4-20-2011

Epistemological Beliefs of Engineering Students: A Comparison of Educational Levels and Institutional Type

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EPISTEMOLOGICAL BELIEFS OF ENGINEERING STUDENTS: A COMPARISON OF EDUCATIONAL LEVELS AND INSTITUTIONAL TYPE

by

Bethany A. King

A Dissertation

Submitted in Partial Fulfillment of the

Requirements for the Degree of

Doctor of Philosophy

Major: Educational Psychology and Research

The University of Memphis

May 2011

DEDICATION

To my parents, George and Barbara King and my brother, Brandon King:

Thank you for your love, patience, and encouragement.

To the memory of my grandfather, Alfred Julius King, Jr., and my uncle, John A. Greer:

I wish you were here to share this milestone with me.

ACKNOWLEDGEMENTS

I am thankful to several individuals who supported me in various ways as I worked on this dissertation. Without you, this dissertation would not have been possible to complete.

First, I am grateful to my advisor Dr. Susan Magun-Jackson for her words of wisdom, guidance, encouragement and patience. To Dr. Martin Jones, Dr. Christian Mueller, and Dr. Vicki Murrell, thank you for serving on my dissertation committee and for your invaluable advice during this process.

I am thankful to several administrators who allowed me to survey their students and supported me as I worked on this dissertation: Dr. Neal F. Jackson, who was an outstanding director, mentor and friend; Dr. Eric Welch, who always showed an interest in and supported my doctoral work; Dr. S. Keith Hargrove, who supported my research and always expressed a willingness to help me during the dissertation process; and Dr. Richard Warder, who encouraged his faculty to participate in my engineering education research.

I am grateful to the faculty and staff, who welcomed me in their engineering programs and classrooms to survey students. Also, thank you to all the engineering students who took time to complete the epistemological beliefs survey.

Also, thank you to my parents, brother, family, and friends for their constant prayers and words of encouragement. Specifically, thank you to my Disciple Bible study group, Kemba Heard, and Richard Wilkes for your prayers and inspirational words. All of your loving acts of kindness helped me to complete this dissertation more than you will ever know. In closing, thank you God for your grace and mercy.

ABSTRACT

King, Bethany A. Ph.D. The University of Memphis, May 2011. Epistemological Beliefs of Engineering Students: A Comparison of Educational Levels and Institutional Type. Major Professor: Susan Magun-Jackson, Ph.D.

This cross-sectional study used exploratory factor analysis (EFA) to validate the underlying theoretical 4-factor construct of Schommer's Epistemological Questionnaire (SEQ). The EFA solution failed to fit Schommer's construct. As a result, reliable scales were then determined and used to assess 518 engineering students' epistemological beliefs across educational levels. Further, this study compared the beliefs of 90 African American engineering students at a Historically Black University (HBCU) to those of 56 African American engineering students at two Predominantly White Institutions (PWI).

Results indicated that Underclassmen were significantly more likely than Upperclassmen to have beliefs in Quick Learning over and above the effects of students' background characteristics and institutional type. Background characteristics significantly predicted beliefs in Quick Learning, Fixed Ability, and Simple Knowledge. Male students, students attending the HBCU, and students belonging to ethnic groups other than African American and European American were more likely to have Quick Learning beliefs. Furthermore, male students were more likely to have beliefs in Fixed Ability, and African American students were more likely to have beliefs in Simple Knowledge.

No significant differences in epistemological beliefs were found between the African American engineering students at the HBCU and the African American engineering students at the two PWIs. However, being a graduate student, having a below average high school GPA, and having an above average high school GPA significantly predicted beliefs in Quick Learning for African American engineering students attending

the PWIs. Also, being a graduate student and having an above average high school GPA significantly predicted beliefs in Fixed Ability for African American engineering students attending the PWIs. Finally, being an African American Upperclassmen at the HBCU predicted sophisticated beliefs in Simple Knowledge.

This study contributes to engineering education research with conclusions that epistemological beliefs did indeed become more sophisticated as students progressed through college and African American engineering students' epistemological beliefs were not necessarily influenced by campus racial composition. In order to fully understand epistemological beliefs as related to engineering students' development and experience, further research is needed to compare the engineering classroom environment at both HBCUs and PWIs.

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CHAPTER 1

INTRODUCTION AND REVIEW OF LITERATURE

For the past three decades, there have been reports that address the concern that the United States is globally losing its competitive edge in the fields of Science, Technology, Engineering, and Mathematics (STEM) (Collea, 1990; National Science Foundation [NSF], 2010). The United States' competitive edge in STEM fields is important as science and technology perpetuate growth in the economy and in new markets. Furthermore, there is a concern that as American science and engineering workers approach retirement, the number of scientists and engineers to replace them will consistently decline (Committee on Science, Engineering, & Public Policy [COSEPUP], 2007; Southern Education Foundation [SEF], 2005). As engineering and science fields grow faster than jobs in other fields, opportunities in engineering will increase by 15% by the year 2012 (NSF, 2006). With this in mind, the engineering educators and researchers have outlined a course of action to reform engineering education in the United States ("The Research Agenda," 2006).

The educators and researchers started a reform in engineering education after realizing that the primary focus to perpetuate an interest in STEM careers is academic preparation of students in the United States (National Academy of Engineering [NAE], 2005; NSF, 2006). This reform addresses K-12 education in levels as well as undergraduate engineering education. In addition to the preparation of a solid mathematics and science foundation, the reform suggests students be exposed to engineering concepts so that they learn to think like scientists and engineers ("The

Research Agenda," 2006). Students and educators should also be introduced to the positive influences that engineering makes on society.

Engineering education reform incorporates ways to increase the mathematics and science achievement of underrepresented minorities (e.g., African Americans, Hispanics, Native Americans, and women) to fill the pipeline of STEM professionals. The Southern Education Foundation (2005) predicted that minorities would represent 70% of the overall growth of individuals between the ages of 18 and 24 between the years of 2001 and 2010. More specifically, the Southern Education Foundation reported a 19% increase in the population of African Americans within this age group. Furthermore, in 2000, Historically Black Colleges and Universities (HBCUs) awarded 40% of the STEM degrees earned by African Americans. As a result, HBCUs can be considered as a primary source to prepare more African Americans for the field of engineering.

The National Academy of Engineering (2005) states that successful engineering education reform must consider each part of the engineering education system, so that "the teaching, learning, and assessment process will move a student from one state of knowledge and professional preparation to another state" (p. 18). The Accreditation Board for Engineering and Technology [ABET] (2007) also emphasizes the importance of knowledge by requiring engineering programs to assess their students' ability to apply the knowledge of engineering to the real world. Also emphasizing the importance of engineering knowledge, the Research Agenda (2006) for engineering education proposes that research is needed in the area of engineering epistemologies insofar as to understand "what constitutes engineering thinking and knowledge within social contexts now and into the future" (p. 259).

Engineering education researchers are interested in understanding the technical, social, and ethical aspects of engineering epistemologies ("The Research Agenda," 2006). This would assist engineering students in making a seamless and successful transition of applying theoretical skills acquired in college to the practical use of skills in an engineering career. Assessing the epistemological beliefs of engineering students is an initial attempt in understanding and examining engineering epistemologies. Epistemological beliefs can be quantitatively analyzed by examining engineering students' responses to questions that measure individuals' multidimensional beliefs about knowledge.

This cross-sectional, comparative analysis study investigated the effects of educational level and institutional type on the epistemological beliefs of engineering students at two Predominantly White Institutions (PWIs) located in western Tennessee and one Historically Black University located in middle Tennessee. The following literature review will first provide an overview of epistemology and epistemological belief development models. A selective review of these models assessing engineering students will follow. Third, a selective review of the research on African American engineers will be presented. The review of the literature ends with comparative analysis studies of African Americans at HBCUs and PWIs.

Epistemological Beliefs

Epistemology is a branch of philosophy that studies the origin, nature, methods, and limits of human knowledge. Educational psychologists study epistemological development and beliefs to determine how students come to know, what beliefs they have about knowledge, and how epistemological beliefs affect cognitive processes (Hofer & Pintrich, 1997). Three epistemological belief theories that have influenced studies in educational psychology will be reviewed in this section. First, Piaget's (1932) genetic epistemology theory will be discussed, as it is the foundation for studying epistemological beliefs in educational psychology. Then, the development of Perry's (1970) stage theory will be discussed, as he was the first to conduct epistemological belief studies with college students. Finally, this section will conclude with a discussion of Schommer's (1990) theory, as she was the first to suggest that epistemological beliefs are multidimensional and independent.

Jean Piaget

Jean Piaget generated interest in epistemology among developmental psychologists with his study of genetic epistemology (Piaget, 1932). Although he was an accomplished biologist, Piaget had an interest in philosophy. More specifically, he was interested in the branch of philosophy of epistemology. By combining his background in biology with his training in psychology, Piaget studied genetic epistemology in order to observe changes in knowledge from a biological perspective. That is, genetic epistemology is how individuals know what they know.

Piaget's (1932) research in the process of thought led him to the conclusion that the processes were inherent to human makeup. Essentially, individuals develop schemata, which are philosophical reasoning of what the environment is about and how to interact with it and in it, in order to adapt and survive. Two fundamental processes take place, organization and adaptation. Organization refers to an organized rationale or pattern behind the thought process. Adaptation, on the other hand, refers to adapting schema to the environment. When these two processes are in place, the schemata are in equilibration, which basically means the thought is balanced. There are two sub-processes that take place during equilibrium—assimilation and accommodation. Assimilation is the process of taking in or perceiving something new in the environment while accommodation is adjusting one's schemata to account for what was just taken in or assimilated. These two processes are tied together and as such create ”new” schemata.

As a result of his epistemic studies, Piaget defined the cognitive development stage theory, which described the invariant progression of how humans form knowledge and content of thoughts in order to make sense of their environment (Vuyk, 1981; Woolfolk, 2007). Influenced by the work of Piaget, other researchers examined epistemological beliefs beyond childhood and adolescence. William Perry is one such researcher and is considered by many as the pioneer of epistemological development studies of college students (Hofer & Pintrich, 1997; Muis, 2004).

Perry Model

Using open-ended questions, Perry (1970, 1988) conducted two longitudinal studies interviewing male college students about their perceptions of what influenced their college experience. He noticed changes in the students' thinking processes and) mapped the students' college experiences. As a result, Perry formed the foundation of his epistemological development theory for college students. He determined that there are nine positions that are grouped into four broad classifications that represent the students' overall view: dualism, multiplicity, relativism, and commitment.

In addition to the positions and classifications, Perry included three transitions as individuals move from one broad classification to another. The transitions take place at three positions. The first transition is from position 2 to 3. During this transition, an individual moves from Dualism to Multiplicity and realizes that there is some truth that remains uncertain and unknown. The second transition occurs from position 4 to 5. When an individual moves from Multiplicity to Relativism and realizes that knowledge is relative and is influenced by its context. In the last transition, an individual moves from Relativism to Commitment. Specifically, the transition occurs from position 6 to 7. At this point, individuals make an initial commitment based on their beliefs. For example, individuals will make commitments related to their careers and values. The following paragraphs discuss each classification in detail (also see Table 1).

Dualism includes the first two positions (Perry, 1970). In Dualism, an individual thinks that a concept is right or wrong, good or bad. A dualistic individual will believe that an authority figure (e.g., teacher) will always have the right answers. Studies show that most engineering students begin college at the transition between position 2 and position 3 (Fitch & Culver, 1984; Pavelich & Moore, 1996; Wise, Lee, Litzinger, Marra, & Palmer, 2004). Position 3 and position 4 create the second classification, Multiplicity. At these positions, an individual accepts that there are many differing opinions and an authority figure may not know the right answer.

The Relativism classification consists only of position 5 (Perry, 1970). Once individuals are in the relativism classification, they now realize that real world problems have more than one answer. Relativistic individuals also understand that the application of knowledge and information will vary and depend on a given scenario. In addition, when in this classification, individuals begin to think about their own thinking. At this point, individuals begin to see their own opinions and ideas as being relative.

The final positions, 6 through 9, fall under the classification of Commitment. In this classification, individuals realize that their ideas and choices may not always be right. However, they must make the best decisions, which are relative to the situation and information known. Individuals in the Commitment classification have also selected careers, established values, and committed themselves to personal life long relationships, such as marriage (Perry, 1970).

Perry's theory has been the epistemological theory most applied to studies that examine engineering education (Culver & Hackos, 1982; Felder & Brent, 2004; Fedler & Brent, 2005; Fitch & Culver, 1984; Marra & Palmer, 2004; Pavelich & Moore, 1996). These studies have shown that most engineering undergraduate students complete college within the dualism and multiplicity classifications. Perry's theory has also served as a framework for other epistemological development studies (Baxter Magolda, 1992; Belenky, Clinchy, Goldberger, & Tarule, 1986; Fedler & Brent, 2004; Hofer & Pintrich, 1997; King & Kitchener, 1994). Though these studies expanded on his theory, some were initiated to challenge Perry's work. For example, Belenky et al. (1986) challenged Perry's focus on males by specifically evaluating the epistemological beliefs of women. On the other hand, Baxter Magolda (1992), who was influenced by both Perry and by Belenky et al. (1986), examined gender influence on epistemological beliefs. King and Kitchener (1994) assessed how epistemological beliefs affected thinking and reasoning about ill-structured problems, whereas Schommer (1990) introduced dimensionality to epistemological beliefs. Prior to Schommer's research, researchers conceptualized epistemological beliefs as stage-like, one-dimensional models.

