events are those which are unanticipated and impact the subjects during the course of this research; and
4. Notify the IRB office in writing when your research project is complete.

Please note that approved protocols are subject to monitoring by the IRB and that the IRB office has the authority to inspect research records associated with this protocol at any time. If you have questions about the IRB procedures or need any assistance from the Board, please contact Beth McTernan in 219 Cordell North (phone: 405-744-5700, beth.mcternan@okstate.edu).

Sincerely,



Sue C. Jacobs, Chair
Institutional Review Board

VITA

Denna L. Walker Wheeler

Candidate for the Degree of

Doctor of Philosophy

Thesis: THE DEVELOPMENT AND CONSTRUCT VALIDATION OF THE
EPISTEMOLOGICAL BELIEFS SURVEY FOR MATHEMATICS

Major Field: Educational Psychology: Research and Evaluation

Biographical:

Education: Graduated from Muskogee High School, Muskogee, OK in 1980; attended the University of Tulsa, Tulsa, OK from 1980 to 1983; graduated with a B.S. degree in Mathematics in 1984 from the University of Oklahoma, Norman, OK; attended the University of Louisville, Louisville, KY in from 1985 to 1986; graduated with a M.Ed. degree in Counseling from the University of Arkansas, Fayetteville, AR in 1993. Completed the requirements for the Doctor of Philosophy degree with a major in Educational Psychology and emphasis in Research and Evaluation in July 2007.

Experience: Mathematics Teacher, Norman Public Schools, Norman, OK, 1985; Mathematics Teacher, Jefferson County Public Schools, Louisville, KY, 1985 to 1987; Personnel Clerk, The Southern Baptist Theological Seminary, Louisville, KY, 1987 to 1989; Administrative Assistant, Dillard Department Stores, Inc., Little Rock, AR, 1989 to 1990; Mathematics Instructor, University of Arkansas, Fayetteville, AR, 1991 to 1993; Mathematics Instructor, Connors State College, Warner, OK, 1996 to Present.

Professional Memberships: AERA, NCTM, NADE, DKG

Name: Denna L. Walker Wheeler

Date of Degree: July, 2007

Institution: Oklahoma State University

Location: Stillwater, Oklahoma

Title of Study: THE DEVELOPMENT AND CONSTRUCT VALIDATION OF THE
EPISTEMOLOGICAL BELIEFS SURVEY FOR MATHEMATICS

Pages in Study: 163

Candidate for the Degree of Doctor of Philosophy

Major Field: Educational Psychology: Research and Evaluation

Scope and Method of Study:

Item level factor analysis of the EBSM indicated that the data was best characterized by a hierarchical factor structure. Scores on seven uni-dimensional scales, representing hypothesized dimensions of the EBSM, were factor analyzed. The result was a single factor representing beliefs about mathematics and math learning. The internal consistency reliability estimate for the resulting 39 item scale was .93. The construct validity of the EBSM was evaluated through a series of regression analyses.

Findings and Conclusions:

The EBSM scores were regressed onto math related variables including mathematics experience, attitudes toward mathematics, and responses to math-based learning scenarios. Statistically significant relationships were documented. Analysis of mean differences based on demographic variables was conducted and both gender and age seemed to be generally unrelated to epistemological beliefs while academic classification had a small, but statistically significant relationship with beliefs. Mean differences based on academic major were analyzed using both ANOVA and MANOVA. Results indicate that differences exist between students majoring in *hard* and *soft* domains but no differences were found between *pure* and *applied* domains. The Real World Applicability and Innate-General subscales appeared to be primarily responsible for the observed mean differences. In addition, EBSM scores were regressed onto the subscales of a general measure of epistemological beliefs, a measure of achievement goals, and a measure of implicit theories of intelligence. Results indicate that the EBSM was related to theories of intelligence and general epistemological beliefs but unrelated to achievement goals.

ADVISER'S APPROVAL: Laura L. B. Barnes