Table 1

Summary of Perry's Development Theory

	Classification	Description
Position 1	Dualism	Certainty that an answer is either right or wrong.
Position 2	Dualism	Good vs. bad; good authority figures always have the right answer.
***Transition: Realization that some truth remains uncertain and unknown.**		
Position 3	Multiplicity	Authority figures may not always know the right answers.
Position 4	Multiplicity	Begin to think independently because influenced to do so by authority figure.
***Transition: Realization that knowledge is relative and is influenced by its context.**		
Position 5	Relativism	Analyzing and evaluating information without being prompted by authority figure.
Position 6	Relativism	Understanding that the application of knowledge is influenced by the context.
***Transition: Realization that a commitment must be made based on beliefs.**		
Positions 7	Commitment	Realization that decisions must be made relative to the information known.
Position 8	Commitment	Several commitments have been made.
Position 9	Commitment	Learning to balance several commitments.

Note. *Transition between classifications.

Schommer Model

Schommer's (1990) work on epistemological beliefs began in the late 1980s. Her research was different from the previously discussed models in that she suggested that epistemological beliefs were not unidimensional (Schommer, 1990, 1993a, 1997; Schommer & Walker, 1995). She found that the epistemological beliefs system consisted of independent dimensions, which she based on the research of Perry (1970), Dweck and Leggett (1988), and Schoenfield (1983, 1985). Schommer (1990) initially suggested five dimensions: structure of knowledge, certainty of knowledge, control of knowledge, speed of knowledge, and source of knowledge. She believed that these dimensions were independent of one another in that an individual can develop at different rates in different dimensions (Schommer-Aikins, 2004). In other words, one could develop sophisticated or advanced beliefs in one dimension, while having naïve beliefs in another dimension. As Schommer's research continued, only the first four dimensions (e.g., structure, certainty, control, and speed) consistently appeared in factor analysis results (Hofer & Pintrich, 1997; Schommer 1993a, 1997; Schommer & Walker, 1995).

Schommer (1990) states that Perry's (1970) model influenced the first two dimensions of her model: structure of knowledge and certainty of knowledge. The structure of knowledge was either simple or complex. Simple refers to the belief that knowledge consisted of isolated pieces of information that were clearly understood. Complex knowledge consisted of pieces of information that were related and dependent on the other. Certainty of knowledge had the two extremes of either being absolute and not changing or continuously evolving. The next dimension, which was the control of knowledge, was influenced by the work of Dweck and Leggett (1988). The control of knowledge was set at the naïve level of belief. At the sophisticated level, control of knowledge had several layers or increments that allowed knowledge to increase and improve. Finally, Schommer defined the speed of knowledge dimension based on the work of Schoenfield (1983, 1985). Knowledge was believed to be quickly obtained by an individual with naïve beliefs. In contrast, one with more advanced beliefs perceived the speed of knowledge as a gradual process.

In addition to her theory that epistemological beliefs were independent and multidimensional, Schommer created a method to quantitatively assess epistemological beliefs through a 63-item epistemological questionnaire with a Likert five-point rating scale (Hofer & Pintrich, 1997; Schommer 1990). Due to the questionnaire's time efficient evaluation method, Schommer's (1990) theory is a framework for several epistemological studies (Hofer, 2000; Jehng, Johnson, & Anderson, 1993; Kardash & Howell, 2000; Paulsen & Wells, 1998; Qian & Alvermann, 1995; Schommer, 1993a; Schommer, Crouse, & Rhodes, 1992; Schommer-Aikins, Duell, & Barker, 2002; Trautwein & Ludtke, 2007).

Although Schommer's Epistemological Questionnaire (SEQ) (Schommer, 1990) was the first attempt at developing a quantitative instrument to measure epistemological beliefs as independent, multidimensional constructs, Schommer-Aikins (2002) acknowledged the fact that quantifying what individuals think and understand about the nature of knowledge was a challenging task. In a more recent article, Schommer-Aikins (2004) discussed the difficulty she had in selecting the questions for the SEQ in order to capture the content of individuals' thoughts, and then using that information to predict their epistemological beliefs. For this reason, the questionnaire consisted of as many as

63 items. Consequently, the SEQ has been criticized for having methodological problems (Clarebout, Elen, Luyten, & Bamps, 2001; DeBacker, Crowson, Beesley, Thoma, & Hestevold, 2008; Hofer & Pintrich, 1997). These problems regard the factor loadings of the SEQ items (Schommer, 1993b; Schommer, 1998; Schommer & Dunnell, 1994; Schommer et al., 1992; Schommer-Aikins et al., 2002), the internal reliability of the items (Schommer, 1990; Schommer, 1993a; Schommer et al., 1992), and the use of factor coefficients (Paulsen & Wells, 1998; Schommer, 1993a; Schommer, 1997; Schommer & Walker, 1997) to calculate the scores for each of the four epistemological belief dimensions.

Factor loading. Several of Schommer's studies (Schommer, 1993b; Schommer, 1998; Schommer & Dunnell, 1994; Schommer et al., 1992; Schommer-Aikins et al., 2002) claimed to have analyzed data into a 4-factor structure. Two of these studies (Schommer, 1998; Schommer & Dunnell, 1994) replicated the same four epistemological belief factors and explained almost the same amount a variance (55.2%) as the Schommer (1990) study. Using a sample of high school students Schommer and Dunnell (1994) found that the factors accounted for 53.3% of the variance and were listed by high-loadings in the following order: Fixed Ability, Simple Knowledge, Quick Learning, and Certain Knowledge. Although Schommer's (1998) study, which used an adult sample, found the same 4-factor structure, the order of the first two factors were reversed. Based on the highest loadings, the order of the factors was as follows: Simple Knowledge, Fixed Ability, Quick Learning, and Certain Knowledge. This structure accounted for 53.1% of the variance. Overall, the factor loadings were similar in both studies (Schommer, 1998; Schommer & Dunnell, 1994).

However, the reverse order of Simple Knowledge and Fixed Ability suggests that there is a large proportion of measurement error across the studies.

Other studies (Schommer, 1993b; Schommer et al., 1992; Schommer-Aikins et al., 2002) analyzed data into four factors; however, the factors were different from the original 4-factor structure (Schommer's, 1990). For example, both the Schommer (1993b) and Schommer et al. (1992) studies found that a subscale of items that was defined as describing innate ability, the Fixed Ability factor, did not load on the first factor as expected. As a result, the researchers gave the Fixed Ability factor new titles that were more descriptive of the subscales of items that loaded on the factor. These titles were "Learning is externally controlled" (Schommer et al., 1992) and "The ability to learn is unchangeagble" (Schommer, 1993b). Although, Schommer-Aikins et al. (2002) did not explain the subscales of items that loaded on the four factors, the change in factor titles (Stability of Knowledge, Structure of Knowledge, Control of Learning, and Speed of Learning) and the order of factors suggested that the subscales of items loaded differently from the subscales of items in the Schommer (1990) study. The different combination of subscales in the latter studies that made up the epistemological belief factors suggested that there was an empirical problem with the SEQ. In other words, subscale items were not consistently loading on the same factors across studies. As a result of this problem, it can be concluded that studies had different scales to measure the epistemological beliefs of their samples (Debacker et al., 2008). In other words, the epistemological beliefs subscales consisted of various combinations of items depending on the sample.

This is important for researchers who use the SEQ to know because the use of different scales will hinder a true comparison of epistemological belief factors across studies.

Another concern with conducting factor analysis in the previously discussed studies (Schommer, 1993b; Schommer, 1998; Schommer & Dunnell, 1994; Schommer et al., 1992; Schommer-Aikins et al., 2002) was that the analysis was not conducted using the 63 individual questionnaire items. Instead, the analysis was performed using 12 subscales as variables. In other words, the 63 questionnaire items were grouped into 12 subscales a priori based on their similarities in what they measured as related to epistemological beliefs (Schommer, 1990). Schommer-Aikins (2004) claimed that she used the mean of each subscale to conduct analyses because of the modest sample size (117 community college students and 149 university students) in the Schommer (1990) study. With all of this in mind, Schommer's studies have been criticized for having no empirical support that the 63 questionnaire items would actually load on the four epistemological belief factors. In addition, subsequent studies (Qian & Alvermann, 1995; Hofer, 2000) aimed to improve internal reliability by conducting exploratory factor analysis using the questionnaire items as opposed to the 12 subscale scores.

Qian and Alvermann (1995) started with a 53-item questionnaire that they modified from the Schommer and Dunnell (1994) study. Their exploratory factor analysis resulted in a 32-item questionnaire and a three-factor epistemological belief structure. In addition to the Quick Learning and Fixed Ability factors, the Simple and Certain factors merged to form one factor. This factor structure produced high reliability values: a) Quick Learning ($\alpha = .79$), b) Simple-Certain ($\alpha = .68$), and c) Fixed Ability ($\alpha = .62$). Using the 32-item questionnaire from the Qian and Alvermann (1995) study, Hofer

(2000) also conducted an exploratory factor analysis using items rather than subsets as variables. She found a 4-factor solution in which the Simple and Certain factors did not merge as they did in the Qian and Alvermann study. She found the reliability of the Certain and Simple factors merged to be a moderate value of .66.

Inter-item reliability. In addition to the concern of the factor analysis procedure, Schommer's early studies (Schommer, 1990; Schommer, 1993a; Schommer et al., 1992) have been criticized for not reporting reliability scores. In fact, the Schommer (1993b) study was the first to report reliability scores. Unfortunately, Schommer did not explicitly state how the reliabilities for the items were analyzed. In addition, she did not provide a table of all the scores, but provided a range of reliability scores instead (from .51 to .78). Fortunately, Schommer-Aikins et al. (2002) calculated and included a table that displayed reliability scores for each epistemological belief factor (by dimension). The Cronbach's alphas were moderate to high values and ranged from .58 to .73 (see Table 2 for details).

The design of epistemological belief studies can affect the reliability and effect size statistics (Wood & Kardash, 2002). For example, they found that studies, which evaluated samples with wide ranges, were more likely to have higher internal consistencies than studies with samples that had narrow ranges. Wood and Kardash also warned that low reliability should not prevent researchers from identifying differences between groups. As a probable solution to improve reliability, they suggested that researchers increase items that represent a construct of measure. Their rationale for this solution was that the reasoning and vocabulary of epistemological research was complex and, as a result, more items should be loaded on a participant's score. Based on this explanation, the fewer the items loaded on a construct, the lower the reliability value one should expect.

Table 2

Cronbach Alphas for Schommer-Aikins et al.'s (2002) Epistemological Belief Factors (N = 152)

	Academic Domain		
Epistemological Belief	Mathematics	Social Science	Business
Stability of Knowledge	.67	.63	.67
Structure of Knowledge	.66	.60	.64
Control of Learning	.70	.67	.73
Speed of Learning	.58	.64	.62

Factor coefficients. The use of factor coefficients, as opposed to raw mean scores, to calculate the four epistemological belief dimension scores (Paulsen & Wells, 1998; Schommer, 1993a; Schommer, 1997; Schommer & Walker, 1997) has been criticized (Clarebout et al., 2001). The reason for the criticism was that these factor scores were then used to conduct analyses (e.g., regression, ANOVA). The results of these analyses are questionable because studies (Schommer, 1993a, 1997) did not always explain from which source these factor coefficients were obtained. However, when studies (Paulsen & Wells, 1998; Schommer & Walker, 1995, 1997) did identify the source of the factor coefficients, the source studies (Schommer, 1993b; Schommer et al.,

1992) did not provide a clear explanation as to how the factor coefficients were calculated. The use and lack of explanation of the derivation of factor coefficients presents methodological issues. For example, factor coefficients were derived from a specific sample of individuals with their own unique characteristics. Therefore, these factor coefficients should not be used to calculate epistemological factor scores for a different sample of individuals, who have a different set of unique characteristics. As a result of the methodological concerns of the use of factor coefficients, studies such as Qian and Alvermann (1995), Hofer (2000), and Clarebout et al. (2001) used raw mean scores to calculate epistemological belief dimension scores.

Why Epistemological Beliefs Are Important

Epistemological beliefs are critical to engineering education as that they impact how students learn, think, and solve problems (Schommer-Aikins, 2004). For example, research shows that students who believe that knowledge is certain are more likely to draw absolute conclusions from information that may change (Schommer, 1990). Students who believe that knowledge is fixed were less likely to value school (Schommer & Walker, 1997); students who believed that knowledge is quickly acquired are more likely to comprehend information poorly (Schommer, 1990). Students who believe that knowledge is simple are more likely to settle for a memorization study strategy rather than using higher-level cognitive processes such as elaboration (Hofer & Pintrich, 1997).

Students' beliefs may influence how instructors design engineering curriculum. For example, engineering instructors can use information about students' beliefs to change curriculum in order to move less sophisticated thinkers to higher levels of thinking. In addition, the instructors will be able to adjust the curriculum to enhance the intellectual development of students who are sophisticated thinkers (Marra, Palmer, & Litzinger, 2000; Marra & Palmer, 2004; Pavelich & Moore, 1996; Wise, Lee, Litzinger, Marra, & Palmer, 2004). Researchers examined engineering students' epistemological beliefs in the context of studying other students using both qualitative and quantitative methods. Except for Trautwein and Ludktke's study (2007), all demonstrated that epistemological beliefs do indeed become more sophisticated as students progress in educational levels (freshman through graduate level) (Jehng et al., 1993; King & Magun-Jackson, 2009; Marra & Palmer, 2004; Marra et al., 2000; Palmer & Marra, 2004; Paulsen & Wells, 1998; Pavelich & Moore, 1996; Schommer, 1993a; Wise et al., 2004). Also, some of these studies reported that engineering students had less sophisticated epistemological beliefs than students in other majors (Jehng et al., 1993; Paulsen & Wells, 1998; Schommer, 1993a; Trautwein & Ludtke, 2007). However, none of these studies examined African Americans who attended Historically Black Colleges and Universities (HBCUs), leaving a major gap in the epistemological beliefs literature.

It is important to study African American engineering students at HBCUs as these institutions have played a major role in educating African American students since the end of the Civil War. As recently as 2000-2001, HBCUs conferred 21.5% of all undergraduate engineering degrees awarded to African American students (Provasnik & Shafer, 2004; Southern Education Foundation, 2005). Yet, even with such a large percentage, there is a not research examining engineering.

Epistemological Beliefs of Engineering Students

Perry's (1970) and Schommer's (1990) frameworks are used to evaluate epistemological beliefs of engineering students. The following sections provide a review the studies that used both Perry's and Schommer's frameworks respectively to assess the epistemological beliefs of engineering students.

Perry Framework

The review of the literature relating to epistemological beliefs of engineering students yielded very few studies. There were even fewer studies that assessed only engineering students (Marra et al., 2000; Marra & Palmer, 2004; Palmer & Marra, 2004; Pavelich & Moore, 1996; Wise et al., 2004). These studies used the Perry framework to examine the engineering students' beliefs using a semi-structured interviewing technique. In addition, this technique required the use of time-consuming qualitative and mixed method research methodologies.

Pavelich and Moore (1996) used the Perry framework to study undergraduate engineering students at the Colorado School of Mines to determine the thinking processes used The researchers found that the average rating (position 3.27) for the freshmen students classified them as having multiplicity beliefs whereas they acknowledged uncertainty of a right answer as a temporary status. Only 25% of the seniors considered themselves as sources generating knowledge and were no longer dependent upon an authority figure as a source of knowledge (position 5 and above). Overall, Pavelich and Moore found that one third of the sample recognized that many opinions existed and that authority figures will never be certain that an answer was absolutely right (below position 4). In other words, these students realized that knowledge was uncertain. Pavelich and

Moore also found support that engineering students' epistemological beliefs became more sophisticated from freshman to senior year. The average Perry ratings of freshmen and seniors were significantly different in that there was an increase of one position in Perry ratings from freshman to senior year during the four-year cross-sectional study. Furthermore, there were significant differences in epistemological beliefs identified between freshmen and sophomores and between sophomores and seniors.

Wise and colleagues (2004) followed undergraduate engineering students from their freshman to senior years and sought to determine whether there was a link between the students' Perry ratings and taking a first-year design course. They interviewed engineering students at three different times during a longitudinal four-year period. The initial interview was conducted during the students' first year in college. The researchers then conducted interviews in students' third and fourth year in college. Wise and colleagues found that during the first year, most students showed a dualistic (positions 1 and 2) approach in their thinking. For example, students believed that knowledge was certain and that an authority figure (e.g., teacher or textbook) would have the right answers. Although the researchers found that there was no significant difference between students who took the first-year design course and those students that did not take the course, they did find evidence supporting that educational level (e.g., freshman, sophomore, junior, senior) had a significant effect on students' epistemological beliefs. More specifically, there were significant differences in the students' Perry ratings between their first and fourth years in engineering and between their third and fourth years in engineering.

In addition to relationships between engineering students' epistemological beliefs and educational level, research findings (Marra & Palmer, 2004; Marra et al., 2000; Palmer & Marra, 2004) support that design courses that incorporated ill-structured problem-solving were correlated with more sophisticated epistemological beliefs in engineering students. Marra et al. (2000) used the Perry framework to determine whether a first-year engineering design course would influence the epistemological beliefs of undergraduate engineering students. The majority of the students' Perry ratings placed them in the multiplicity classification (average position of 3.17) in which they believed knowledge was uncertain.

Students completing the first-year design course had more sophisticated epistemological beliefs than those students who did not take the course (Marra et al., 2000). Marra and colleagues concluded that the design course required students to learn and use open-ended problem-solving skills that exposed students to the uncertainty and ambiguity of solving real-world problems. As a result, this uncertainty and ambiguity more than likely contributed to the development of students' more sophisticated beliefs.

Marra and Palmer (2004) also found support that exposure to ill-structured problem-solving was correlated with sophisticated epistemological beliefs in engineering students. They concluded that these problem-solving skills were also acquired via cooperative education experiences. In this study, Marra and Palmer (2004) randomly selected senior-level students from nine engineering majors to determine how their college experiences contributed to the development of the characteristics of a successful graduate. After dividing the engineering-only sample into students with naïve epistemological beliefs and students with sophisticated epistemological beliefs, Marra and Palmer found that the two groups of engineering students differed in their views of problem-solving processes. The students with sophisticated epistemological beliefs reported that they appreciated the process of developing skills to solve ill-structured problems more than the students with naïve epistemological beliefs reported. This may also be related to the finding in this research that students with naïve beliefs experienced difficulty with ill-structured problems.

Marra and Palmer (2004) found that when cooperative education experiences were incorporated into engineering curriculum, students with sophisticated beliefs participated in cooperative education more than students with naïve beliefs. The researchers also suggested that cooperative education experiences exposed students to ill-structured problems and influenced how well a student accepted the challenge of ill-structured problems. Overall, Marra and Palmer suggested that this study provided supporting evidence that refining engineering curriculum could advance the epistemological beliefs of engineering students.

In another study, Palmer and Marra (2004) used the Perry framework to examine engineering and science students' epistemological beliefs across academic domains of science and humanities/social sciences. After examining a sample of students that included first-semester juniors and second-semester seniors, the researchers found support that when students experienced open-ended problems within science, they were more likely to have higher epistemological belief classifications in the science domain than they had in the humanities/social sciences domain. Palmer and Marra suggested that this was the result of the science and engineering students taking more science courses than humanities and social sciences courses. A finding in this study was also that engineering students at higher educational levels will likely demonstrate more sophisticated epistemological beliefs as they have completed more courses that incorporated open-ended problem solving.

Schommer Framework

In addition to the epistemological belief studies that used the Perry framework, there have been a few studies that used the Schommer framework to study epistemological beliefs of engineering students (Jehng et al., 1993; King & Magun-Jackson, 2009; Paulsen & Wells, 1998; Schommer, 1993a; Trautwein & Ludtke, 2007). These studies differed from the Perry framework in that they used a quantitative research methodology. The Schommer framework studies were also different from the Perry framework studies in that only one of the studies (King & Magun-Jackson, 2009) examined only engineering students. Like the Perry framework studies, the review of the Schommer framework studies found that for college students the progression in educational level was correlated with more sophisticated epistemological beliefs in college students. In addition, findings in the Schommer framework studies also supported that differences in epistemological beliefs continued to exist when background variables were controlled.

Schommer (1993a) conducted a study with college students including engineering students to determine whether there was a difference in the epistemological beliefs between community college students and first- and second-year university students and whether there was a difference between the students who majored in social sciences (e.g., education) and the students who majored in technical areas (e.g., engineering). She found that community college students and university students differed on all four epistemological factors. Community college students were more likely to believe that knowledge was simple, certain, and quick, whereas university students were more likely to believe that knowledge was innate. When background variables were controlled, the differences in innate ability and certainty of knowledge between community college students and university students were still present. Engineering students were more likely to believe in quick learning, but education majors were more likely to believe in simple knowledge.

Influenced by the works of Schommer (1990), Jehng et al. (1993) conducted a cross-sectional investigation to determine whether students' educational levels and fields of study had any influence on their epistemological beliefs. Overall, Jehng et al. found that both educational level and field of study showed significant main effects, but there was no interaction between the two. Although there were no significant differences between graduate students and undergraduate students in their beliefs that knowledge was innate and quickly acquired, graduate students were less likely to have certainty beliefs. Graduate students were also less likely than undergraduate students to believe that the structure of knowledge was simple. In addition, upper-level undergraduate students were less likely than lower-level undergraduate students to have certainty beliefs. After comparing the students in different fields of study, Jehng and colleagues found that engineering students were the most likely to believe that knowledge was certain and, except for business majors, to believe that knowledge was simple and innate. However, engineering students were less likely to believe that knowledge was quickly acquired.

Like Jehng et al. (1993), Paulsen and Wells (1998) also found differences in epistemological beliefs across educational levels of college students. Paulsen and Wells sampled college students to determine whether their beliefs differed between major fields of study (e.g., humanities/arts, social sciences, education, business, mathematics, natural sciences, and engineering). Although Paulsen and Wells found that students' epistemological beliefs became more sophisticated as they progressed in their levels of education, they found that engineering students were less sophisticated in their beliefs than those students in humanities/arts, social sciences, and education. For example, engineering students were more likely to have naïve beliefs that knowledge was certain, simple, and acquired quickly. These differences remained after controlling for student characteristics such as age, gender, education level, and grade point average.

There are some inconsistencies in the literature related to the relationship between epistemological beliefs and educational level. After longitudinally assessing the certainty beliefs of students during their final year of secondary school and second year of college, Trautwein and Ludtke (2007) found that engineering students were the only group of students to show an increase, although slight, in their certainty scores during the period of the study. In other words, engineering students were the only group of students that did not demonstrate more sophisticated beliefs with progression in educational level. However, in line with the other Schommer framework studies (Jehng et al., 1993; Paulsen & Wells, 1998), engineering students were more likely to have naïve certainty beliefs than students in the other academic majors (e.g., humanities/arts, mathematics/natural sciences, business, social sciences, medicine, and law).

In the only study that used the Schommer framework to examine only engineering students to predict epistemological beliefs across educational levels, King and Magun-Jackson (2009) found that underclassmen (ie., freshmen and sophomores) were more likely than upperclassmen (juniors and seniors) to believe knowledge was quickly acquired and certain beyond the effects of students' background characteristics (gender, ethnicity, and high school grade point average). However, the researchers did not find any significant differences in the beliefs between graduate students and undergraduate students. Although this non-significant result was inconsistent with the epistemological literature (Jehng et al., 1993), it was likely influenced by the study's small sample size of graduate students (N =19).

Why It is Important to Examine Students at HBCUs

The majority of HBCUs were established after the Civil War (but prior to 1964) in order to educate newly freed slaves (Kim, 2002; Provasnik & Shafer, 2004). Since creation until the 1960s, HBCUs educated over 90% of African Americans who pursued a college degree (Fleming, 1984). However, circa 1967, there was a shift in HBCU enrollment that both Fleming (1984) and Allen (1992) believed was influenced by the 1954 *Brown v. Board of Education* Supreme Court decision, which ruled that racial segregation in public schools was illegal. As a result, more African Americans enrolled into Predominantly White Institutions (PWI). In doing so, African Americans thought that they would have equal access to higher education as their White peers (Allen, 1992; Fleming, 1984).

According to the U.S. Department of Education (2005), there are currently 105 HBCUs. In 2001, 13% of all African Americans enrolled in college were students in HBCUs, and women accounted for 61% of these students enrolled (Provasnik & Shafer, 2004). Also, in 2004, HBCUs awarded 22% of all bachelor's degrees that were awarded to African American students (Perna et al., 2009).

In past years, there has been an ongoing debate of whether HBCUs are still needed in higher education. On one hand, some believe that HBCUs perpetuate segregation in higher education and are no longer needed since African Americans have the same civil rights as White (Brown, 2002). On the other hand, some believe that HBCUs are needed to provide campus environments that provide support to the psychosocial and cognitive developmental needs of African Americans (Berger & Milem, 2000; Pascarella, Smart, Ethington, & Nettles, 1987; Pascarella, Edison, Nora, Hagedorn, & Terenzini, 1996; Seifert, Drummond, & Pascarella, 2006; U.S. Department of Education, 2005). Studies show that HBCUs are critical to educating African American students because they are more likely than PWIs to admit students who are from a lower socioeconomic status, to admit students who are less academically prepared for college studies, to offer more remedial courses and to have positive interactions between students and faculty (Allen, 1992; Cokley, 2000; Fleming, 1984; Kim & Conrad, 2002; Lent et al., 2005; Perna et al., 2009; Southern Education Foundation, 2005).

Fleming (1984) suggested that many of these studies on campus racial composition only assessed "interpersonal relationships, identity, and black consciousness" (as cited in Butler, 1985, p. 21). As a result, Fleming was the first to examine the combined intellectual and psychosocial effects that institutional type (HBCU vs. PWI) and campus racial composition had on African American student development. Using both quantitative and qualitative analyses, she conducted a four-year cross sectional study on freshmen and seniors and discovered that the students at HBCUs were more likely to show gains in intellectual and psychosocial development. For example, students attending HBCUs were more satisfied with their academic lives and reported more positive interactions with faculty than the students at PWIs. Moreover, HBCU students had higher gains in social assertiveness and were more likely to demonstrate better social adjustment than their peers at PWIs.

Comparing African Americans at HBCUs and PWIs

Since Fleming’s 1984 study, there have been other studies that investigated the effects that campus racial composition has on African American students (Allen, 1992; Berger & Milem, 2000; Bohr, Pascarella, Nora, & Terenzini, 1995; Cokely, 2000; Cokely, 2002; Davis, 1995; Flowers, 2002; Good, Halpin, & Halpin, 2001-2002; Kim, 2002; Kim & Conrad, 2006; Lent et al., 2005; Pascarella et al., 1987; Pascarella & Terenzini, 1991; Perna et al., 2009; Seifert et al., 2006; Webster, 2002). Few studies compare African American engineering students at HBCUs to African American engineering students at PWIs. Further, there are no studies comparing the epistemological beliefs of African American engineering students attending HBCUs to those African American engineering students attending PWIs. However, there are a few studies (Good et al., 2001-2002; Lent et al., 2005; Perna et al., 2009) that show that Minority Engineering Programs (MEP) and HBCUs provided supportive learning environments that motivated students to persist with their engineering studies. In addition, these programs were more likely to address the problem of variability in African American students' pre-college preparation for majors in science, technology, engineering, and mathematics (Collea, 1990; Good et al., 2001-2002; Lent et al., 2005; Perna et al., 2009).

African American Engineering Students

Two studies show that African Americans, who earned undergraduate science, technology, engineering, and mathematics (STEM) degrees from HBCUs, were more likely to continue their education and earn graduate and professional degrees than African Americans who attended PWIs (National Science Foundation, 1996; Solorzano, 1995). Research studies have also shown that minority students (e.g., African Americans, Hispanics, Native Americans, women) perceive minority engineering programs (MEP) at colleges and universities as being a supportive environment for learning as they are surrounded by and feel connected to their peers (Collea, 1990; Good et al., 2001-2002). For example, Good et al. (2001-2002) examined African American students in a MEP and African American students who did not participate in a MEP. They found that the students in the MEP were more likely to feel connected to the engineering community and were more likely to persist with their engineering studies than the non-participants. In the same vein of persistence in engineering studies, Astin and Astin (1992) found that students were more likely to persist with their engineering studies if most of their peers also majored in engineering. Positive peer influence could also be extended to African American engineering students at HBCUs. For example, Lent and colleagues (2005) found that undergraduate engineering students at HBCUs were more likely to have higher self-efficacy than their peers at PWIs. In addition, the researchers found that the students attending the HBCUs were more likely to have interests in engineering activities and interests in pursuing engineering as a career.

In a study that examined African American STEM students in an all-women's historically black college, Perna and colleagues (2009) found that the students often expressed that their peers and faculty were supportive. The study also observed that the college accepted and addressed the fact that students varied in their pre-college preparation for STEM study. As a result, academic support services, such as peer tutoring, were available to students. Moreover, the researchers found that members of the faculty were available to students outside of class and were willing to change their pedagogical methods to meet the learning needs of their students. As expected, students valued these student-centered approaches as a refreshing change to the competitive climate that is characteristic of most STEM programs (Astin & Astin, 1992; Perna et al., 2009).

Effects of Campus Racial Composition

Four perceptions emerged from the review of the literature in which African American students who attended HBCUs were compared to African American students who attended PWIs. These perceptions were self-concept, experiences with faculty and peers, academic achievement, and cognitive abilities. Although these perceptions are not directly related to engineering students and their epistemological beliefs, they may inform the current study as they provide insight to the other effects that campus racial composition has on African American students. They can also be indirectly associated with epistemological beliefs based on the Schommer-Aikins (2004) high-level embedded systemic model of epistemological beliefs.

Schommer-Aikins' (2004) model suggests that the way individuals perceive their environment and the interactions among people within their environment (i.e., cultural relational views) will influence the epistemological beliefs of those individuals. These perceptions include how individuals view the status among people (e.g., social hierarchy) within an environment. Self-concept is similar to what Schommer-Aikins defined as cultural relational views in that self-concept is the perception an individual has of one's self in relation to other individuals within the environment. Moreover, the perception of experiences with faculty and peers in the campus racial composition literature considers the relationships that students perceive they have with their peers and teachers within their college environment (Seifert et al., 2006; Webster, 2002).

Self-Concept. Generally, self-concept is the way that students perceive themselves in relation to their peers (Pascarella & Terenzini, 1991). However, the self-concept construct is more complex than this. Using causal model designs, research findings support the self-concept construct as multidimensional in that it can be either academic or non-academic (Guay, Marsh, & Boivin, 2003). In addition, each dimension of self-concept is multifaceted. For example, its academic dimension has been measured as a verbal component or a mathematical component (Marsh, Byrne, & Shavelson, 1988). On the other hand, its non-academic dimension has been measured by social and emotional aspects (Pascarella & Terenzini, 1991). There is a segment of literature that examines whether the self-concept of African American students differed by whether they attended a HBCU as opposed to whether they attended a PWI (Berger & Milem, 2000; Cokley, 2000, 2002; Pascarella et al., 1987).

Using the framework of causal models, Pascarella and colleagues (1987) investigated the influences of college on the academic self-concept development of African American and White students. Their model suggested that pre-college characteristics, the type of undergraduate institution attended, students' collegiate experience, and post-baccalaureate characteristics would influence the post-college self-concept for students. Overall, Pascarella and colleagues found that there were no significant negative impacts on academic self-concept or social self-concept from attending a HBCU. This study also found that attending a large, public university had a significant and negative indirect effect on social self-concept. As a result, the researchers believed this finding implied that smaller colleges and universities provided environments that were more conducive to students' psychosocial development.

After conducting two studies that examined self-concept of African American students, Cokley (2000, 2002) discovered inconsistent findings. In his 2000 study, he found that there was no significant difference in academic self-concept scores between African American students at HBCUs and African American students at PWIs. On the other hand, in 2002, he found a significant difference in academic self-concept between the students attending HBCUs versus PWIs. Cokley (2002) contributed this difference to the fact that the sample size in the 2002 study was doubled. However, in both studies, students at HBCUs had significantly higher college grade point averages, reported higher quality of student-faculty interactions, and were more likely to perceive academic performance evaluation of African American students as fair. It is important to note that in both studies Cokley (2000, 2002) included and controlled for individual-level variables such as high school grade point average, college grade point average, gender, and under- and upper- classmen.

Berger and Milem (2000) examined how campus racial composition might affect the academic self-concept of African Americans. They found some differences between students attending HBCUs and the students attending PWIs. For example, they found that attending a HBCU, academic support from faculty, same-race contact, collaborative learning, and high school grade point averages were significant and positive predictors of academic self-concept for African American students. As an overall result of their findings, Berger and Milem concluded that HBCUs have an environment that is more likely than PWIs to promote positive educational outcomes for African American students.

Experiences with Faculty and Peers. Studies have shown that students' experiences with faculty and peers in and outside the classroom are critical to student outcomes and that these experiences can be predicted by institutional type (e.g., HBCU, PWI, research, regional) (Seifert et al., 2006; Webster, 2002). For example, Webster (2002) compared African American students in teacher education programs and found that the students at HBCUs were more likely to have closer relationships with faculty and to participate more in campus activities and student organizations than the African American students at PWIs. In another study that also considered African American students' experiences, Seifert et al., (2006) examined students' experiences inside and outside the classroom with faculty and peers. As a result, they found significant differences among students at HBCUs, research, regional, and liberal arts institutions. The students at the HBCU compared to students at the research universities reported having quality non-classroom interaction with faculty and that faculty demonstrated an interest in teaching and student development. Compared to the students at regional universities, HBCU students were more likely to report exerting more effort towards and placing more emphasis on educational pursuits.

Additionally, HBCU students reported more interaction with their peers in and outside the classroom than did the students at regional universities. They were also more likely to report faculty having high scholarly and intellectual expectations of student learning than their peers at both the research and regional institutions.

Academic Achievement. Schommer-Aikins' (2004) embedded systemic model of epistemological beliefs proposes that the epistemological beliefs of individuals will influence their classroom performance (e.g., academic achievement, cognitive abilities). In addition, Schommer-Aikins (2004) believes that there is a reciprocal relationship between epistemological beliefs and classroom performance. As such, it is necessary to review the studies in the literature that research the effects that campus racial composition has on the academic achievement and cognitive abilities of African American students.

Allen (1992) analyzed African American students at PWIs and HBCUs to determine whether individual student characteristics and institutional characteristics would influence academic achievement (measured by college grade point average). Allen found differences between the students at the two types of institutions. For example, he found that students at the HBCUs reported more positive relationships with faculty. He also found that students at PWIs were more likely to have lower college grades and have higher high school grades, and that overall, students attending HBCUs reported significantly higher academic achievement than students at PWIs. Davis (1995) found that a different set of factors contributed to academic achievement of African American students at HBCUs than of African American students at PWIs. For example, personal background factors such as high school grade point averages and higher degree aspirations were the strongest predictors of academic achievement for the students at the PWIs. In contrast, college environmental factors such as academic integration, study habits, peer relations, and institutional support were the strongest predictors of academic achievement for students at HBCUs.

Kim and Conrad (2006) defined academic achievement in terms of students' probability to obtain a bachelor's degree. In this study, they found differences between the students' background characteristics, such as the students at PWIs reporting higher SAT scores and higher high school grade point averages. However, the students at HBCUs were more involved in faculty research projects and reported a higher student-faculty interaction. Kim and Conrad reported that all of these factors were significant predictors of bachelor's degree completion, but that there were no significant differences in degree completion between African American students at HBCUs versus PWIs.

Cognitive Abilities. For the most part, researchers found very few significant differences in cognitive abilities between African American students attending HBCUs and PWIs. Bohr et al., (1995) used the National Study of Student Learning longitudinal data to investigate cognitive abilities (e.g., reading, mathematics, and critical thinking) at the end of students' first year in college. Bohr and colleagues found no significant differences in any of the measures of cognitive abilities between African American students at HBCUs versus PWIs, but they did note that HBCU students demonstrated more gains in all three cognitive measures. In an extension of the 1995 study, Pascarella et al. (1996) examined the effects of campus racial composition on writing and science reasoning scores of African American students through the end of their second year in college. Although there were no significant differences in the science reasoning scores, they found that African American students at HBCUs had significantly higher scores in writing skills.

Similarly, Kim (2002) analyzed cognitive abilities in academic ability, mathematic ability, and writing ability and found no differences in cognitive abilities between students who attended HBCUs versus PWIs. However, Flowers (2002) found that the students at the HBCUs were significantly more likely to report gains in cognitive abilities such as understanding arts and humanities, science and technology, and intellectual and writing skills. It is important to note that these significant differences in cognitive abilities remained after statistically controlling for student background characteristics (e.g., age and gender) and students' experiences (year in school, grade point average, and college major).

Summary

Epistemological beliefs of college students have been examined by both qualitative and quantitative research methods. Both kinds of studies used these methods to provide support that epistemological beliefs become more sophisticated as students' educational levels advance (Jehng et al., 1993; Paulsen & Wells, 1998; Pavelich & Moore, 1996; Schommer, 1993a; Wise et al., 2004). In these studies, younger students have shown naïve (not sophisticated) beliefs in that they believed knowledge was certain, simply structured, quickly acquired, and from an authority figure. Although qualitative research methods have been used to examine engineering students, the King and Magun-Jackson (2009) study is the only quantitative study that examined the relationship between epistemological beliefs (in each of the four dimensions) and educational level of a sample of all engineering students.

Comparative analysis studies have also been conducted to investigate self-concept (Berger & Milem, 2000; Cokley, 2000; Cokley, 2002; Pascarella et al., 1987), experiences with faculty and peers (Seifert et al., 2006; Webster, 2002), academic achievement (Allen, 1992; Davis, 1995; Kim & Conrad, 2006), and cognitive abilities (Bohr et al., 1995; Flowers, 2002; Kim, 2002; Pascarella et al., 1996) of African American college students attending HBCUs versus PWIs. While each of these works provides evidence for both sides of the debate of whether there are significant differences in student outcomes for African Americans attending HBCUs versus PWIs, none of these studies compare the epistemological beliefs of African American engineering students attending HBCUs versus PWIs. Based on the review of the literature, it is worth investigating whether there are differences between the epistemological beliefs of African American engineering students at HBCUs and at PWIs.

Statement of the Problem

Consequently, the interest of this research study was two-fold. It first replicated and extended the research of King and Magun-Jackson (2009) by increasing the sample size of engineering students and examining the overall epistemological beliefs of engineering students (regardless of ethnicity) across educational levels. Second, this study compared the epistemological beliefs of African American engineering students at HBCUs versus PWIs. Hence, the purpose of this cross-sectional study used Schommer's Epistemological Questionnaire (Schommer, 1990; 1998) to understand the relationship between individual-level factors (gender, ethnicity, educational level, and high school grade point average) and epistemological beliefs (certainty, structure, control, and speed) by examining how these factors affect engineering students across educational levels. Further, it attempted to understand the relationship between individual-level factors, institutional type, and epistemological beliefs by examining how these factors exclusively affected African American engineering students attending HBCUs and PWIs.

The four research questions for this study were:

1) Do epistemological belief dimensions (certainty, structure, control, and speed) of engineering students differ across educational levels (freshman, sophomore, junior, senior, master, doctoral)?

2) Which variables best predict epistemological beliefs for engineering students across the educational levels?

3) Do epistemological belief dimensions (certainty, structure, control, and speed) significantly differ for African American engineering students attending HBCUs from those attending PWIs?

4) Which variables best predict epistemological beliefs for African American engineering students attending HBCUs and PWIs?

CHAPTER 2

METHOD

The current study was conducted in four parts. First, exploratory factor analysis (EFA) was used to explore the collective factor structure of items contained in the Schommer Epistemological Questionnaire (SEQ) (Schommer, 1990). Second, inter-item reliability was calculated for the items composing each factor of epistemological beliefs. Reliability scores were calculated separately for the sample of all engineering students and the sample of African American engineering students. Third, an analysis of variance (ANOVA) and hierarchical multiple regression analysis were conducted on the full sample of engineering students. Finally, a t-test and hierarchical multiple regression analyses were conducted on the sample of African American engineering students.

Participants

The main inclusion criterion for this study was that the voluntary participants were enrolled in an engineering program. In the fall 2009 semester, data was collected from engineering students at two universities located in west Tennessee. Then, in the spring 2010 semester, data was collected from engineering students at a university located in middle Tennessee. These universities were selected to participate in this study because of their similarities. For example, each university was located in Tennessee and accredited by the Southern Association of Colleges and Schools (SACS). In addition, all three universities had engineering programs that were accredited by the Accreditation Board for Engineering and Technology (ABET). Two of the universities were public research institutions; one was a historically black university (HBCU) and the other was a predominantly white institution (PWI). The third university was a predominantly white (PWI), small, private, Catholic, and teaching-focused university.

Students were solicited from seven different engineering disciplines: architectural, civil, electrical, mechanical, chemical, biomedical, and engineering management. They were classified at various educational levels (freshman, sophomore, junior, senior, and graduate). Overall, there were 518 engineering students who completed questionnaires: 148 students were enrolled at the medium public research-focused HBCU, 267 were enrolled at the large public research-focused PWI, and 103 were enrolled at the small private teaching-focused PWI. Table 3 gives details of the descriptive characteristics of the students' educational levels gender, ethnicity, and high school grade point averages.

Table 3

Descriptive Statistics Comparing Demographic Characteristics of Engineering Programs at the Public HBCU (N =148), the Public PWI (N =267), and the Private PWI (N =103)

	HBCU		PWI[a]		Overall	
Participants	*n*	*%*	*n*	*%*	*n*	*%*
Educational Level						
Freshman	28	18.90	102	27.70	130	25.20
Sophomore	18	12.20	80	21.70	98	19.00
Junior	30	20.30	74	20.10	104	20.20
Senior	57	38.50	93	25.30	150	29.10
Master	12	8.10	17	4.60	29	5.60
Doctoral	3	2.00	2	.50	5	1
Gender						
Male	117	80.10	304	83.10	421	82.20
Female	29	19.90	62	16.90	91	17.80
Ethnicity						
African American	90	61.60	56	15.30	146	28.60
Alaskan/Pacific	0	0	2	.50	2	.40
Asian American	6	4.10	20	5.50	26	5.10
Euro American	29	19.90	249	68.20	278	54.40
Hispanic	4	2.10	8	2.20	11	2.20
Multi Ethnic	11	2.70	7	.50	11	2.20
Native American	0	0	2	1.90	2	.40
Other	14	9.60	21	5.80	35	6.80
High School GPA						
Below Average						
1.0-1.5	1	.70	0	0	1	.20
1.6-2.0	4	2.70	3	.80	7	1.40
Average						
2.1-2.5	7	4.80	16	4.40	23	4.50
2.6-3.0	31	21.10	48	13.20	79	15.50
Above Average						
3.1-3.5	50	34	104	28.60	154	30.10
3.6-4.0	45	30.60	179	49.20	224	43.80
Don't Know	9	6.10	14	3.80	23	4.50

Note. PWI[a] column includes the total values of both the public PWI and the private PWI.

Instruments

Epistemological Beliefs

The Schommer Epistemological Questionnaire (Schommer, 1990) assessed the students' epistemological beliefs within four dimensions: certainty (i.e., certainty that knowledge was either absolute and unchanging, or it was continuously evolving); structure (i.e., structure of knowledge either consisted of isolated pieces of information that were clearly understood, or it consisted of pieces of information that were related and dependent on the other); control (i.e., control of knowledge acquisition was either innate, or it could be gradually increased and improved as it was acquired); and speed (i.e., speed of knowledge acquisition was either quickly obtained, or it was obtained gradually). Participants were presented 63 statements about knowledge and were asked to rate the statements (e.g., "The only thing that is certain is uncertainty itself.") using a Likert scale which ranged from 1= strongly disagree to 5 = strongly agree. These numbers were summed to form 12 subscales that yielded four factor scores (certain knowledge, simple knowledge, fixed ability, and quick learning) for each individual. Investigating the internal structure of the instrument, Schommer (1993a) determined that the alpha coefficients ranged from .63 to .85 (see Appendix A).

Students' Background Information

The students were surveyed to determine their personal and pre-college characteristics using Barker's (1998) background information form. As a result, the students self-reported their gender, ethnicity, native language, high school grade point average, college grade point average, educational level, engineering discipline, and the number of engineering courses completed (see Appendix B).

Procedure

After receiving approval from the three Deans of Engineering and the Institutional Review Boards, engineering instructors at each of the universities were contacted and asked to participate in the current study. Based on the preference of the instructors, the researcher, or data collection assistant, visited and administered the questionnaires to some of the classes. The remaining instructors administered the questionnaires without the researcher being present. The students were given a consent form (see Appendix C) that explained that the objective of the study was to gather data on engineering students' beliefs and views toward various topics. The students were also told that participation in the study was voluntary, confidential, and would not affect their status with the university or with their instructors. The epistemological questionnaire and background information questionnaire were given to groups of students who agreed to participate in this study in their classrooms during their regularly scheduled class time.

Design and Data Analysis

This study used a cross-sectional study design in which two sets of comparison groups were statistically equated on pre-college and other variables. The first set (N = 518) of comparison was the educational levels (freshman, sophomore, junior, senior, and graduate) of all the engineering students attending three separate institutions: a medium public, research-focused HBCU, and two were PWIs. One of the PWIs was a small private teaching-focused institution, and the other a large public research-focused institution. The second set (N = 146) of comparison groups was a sub-sample of the first set. It consisted of the African American engineering students attending the public HBCU and the African Americans engineering students attending the two PWIs. The dependent variables were the mean scores of the four epistemological belief dimensions (certain, simple, fixed, and quick).

Per Schommer's instructions, 27 items were reverse coded before conducting any analyses. Next, preliminary analyses, which included exploratory factor analysis (EFA) and inter-item reliability analysis, were conducted to establish the validity of using the SEQ to measure the epistemological beliefs of engineering students. Using SPSS, EFA was conducted for the full sample of engineering students (N = 518). Similar to Hofer (2000) and Qian and Alvermann (1995), the EFA analyzed all 63 items (with an eigenvalue > 1 criteria) from the SEQ to replicate the factor structure defined by Schommer (1990).

Tabachnik and Fidell (2007) suggested that a sample size of at least 300 should be used for factor analysis; however, they also stated that a smaller sample of 150 could be used if high-loading variables (above .80) were present. Although the full sample of engineering students (N = 518) followed Tabachnik and Fidell's rule of thumb, the sample size of African American engineering students (N = 146) was too small to conduct EFA. As a result of this study's small sample size for the African American engineering students, the scale to measure the students' epistemological belief dimensions was constructed by using inter-item reliability analyses (Clarebout et al., 2001; Cole, Goetz, & Willson, 2000). Using this reliability procedure to create new scales also increased the internal consistency of the instrument used to predict the epistemological beliefs of the engineering students in the present study.

Inter-item reliability analysis was calculated for each of the four epistemological belief dimensions instead of calculating reliability for each of the 12 subscales. This procedure for calculating reliability scores was also done in other studies (Hofer, 2000; Qian & Alvermann, 1995; Schommer-Aikins et al., 2002). Multiple iterations of removing questionnaire items and conducting the reliability analysis were repeated until the Cronbach's alpha reached .60 (Cole et al., 2000). Using the items that remained, mean scores were calculated for each epistemological belief dimension. These mean scores were then used to conduct the analyses to answer the present study's four research questions as was done in the Hofer (2000) and Qian and Alvermann (1995) studies.

Next, to address the first research question, *Do epistemological belief dimensions (certainty, structure, control, and speed) of engineering students differ across educational levels (freshman, sophomore, junior, senior, master, doctoral),* one-way analysis of variance (ANOVA) was used. Participants were divided into three different groups according to their classification (Underclassmen: freshmen and sophomores; Upperclassmen: juniors and seniors; Graduate: masters and doctoral). Missing values were handled by selecting the option to exclude cases listwise in SPSS.

Since differences were detected among educational levels, the second research question, *Which variables best predict epistemological beliefs for engineering students across the educational levels,* was answered using hierarchical multiple regression. The individual-level variables (gender, ethnicity, and high school grade point average) and institutional type variables were entered at step 1 of the regression model. After controlling for the individual-level and institutional type variables, educational level variables were entered at step 2 of the regression model. Since gender (male or female) and institutional type (PWI or HBCU) were the only dichotomous variables, dummy-coding was used for the remaining three variables: high school grade point average (GPA), ethnicity, and educational level. Two groups of educational level, Upperclassmen and Graduate, were included in the analysis; Underclassmen was used as the primary reference group. In addition, two groups of high school GPA, above average and below average, were included in the analysis. Average GPA was used as the primary reference group. Moreover, two groups of ethnicity, African American and Other ethnicity, were included in the analysis. European American, the largest group, was the reference group. Missing values were handled by selecting the option to exclude cases listwise in SPSS. Preliminary analyses were also conducted to ensure no violation of the assumptions of normality, linearity, multicollinearity and homoscedasticity.

The third research question, *Do epistemological belief dimensions (certainty, structure, control, and speed) significantly differ for African American engineering students attending HBCUs from those attending PWIs*, was examined by using an independent samples t-test. The t-test compared the epistemological belief scores for African American engineering students attending a HBCU to the epistemological belief scores for African American engineering students attending two PWIs. For this analysis, the sample of African American students at the private PWI (N = 13) was combined with the sample of African American students at the public PWI (N = 43). This was deemed acceptable because the students' demographics (i.e., high school attended, gender, and ethnicity) at the private and public PWIs were similar at the time of data collection in the fall 2009. Demographic data was gathered from institutional effectiveness research of each university. According to the data, both universities shared 13 of the top 20 high schools from which students graduated. This suggests that the students' socioeconomic statuses were similar at the two PWIs. In addition, the proportions of males and females at each PWI were similar in the fall 2009 semester. At each university, the females outnumbered the males. The public PWI consisted of 61.6% females and 38.4% males; the private PWI consisted of 52% females and 48% males. Finally, the ethnicity of the public PWI was 56% European American, 40% African American, 2% Hispanic, and 2% Asian; the ethnicity of the private PWI was 62% European American, 29% African American, 6% Asian, and 3% Hispanic.

Finally, to answer the fourth research question, *Which variables (gender, high school GPA, educational level) best predict epistemological beliefs for African American engineering students attending HBCUs and PWIs*, was answered using hierarchical multiple regression. An analysis was done separately for each institutional type. The individual-level variables gender and high school grade point average were entered at step 1 of the regression model. After controlling for the individual-level, educational level variables were entered at step 2 of the regression model. Since gender (male or female) was the only dichotomous variable, dummy-coding was used for the remaining two variables: high school grade point average (GPA) and educational level like the hierarchical analyses previously described for the first research question. Preliminary analyses were also conducted to ensure no violation of the assumptions of normality, linearity, multicollinearity and homoscedasticity.

CHAPTER 3

RESULTS

Preliminary Analyses

Exploratory Factor Analysis

The overall focus of the current study was to compare epistemological beliefs of engineering students across educational levels and institutional types. In addition, this study aimed to determine whether the sample of engineering students' beliefs would support Schommer's (1990) underlying theoretical 4-factor construct. It could not be assumed that the engineering students' responses to Schommer's Epistemological Questionnaire (SEQ) would fit the theoretical construct; therefore, exploratory factor analysis (EFA) was used to determine whether the SEQ was a valid instrument to measure the engineering students' epistemological beliefs.

Principal axis factoring with varimax rotation was used to determine whether or not the 63 items of the SEQ (Schommer, 1990) would be associated with an underlying theoretical 4-factor construct. In addition, the EFA would determine with which construct each item was associated. As a result, 19 components were extracted, but the rotation failed to converge after 25 iterations. As a result, a second attempt at EFA was made to force a 12-factor solution. This consideration was based on the literature (Schommer, 1993b; Schommer, 1998; Schommer & Dunnell, 1994; Schommer et al., 1992; Schommer-Aikins et al., 2002) that Schommer's 63 items have been grouped into 12 subscales that load onto a 4-factor structure that represented the epistemological belief dimensions (Simple Knowledge, Fixed Ability, Quick Learning, Certainty). The forced 12-factor structure explained 46.06% percent of the variance of the engineering students' responses.

There were some low item loadings (< .30) which means that the variable was a poor measure of the factor (Tabacnick & Fidell, 2007). In addition, some items loaded on multiple factors. This suggested that the epistemological belief dimensions were not necessarily independent of each other, as each variable should ideally load on only one factor according to Tabachnik and Fidell. There were also some negative factor loadings. This suggested that these variables were indirectly related to the other variables loading on the same factor. In other words, if the majority of the variables that loaded on the factor were worded so that individuals with sophisticated epistemological beliefs would strongly agree, then individuals with naïve epistemological beliefs would strongly agree with the negative loading factor. Finally, there was a negative Cronbach's alpha value for factor 3. This suggested that there was a reversed phrased item or items that should be reversed coded (Field, 2005). However, all items that were associated with this factor were reviewed for accuracy of coding. As a result of the review, each item had been correctly coded per Schommer's (1990) instructions. With this in mind, the negative Cronbach's alpha value could suggest the instrument has construct validity issues as discussed in Hofer and Pintrich (1997). In other words, the questions that loaded on this factor may not be measuring the belief dimension intended by Schommer. The results of the forced 12-factor solution with loadings above .30 are presented in Table 4.

Next, a third EFA attempt was made to force a 4-factor structure. This solution was considered because previous studies (Schommer, 1993b; Schommer, 1998;

Schommer & Dunnell, 1994; Schommer et al., 1992: Schommer-Aikins et al., 2002) claimed to have analyzed data into a 4-factor structure. The resulting forced 4-factor structure explained 27.12% of the variance of the engineering students’ responses. Like the 12-factor solution, there were some low item loadings (< .30), and some items loaded on multiple factors. Again, this suggested that the epistemological belief dimensions were not independent of each other. This study’s 4-factor structure did not match the structure as defined by Schommer (1990). The results of the forced 4-factor solution with loadings above .30 are presented in Table 5.

Table 4

Factor Analysis of the Twelve-Factor Solution

Scale	α	Eigenvalue	% Variance	Item	Loading
Factor 1	.74	6.74	10.70	Often, even advice from experts should be questioned.	.66
				You should evaluate the accuracy of information in a textbook, if you are familiar with the topic.	.66
				If a person can't understand something within a short amount of time, they should keep trying.	.62
				Wisdom is not knowing the answers, but knowing how to find the answers.	.57
				Getting ahead takes a lot of work.	.54
				I try my best to combine information across chapters or even across classes.	.53
				If a person forgot details, and yet was able to come up with new ideas from text, I would think they were bright.	(.48)

Note. Numbers in parentheses indicate multiple loadings above .30.

Table 4

Factor Analysis of the Twelve-Factor Solution

Scale	α	Eigenvalue	% Variance	Item	Loading
Factor 1	.74	6.74	10.70	Everyone needs to learn how to learn.	(.43)
				Learning is a slow process of building up knowledge.	(.42)
				Usually you can figure out difficult concepts if you eliminate all outside distractions and really concentrate.	(.42)
				It is annoying to listen to a lecturer who cannot seem to make up his mind as to what he really believes.	(-.41)
				Today facts may be tomorrow's fiction.	.34
				A really good way to understand a textbook is to re-organize the information according to your own personal scheme.	.31

Note. Numbers in parentheses indicate multiple loadings above .30.

Table 4

Factor Analysis of the Twelve-Factor Solution

Scale	α	Eigenvalue	% Variance	Item	Loading
Factor 2	.64	5.67	9.00	Learning definitions word-for-word is often necessary to do well on tests.	.61
				Being a good student generally involves memorizing facts.	.52
				Most words have one clear meaning.	.52
				Whenever I encounter a difficult problem in life, I consult with my parents.	.49
				Almost all the information you can learn from a textbook, you will get during the first reading.	(.42)
				Truth is unchanging.	(.40)
				You can believe almost everything you read.	.39
				Working hard on a difficult problem for an extended period of time only pays off for really smart students.	(.38)

Note. Numbers in parentheses indicate multiple loadings above .30.

Table 4

Factor Analysis of the Twelve-Factor Solution.

Scale	α	Eigenvalue	% Variance	Item	Loading
Factor 2	.64	5.67	9.00	For success in school, it's best not to ask too many questions.	.38
				People who challenge authority are over-confident.	(.37)
				A course in study skills would probably be valuable.	(-.35)
Factor 3	-.012	2.51	3.98	Everyone needs to learn how to learn.	(.36)
				A sentence has little meaning unless you know the situation in which it is spoken.	(.31)
				Truth is unchanging.	(-.38)
				A course in study skills would probably be valuable.	(.33)

Note. Numbers in parentheses indicate multiple loadings above .30.
[+]Only one item; therefore, the reliability score is not applicable.

Table 4

Factor Analysis of the Twelve-Factor Solution

Scale	α	Eigenvalue	% Variance	Item	Loading
Factor 4⁺		2.15	3.42	Working hard on a difficult problem for an extended period of time only pays off for really smart students.	(.37)
Factor 5⁺		1.81	2.87	Almost all the information you can learn from a textbook you will get during the first reading.	(.36)
Factor 6⁺		1.64	2.02	It is annoying to listen to a lecturer who cannot seem to make up his mind as to what he really believes.	(.32)
Factor 7	.34	1.60	2.54	Almost all the information you can learn from a textbook you will get during the first reading.	(.37)
				People who challenge authority are over confident.	(.36)

Note. Numbers in parentheses indicate multiple loadings above .30.
⁺Only one item; therefore, the reliability score is not applicable.
*Factor did not have any loadings above .30.

Table 4

Factor Analysis of the Twelve-Factor Solution

Scale	α	Eigenvalue	% Variance	Item	Loading
Factor 8	.44	1.54	2.44	Learning is a slow process of building up knowledge.	(-.34)
				Usually you can figure out difficult concepts if you eliminate all outside distractions and really concentrate.	(-.32)
Factor 9[+]*		1.43	2.27		
Factor 10[+]		1.36	2.16	If a person forgot details, and yet was able to come up with new ideas from a text, I would think they were bright.	(-.38)
Factor 11[+]*		1.29	2.04		
Factor 12[+]		1.27	2.02	A course in study skills would probably be valuable.	(-.32)

Note. Numbers in parentheses indicate multiple loadings above .30.
*Factor did not have any loadings above .30.
[+]Only one item; therefore, the reliability score is not applicable.

Table 5

Factor Analysis of the Four-Factor Solution

Scale	α	Eigenvalue	% Variance	Item	Loading
Factor 1	.75	6.74	10.70	Often, even advice from experts should be questioned.	.63
				If a person can't understand something within a short amount of time, they should keep trying.	.58
				Wisdom is not knowing the answers, but knowing how to find the answers.	.58
				You should evaluate the accuracy of information in a textbook, if you are familiar with the topic.	.57
				The most successful people have discovered how to improve their ability to learn.	.52
				Getting ahead takes a lot of work.	.50
				It is annoying to listen to a lecturer who cannot seem to make up his mind as to what he really likes.	-.49
				Everyone needs to learn how to learn.	.49

Note. Numbers in parentheses indicate multiple loadings above .30

Table 5

Factor Analysis of the Four-Factor Solution

Scale	α	Eigenvalue	%Variance	Item	Loading
Factor 1	.75	6.74	10.70	A sentence has little meaning unless you know the situation in which it is spoken.	.48
				If a person forgot details, and yet was able to come up with new ideas from a text, I would think they are bright.	.47
				I try my best to combine information across chapters or even across classes.	.47
				Learning is a slow process of building up knowledge.	.47
				Usually you can figure out difficult concepts if you eliminate all outside distractions and really concentrate.	.46
				Today's facts may be tomorrow's fiction.	.44
				A really good way to understand a textbook is to re-organize the information according to your own personal scheme.	.43

Note. Numbers in parentheses indicate multiple loadings above .30.

Table 5

Factor Analysis of the Four-Factor Solution

Scale	α	Eigenvalue	%Variance	Item	Loading
Factor 1	.75	6.71	10.70	If I find the time to re-read a textbook chapter, I get a lot more out of it the second time.	(.42)
				The ability to learn is innate.	-.34
				Genius is 10% ability and 90% hard work.	.32
				The most important part of scientific work is original thinking.	.31
				For success in school, it's best not to ask too many questions.	.31
				Working hard on a difficult problem for an extended period of time only pays off for really smart students.	(.33)
				Students who are "average" in school will remain "average" for the rest of their lives.	(.33)
Factor 2	.71	5.67	9.00	The really smart students don't have to work hard to do well in school.	.57

Note. Numbers in parentheses indicate multiple loadings above .30.

Table 5

Factor Analysis of the Four-Factor Solution

Scale	α	Eigenvalue	%Variance	Item	Loading
Factor 2	.71	5.67	9.00	You will just get confused you try to integrate new ideas in a textbook with knowledge you already have about a topic.	.57
				Working hard on a difficult problem for an extended period of time only pays off for really smart students.	(.56)
				If a person tries too hard to understand a problem, they will most likely end up being confused.	.55
				Almost all the information you can learn from a textbook you will get during the first reading.	.48
				How much a person gets out of school mostly depends on the quality of the teacher.	.48

Note. Numbers in parentheses indicate multiple loadings above .30

Table 5

Factor Analysis of the Four-Factor Solution

Scale	α	Eigenvalue	%Variance	Item	Loading
Factor 2	.71	5.67	9.00	Successful students understand things quickly.	.46
				Students who are "average" in school will remain "average" for the rest of their lives.	(.46)
				It's a waste of time to work on problems which have no possibility of coming out with a clear-cut and unambiguous answer.	(.40)
				Things are simpler than most professor would have you believe.	.38
				Educators should know by now which is the best method, lectures or small group discussions.	.37
				A tidy mind is an empty mind.	-.34
				Self-help books are not much help.	.32
				To me studying means getting the big ideas from the text, rather than details.	-.31

Note. Numbers in parentheses indicate multiple loadings above .30.

Table 5

Factor Analysis of the Four-Factor Solution

Scale	α	Eigenvalue	%Variance	Item	Loading
Factor 3	.60	2.51	3.98	If I find the time to re-read a textbook chapter, I get a lot more out of it the second time.	(-.36)
				It's a waste of time to work on problems which have no possibility of coming out with a clear-cut and unambiguous answer.	(.32)
				When I study, I look for specific facts.	.53
				The most important aspect of scientific work is precise measurement and careful work.	.50
				Truth is unchanging.	.48
				If professors would stick more to the facts and do less theorizing, one could get more out of college.	.45
				A course in study skills would probably be valuable.	-.44

Note. Numbers in parentheses indicate multiple loadings above .30.

Table 5

Factor Analysis of the Four-Factor Solution

Scale	α	Eigenvalue	%Variance	Item	Loading
Factor 3	.60	2.51	3.98	Learning definitions word-for-word is often necessary to do well on tests.	.44
				Being a good student generally involves memorizing facts.	.42
				Most words have one clear meaning.	.40
				People who challenge authority are over-confident.	.39
				Whenever I encounter a difficult problem in life, I consult with my parents.	.38
				An expert is someone who has a special gift in some area.	.37
				Students have a lot of control over how much they can get out of a textbook.	(-.37)
				I really appreciate instructors who organize their lectures meticulously and then stick to their plan.	.36

Note. Numbers in parentheses indicate multiple loadings above .30.

Table 5

Factor Analysis of the Four-Factor Solution

Scale	α	Eigenvalue	%Variance	Item	Loading
Factor 3	.60	2.51	3.98	A good teacher's job is to keep his students from wandering from the right track.	.35
				The best thing about science courses is that most problems have only one right answer.	.33
Factor 4	.13	2.16	3.42	It's a waste of time to work on problems which have no possibility of coming out with a clear-cut and unambiguous answer.	(.32)
				Students have a lot of control over how much they can get out of a textbook.	(.34)
				If scientists try hard enough, they can find the truth to almost anything.	-.46
				Scientists can ultimately get to the truth.	-.45

Note. Numbers in parentheses indicate multiple loadings above .30.

Table 5

Factor Analysis of the Four-Factor Solution

Scale	α	Eigenvalue	%Variance	Item	Loading
Factor 4	.13	2.16	3.42	I don't like movies that don't have an ending.	.41
				I find it refreshing to think about issues that authorities can't agree on.	.38
				If you are going to be able to understand something, it will make sense to you the first time you hear it.	-.36

Note. Numbers in parentheses indicate multiple loadings above .30.

The current study's EFA solutions failed to fit Schommer's (1990) underlying theoretical 4-factor structure. As a result, reliability analysis was used to create valid scales to measure the engineering students' epistemological beliefs. That is, inter-item reliabilities were calculated based upon Schommer's four epistemological belief factors. Cole et al.'s (2001) procedure of dropping items with low Cronbach's alpha values (< .60) was then used to improve the reliability of each epistemological belief scale. The following sections provide the reliability results of both the full engineering students' sample and reliability results for the African American engineering students' sample. Table 6 is a summary of the reliability scores of each epistemological dimension.

Reliability Analysis of the Full Sample

Fixed Ability. Sixteen questionnaire items were associated with this belief dimension. It had an appropriate Cronbach's alpha value of .65 after the first iteration of analysis. This scale included such items as "Some people are born good learners, others are just stuck with limited ability."

Simple Knowledge. Twenty-eight questionnaire items were associated with this belief dimension. Two items were removed before the Cronbach's alpha value reached .61. This scale included such items as "I try my best to combine information across chapters or even across classes."

Quick Learning. Thirteen questionnaire items were associated with this belief dimension. It had an appropriate Cronbach's alpha value of .64 after the first iteration of analysis. This scale included such items as "If a person can't understand something in a short amount of time, they should keep on trying."

Certain Knowledge. Six questionnaire items were associated with this belief dimension. After 4 items were removed, the Cronbach's alpha value reached .59. This is the closest to .60 that the reliability score would reach. This scale included such items as, "Scientists can ultimately get to the truth."

Reliability Analysis of the African American Sample

Fixed Ability. Sixteen questionnaire items were associated with this belief dimension. It had an appropriate Cronbach's alpha value of .72 after the first iteration of analysis. This scale included such items as "Students have a lot of control on how much they can get out of a textbook."

Simple Knowledge. Twenty-eight questionnaire items were associated with this belief dimension. Five items were removed before the Cronbach's alpha value reached .62. This scale included such items as "A sentence has little meaning unless you know the situation in which it is spoken."

Quick Learning. Thirteen questionnaire items were associated with this belief dimension. Like Fixed Ability, it had an appropriate Cronbach's alpha value of .64 after the first iteration of analysis. This scale included such items as "Learning is a slow process of building up knowledge."

Certain Knowledge. Six questionnaire items were associated with this belief dimension. After 4 items were removed, the Cronbach's alpha value only reached .46. This is the highest that the reliability score would reach. This scale included such items as, "If scientists try hard enough, they can find the truth to almost anything." Because the reliability score was low with a scale consisting of only 2 questionnaire items, it was determined that the Certain Knowledge scale was not reliable enough to be used to evaluate the sample of African American engineering students (*N* = 146).

For this reason, a three-factor structure was defined to evaluate the epistemological beliefs for this sample of students.

Table 6

Cronbach's Alphas for each Epistemological Belief Factor.

Factor	All Students (*n* = 518)	African American Students (*n* = 146)
Fixed Ability	.65	.72
Simple Knowledge	.61	.62
Quick Learning	.64	.64
Certain Knowledge*	.59	.46

**Note*. Regardless of how many items were removed from the scale, the reliability of the Certain factor did not reach .60.

Epistemological Beliefs Across Educational Levels

Research Question 1: *Do epistemological belief dimensions (certainty, structure, control, and speed) of engineering students differ across educational levels (freshman, sophomore, junior, senior, and graduate)?* Only one of the four epistemological belief factors demonstrated a statistically significant difference. The speed dimension, or the belief that learning is quickly acquired, was statistically significant, F (2, 513) = 9.98, $p <$ .001. Despite reaching statistical significance, the actual difference in mean scores among the educational levels was small. The effect size, calculated using eta squared, was .04 (see Table 7 for details). Post-hoc comparisons using the Tukey HSD test indicated that the mean score for Underclassmen (M = 2.42, SD = .48) was significantly different from

Upperclassmen (*M* = 2.23, *SD* = .45). Graduate students did not differ significantly from either Underclassmen or Upperclassmen.

Table 7

Analysis of Variance Comparing Engineering Students' Epistemological Beliefs Across Educational Levels

Belief Dimension	*df*	*F*	η^2	*p*
Fixed Ability	2	1.88	.007	.15
Simple Knowledge	2	.75	.003	.47
Quick Learning	2	9.98*	.02	.00
Certain Knowledge	2	2.75	.01	.065

*$p < .001$.

Research Question 2: *Which variables best predict epistemological beliefs for engineering students across the educational levels?* The Quick Learning factor was examined first since it was the only epistemological belief factor that significantly differed between two educational levels. Its first set of predictors, which were entered at step 1 of the regression model, individual-level (gender, ethnicity, high school GPA) and institutional type variables (PWI or HBCU) accounted for a significant amount of the Quick Learning factor variability, $R^2 = .04$, F (6, 475) = 3.27, $p < .01$ (see Table 8). This indicated that the male engineering students who were an ethnicity other than European American and African American were more likely to have naïve beliefs in Quick Learning. In step 2 of the regression model, educational level accounted for a significant proportion of the Quick Learning factor variance after controlling for the effects of the individual-level and institutional type variables, R^2 change = .038, F (8, 473) = 9.74, $p <$ .001 (see Table 8). This indicated that educational level predicted beliefs in Quick Learning over and above individual-level and institutional type variables. These results suggested that Underclassmen (dummy coded reference group), who are male and an ethnicity other than European American and African American, are more likely than Upperclassmen to have naïve beliefs in Quick Learning.

In step 1 of the regression model for the control factor, or Fixed Ability factor, individual-level (gender, ethnicity, high school GPA) and institutional type variables (PWI or HBCU) accounted for a significant amount of the Fixed Ability factor variability, R^2 = .028, F (6, 475) = 2.32, $p < .05$ (see Table 9). This indicated that the male engineering students were more likely to have naïve beliefs in Fixed Ability. In step 2 of the regression model, educational level did not account for a significant proportion of the Fixed Ability factor variance after controlling for the effects of the individual-level and institutional type variables. In addition, step 2 was not a statistically significant contribution to the regression model as a whole; however, gender remained a significant predictor of the Fixed Ability dimension in step 2 of the regression model (see Table 9). These results indicated that the male engineering students were more likely than the female engineering students to have naïve beliefs in Fixed Ability over and above individual-level and institutional type variables.

Like the regression analysis of Fixed Ability, there was only one variable that remained a significant predictor of the structure of knowledge factor, the Simple Knowledge factor. The set of variables, in step 1 of the regression model, accounted for a significant amount of the Simple Knowledge factor variability, R^2 = .028, F (6, 475) =

2.31, $p < .05$ (see Table 10). This indicated that the African American engineering students were more likely than European American engineering students (dummy coded reference group) to have naïve beliefs in Simple Knowledge. In step 2 of the regression model, educational level did not account for a significant proportion of the Simple Learning factor variance after controlling for the effects of the individual-level and institutional type variables. In addition, step 2 was not a statistically significant contribution to the regression model as a whole; however, ethnicity remained significant in step 2 of the regression model (see Table 10). These results suggested that the African American engineering students were more likely than European American engineering students (dummy coded reference group) to have naïve beliefs in Simple Knowledge over and above individual-level and institutional type variables.

Table 8

Hierarchical Multiple Regression Analysis Predicting Engineering Students' Quick Learning Beliefs from Background Characteristics

Predictor	ΔR^2	β
Step 1	.04**	
Above average GPA		-.006
Below average GPA		-.079
Gender (female)		-.141
African American		.103
Other[a]		.103
Institutional Type (HBCU)		-.002
Step 2	.038***	
Above average GPA		-.005
Below average GPA		-.087
Gender (female)		-.140**
African American		.094
Other[a]		.105*
Institutional Type (HBCU)		.029
Upperclassmen		-.203***
Graduate		-.032
Total R^2	.078***	
n	481	

Note. Reference group for high school grade point average (GPA) is Average GPA, the reference group for Ethnicity is European American, and the reference group for Educational level is Underclassmen (e.g., freshmen and sophomores).
Other[a] variable includes the following ethnicities: Alaskan Pacific Islander, Asian American, Hispanic, Multi-ethnic/racial, and Native American. It also includes those individuals who reported their ethnicity as Other.

*$p < .05$. **$p < .01$. ***$p < .001$.

Table 9

Hierarchical Multiple Regression Analysis Predicting Engineering Students' Fixed Ability Beliefs from Background Characteristics

Predictor	ΔR^2	β
Step 1	.028*	
Above average GPA		-.058
Below average GPA		.012
Gender (female)		-.118
African American		-.006
Other[a]		.084
Institutional Type (HBCU)		-.046
Step 2	.005	
Above average GPA		.057
Below average GPA		.009
Gender (female)		-.117*
African American		-.008
Other[a]		.083
Institutional Type (HBCU)		-.037
Upperclassmen		-.068
Graduate		.010
Total R^2	.033*	
n	481	

Note. Reference group for high school grade point average (GPA) is Average GPA, the reference group for Ethnicity is European American, and the reference group for Educational level is Underclassmen (e.g., freshmen and sophomores).
Other[a] variable includes the following ethnicities: Alaskan Pacific Islander, Asian American, Hispanic, Multi-ethnic/racial, and Native American. It also includes those individuals who reported their ethnicity as Other.

*$p < .05$.

Table 10

Hierarchical Multiple Regression Analysis Predicting Engineering Students' Simple Knowledge Beliefs from Background Characteristics

Predictor	ΔR^2	β
Step 1	.028*	
Above average GPA		-.023
Below average GPA		-.015
Gender (female)		-.055
African American		.173
Other[a]		.016
Institutional Type (HBCU)		-.019
Step 2	.005	
Above average GPA		-.022
Below average GPA		-.018
Gender (female)		-.055
African American		.170**
Other[a]		.018
Institutional Type (HBCU)		-.007
Upperclassmen		-.075
Graduate		-.018
Total R^2	.034*	
n	481	

Note. Reference group for high school grade point average (GPA) is Average GPA, the reference group for Ethnicity is European American, and the reference group for Educational level is Underclassmen (e.g., freshmen and sophomores).
Other[a] variable includes the following ethnicities: Alaskan Pacific Islander, Asian American, Hispanic, Multi-ethnic/racial, and Native American. It also includes those individuals who reported their ethnicity as Other.

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

HBCUs vs. PWIs

As stated in the Preliminary Analyses section, the Cronbach's alpha for the Certain Knowledge factor did not reach .60; therefore, it was determined that the Certain Knowledge scale was not reliable enough to measure the epistemological beliefs of the sample of African American engineering students (Cronbach, 1951). The analyses conducted for the last two research questions consisted of only three epistemological belief dimensions (Fixed Ability, Simple Knowledge, and Quick Learning). The results are presented in the following sections.

Research Question 3: *Do epistemological belief dimensions (certainty, structure, control, and speed) significantly differ for African American engineering students attending HBCUs from those attending PWIs?* There were no significant differences in any of the epistemological belief scores for the African American engineering students attending the HBCU (*N* = 90) and the African American engineering students attending the PWIs (*N* = 56) (see Table 11).

Table 11

Comparison of African American Engineering Students' Epistemological Beliefs in Black and White Institutions with t-tests (HBCU, N =90; PWIs, N =56)

Belief Dimension	Mean	*SD*	t-ratio	*p* (two-tailed)
Fixed Ability			.41	.68
PWI	2.43	.51		
HBCU	2.40	.48		
Simple Knowledge			-.21	.84
PWI	3.04	.37		
HBCU	3.06	.37		
Quick Learning			-.026	.98
PWI	2.35	.49		
HBCU	2.35	.50		

Research Question 4: *Which variables (gender, high school GPA, educational level) best predict epistemological beliefs for African American engineering students attending HBCUs and PWIs?* The individual-level variables (gender and high school GPA) entered at step 1 of the regression model did not account for a significant amount of the Simple Knowledge factor variability for the African American engineering students at the HBCU. However, in step 2, educational level (Upperclassmen) accounted for a significant amount of the Simple Knowledge factor variability after controlling for the effects of the individual-level variables, R^2 change = .086, F (2, 83) = 4.18, $p < .05$ (see Table 12). This indicated that the African American engineering students at the HBCU who were Underclassmen (dummy coded reference variable) were more likely to have naïve beliefs in Simple Knowledge than those students who were Upperclassmen.

Next, the predictor variables were examined for the African American engineering students at PWIs. The individual-level variables (gender and high school GPA) entered at step 1 of the regression model did not account for a significant amount of the Fixed Ability factor variability. However, in step 2, educational level (Graduate) and high school GPA (Above Average) variables accounted for a significant amount of the Fixed Ability factor variability after controlling for the effects of the individual-level variables, R^2 change = .19, F (2, 46) = 5.64, $p < .01$ (see Table 13). This indicated that the African American engineering students at PWIs who were graduate students and had above average high school GPAs were more likely to have naïve beliefs in Fixed Ability than those students who were undergraduates (dummy coded reference variable) and had average high school GPAs (dummy coded reference variable).

Table 12

Hierarchical Multiple Regression Analysis Predicting Simple Knowledge Beliefs of African American Engineering Students at the HBCU (N = 88)

Predictor	ΔR^2	β
Step 1	.061	
Above average GPA		-.098
Below average GPA		.108
Gender (female)		-.144
Step 2	.086*	
Above average GPA		-.020
Below average GPA		.052
Gender (female)		-.133
Upperclassmen		-.305**
Graduate		-.203
Total R^2	.147*	
n	88	

Note. Reference group for high school grade point average (GPA) is Average GPA, and the reference group for Educational level is Underclassmen (e.g., freshmen and sophomores).

$^*p < .05$. $^{**}p < .01$.

High school GPA and educational level also predicted Quick Learning beliefs for African American engineering students at PWIs. The individual-level variables did not account for any variability in the Quick Learning factor in step 1 of the regression model. In step 2 of the regression model, high school GPA (Above Average GPA and Below Average GPA) and educational level (Graduate) variables accounted for a significant proportion of the Quick Learning factor variance after controlling for the effects of the individual-level variables, R^2 change = .290, F (2, 46) = 4.86, p < .001 (see Table 14). These results suggested that the African American engineering students at PWIs who were graduate students, had above average high school GPAs, and had below average high school GPAs were more likely to have naïve beliefs in Quick Learning than those students who were undergraduates (dummy coded reference variable) and had average high school GPAs (dummy coded reference variable).

Table 13

Hierarchical Multiple Regression Analysis Predicting Fixed Ability Beliefs of African American Engineering Students at PWIs (N = 51)

Predictor	ΔR^2	β
Step 1	.044	
Above average GPA		.220
Below average GPA		.074
Gender (female)		-.015
Step 2	.188**	
Above average GPA		.330*
Below average GPA		-.336
Gender (female)		-.015
Upperclassmen		-.034
Graduate		.618**
Total R^2	.232*	
n	51	

Note. Reference group for high school grade point average (GPA) is Average GPA, and the reference group for Educational level is Underclassmen (e.g., freshmen and sophomores).

*p < .05. **p < .01.

Table 14

Hierarchical Multiple Regression Analysis Predicting Quick Learning Beliefs of African American Engineering Students at PWIs (N = 51)

Predictor	ΔR^2	β
Step 1	.056	
Above average GPA		.252
Below average GPA		.020
Gender (female)		-.109
Step 2	.290***	
Above average GPA		.333*
Below average GPA		-.442*
Gender (female)		-.109
Upperclassmen		-.237
Graduate		.648**
Total R^2	.346**	
n	51	

Note. Reference group for high school grade point average (GPA) is Average GPA, and the reference group for Educational level is Underclassmen (e.g., freshmen and sophomores).

**p* < .05. ***p* < .01. ****p* < .001.

CHAPTER 4

DISCUSSION

Summary of Study

The purpose of this study was to cross-sectionally assess the epistemological beliefs of engineering students at a public Predominantly White Institution, a private Predominantly White Institution, and a public Historically Black University all located in Tennessee. The four research questions were:

1) Do epistemological belief dimensions (certainty, structure, control, and speed) of engineering students differ across educational levels (freshman, sophomore, junior, senior, master, doctoral)?

2) Which variables best predict epistemological beliefs for engineering students across the educational levels?

3) Do epistemological belief dimensions (certainty, structure, control, and speed) significantly differ for African American engineering students attending HBCUs from those attending PWIs?

4) Which variables best predict epistemological beliefs for African American engineering students attending HBCUs and PWIs?

Underlying Structure of the Schommer Epistemological Questionnaire (SEQ)

The results of this study suggest that the hypothetical dimensions (Schommer, 1990) underlying the SEQ could not be replicated for this study's sample of engineering students. Like two other studies (Hofer, 2000; Qian & Alvernmann, 1995), this study attempted to conduct EFA on all items of the SEQ. However, unlike the two studies, this study's EFA of individual questionnaire items failed to converge after 25 iterations.

Also unlike the Qian and Alvermann (1995) and Hofer (2000) studies, this study analyzed all 63 items of the original SEQ. Although not successful, the current study was the first to attempt to factor analyze engineering students' responses to all 63 items on the SEQ.

Furthermore, the results of the second EFA attempt to force a 12-factor solution suggest that the a priori 12 subscales (Seek Single Answers, Avoid Integration Score, Avoid Ambiguity, Depend on Authority, Don't Criticize Authority, Learning is Quick, Concentrated Effort is a Waste of Time, Ability to Learn is Innate, Can't Learn How to Learn, Success is Unrelated to Hard Work, Learn the First Time, Knowledge is Certain) underlying the SEQ (Schommer, 1990) could not be replicated for this study of engineering students. In addition, the final EFA attempt to force a 4-factor solution also suggests that the 4-factor structure (Fixed Ability, Simple Knowledge, Quick Learning, Certain Knowledge) underlying the SEQ (Schommer, 1990) could not be replicated for this study of engineering students.

This current study's results differ from other epistemological studies (Qian & Alvermann, 1995; Schommer, 1990; Schommer, 1993b; Schommer, 1998; Schommer & Dunnell, 1994; Schommer et al., 1992; Schommer-Aikins et al., 2002) in that the items did not factor in a meaningful way. In other words, the items neither loaded distinctly on 12 subscales nor did the items load distinctly on four epistemological belief dimensions. Hofer's (2000) study, which factor analyzed a 32-item modified epistemological questionnaire, also supports this finding in that she stated, "the overall 4-factor solution that emerged from an item-based factor analysis had no single factor that replicated those factors reported by Schommer and others when a factor analysis [was] conducted using subscales" (p. 392). Further, there were items in this study that loaded on more than one factor. Hofer (2000) also found items that loaded on more than one factor. The multiple factor loading suggests that the factors created from the responses of this sample of engineering students were not independent of each other as Schommer's studies suggest (Schommer, 1990; Schommer, 1993b; Schommer, 1998; Schommer & Dunnell, 1994; Schommer et al., 1992; Schommer-Aikins et al., 2002). In a study that examined underprepared students, Cole et al. (2000) also found evidence that indicated that epistemological beliefs dimensions are not necessarily independent. This study along with Hofer (2000) and Cole et al. (2000) supports Hofer and Pintrich's (1997) assertion that further research is need to explore whether epistemological beliefs are more or less independent dimensions.

Due to the previously discussed inconsistencies in replicating Schommer's (1990) theoretical rationale for epistemological belief dimensions, Cole et al.'s (2000) approach for creating distinct epistemological belief dimension scales was used to measure the beliefs of this study's sample of engineering students. All the items of the Fixed Ability and Quick Learning scales were used for analysis. This supports the internal consistency of these two scales in that the instrument maintained its original items (Schommer, 1990). However, 2 of the 28 items were removed from the Simple Knowledge scale for the full sample (N = 518), and 5 of the 28 items were removed for African American sample (N = 146). Again, this supports the internal consistency of the Simple Knowledge scale, as at least 82% of this scale's original items were maintained. This also supports Wood and Kardash's (2002) suggestion that the more items to represent a construct of measure, the higher the reliability of the instrument. The noteworthy distinction between the current study and the past Schommer studies (Qian & Alvermann, 1995; Schommer, 1990; Schommer, 1993b; Schommer, 1998; Schommer & Dunnell, 1994; Schommer et al., 1992; Schommer-Aikins et al., 2002) is that only 2 of the 6 items were used to measure the Certain Knowledge dimension for the full sample of engineering students, whereas the Certain Knowledge dimension was removed and not used to measure the epistemological beliefs for the African American engineering students. Also supporting Wood and Kardash’s (2002) observation regarding the relationship between the number of items on a construct and reliability, the lowest reliability of the four scales was that of Certain Knowledge, and it consisted of the fewest items of all the epistemological belief dimensions. Overall, the reliabilities of the four epistemological beliefs for this study were comparable to past studies or higher (Schommer, 1993b; Schommer et al., 2002)

There are a few possibilities as to why the reliability analysis produced all four belief dimensions for the full sample of engineering students (*N* = 518) and three belief dimensions for the African American sample of engineering students (*N* = 146). The Certain Knowledge factor was not used to assess the African American students beliefs because it never reached an acceptable reliability (.60). The Certain Knowledge subscale consists of only 6 items, whereas the other subscales consist of 13 - 28 items. Therefore, there are not many opportunities to eliminate items from the Certain Knowledge subscale to increase its reliability. In the case of this study, it was determined that Certain Knowledge should be removed to reduce the possibility of introducing low internal consistency into the analysis of the African American engineering students’ epistemological beliefs (DeBacker et al., 2008). On the other hand, the Certain Knowledge subscale was .01 less than the acceptable reliability value (.60) for the full sample; however, since it was close to .60, it was kept as a subscale. Moreover, Qian and Alvermann (1995) found that Simple Knowledge and Certain Knowledge merged to form one subscale. This merged subscale along with the subscales Fixed Ability and Quick Learning produced higher reliability scores than the studies that maintained the four-subscale structure (Schommer, 1990; Schommer, 1993b, Schommer-Aikins et al., 2002).

Differences Across Educational Levels

This study supported several epistemological studies in that there were findings that engineering students' epistemological beliefs became more sophisticated as they progressed through college (Jehng et al., 1993, King & Magun-Jackson, 2009; Paulsen & Wells, 1998; Pavelich & Moore, 1996; Schommer, 1993a; Wise et al., 2004). However, this study's findings only showed significant differences in engineering students' beliefs in the speed dimension, or beliefs in Quick Learning. In other words, Quick Learning was the naïve belief that knowledge is acquired quickly as opposed to the sophisticated belief that knowledge is acquired gradually. More specifically, in this study, the beliefs in Quick Learning became more sophisticated as students progressed from Underclassmen (freshmen and sophomores) to Upperclassmen (juniors and seniors). Like Paulsen and Wells (1998) and Schommer (1993a), this study found that engineering students' beliefs in Quick Learning became more sophisticated in their junior and senior years.

Variables Predicted Epistemological Beliefs

When looking at all engineering students, educational level predicted beliefs in Quick Learning over and above the effects of background individual-level characteristics and institutional type. For example, being an Underclassman, compared to being an Upperclassman, was a predictor that engineering students believed that learning was acquired quickly. These findings are consistent with studies (King & Magun-Jackson, 2009; Paulsen & Wells, 1998) that also found educational level predicted beliefs in quick learning over and above the effects of background characteristics. For example, King and Magun-Jackson's (2009) study found that educational level predicted epistemological beliefs over and above the effects of the background characteristics such as gender, ethnicity, and high school grade point average. Moreover, Paulsen and Wells (1998) specifically found that engineering students were more likely than other majors to have beliefs in Quick Learning when gender, GPA, and educational level were controlled.

In addition to educational level, three variables (i.e., gender, institutional type, and ethnicity) were significant predictors of engineering students' beliefs in Quick Learning. In order of importance, the following conclusions could be drawn about engineering students' beliefs overall. Males were more likely to have beliefs in Quick Learning. Students at HBCUs were more likely to have beliefs in Quick Learning. Moreover, ethnic groups, other than European Americans and African Americans, were more likely to have beliefs in Quick Learning. Like this study, King and Magun-Jackson (2009), Paulsen and Wells (1998), and Schommer (1993a) found that males were more likely than females to have beliefs in Quick Learning. However, the King and Magun-Jackson study was the only one of these three that examined engineering students. Furthermore, there were no other studies to support this study's findings related to the Quick Learning beliefs of engineering students at HBCUs and non-European American ethnic groups, as this study was the first to examine these characteristics of engineering students as they related to epistemological beliefs.

In addition to Quick Learning, individual-level variables predicted epistemological beliefs in Fixed Knowledge and Simple Knowledge. For example, male engineering students were more likely to have beliefs in Fixed Knowledge. This finding was not surprising as Paulsen and Wells (1998) also found that college males, although not engineering students, were more likely than females to have beliefs in Fixed Knowledge. In addition, the current study found that African American engineering students were more likely to have naïve beliefs in Simple Knowledge than European American engineering students.

Differences Between Institutional Types

The finding in this study that there were no significant differences (at the $p < .05$ level) in epistemological beliefs between the African American engineering students attending the HBCU ($N = 90$) and those students attending the PWI ($N = 56$) is consistent with other comparative analysis studies in which no significant differences were found. Since this study is the only one to have compared the epistemological beliefs of African American engineering students at HBCUs versus at PWIs, this study's results can only be supported by studies that compared African American college students by other characteristics.

Variables Predicted African American Students' Beliefs

Additional findings in this study were that background characteristics significantly predicted beliefs in Quick Learning and Fixed Ability for African American engineering students attending the PWIs. For example, being an African American engineering graduate student compared to being an Underclassman (dummy coded reference group) and being an African American engineering student with a below average high school GPA compared to being a student with an average high school GPA, predicted beliefs in knowledge as quickly learned or acquired. Furthermore, being an African American engineering graduate student at a PWI and having an above average high school GPA predicted beliefs in Fixed Ability. Finally, being an African American upperclassman at a HBCU predicted beliefs in Simple Knowledge. Again, no other studies have examined the epistemological beliefs of engineering students at HBCUs and PWIs. As a result, there are no previous studies that support these findings.

Implications

There are four implications of this study's results. The first implication is that engineering students are less likely to believe that learning is quickly acquired as they progress through college. This supports that older engineering students, as suggested by Schommer's 1990 study, comprehend engineering course information better as juniors and seniors than when they started their program of studies as freshmen and sophomores. A second implication of this study is that there are gender differences in epistemological beliefs in Quick Learning and Fixed Knowledge, wherein female engineering students are less likely to have beliefs in these two epistemological dimensions. Considering Hofer and Pintrich's (1997) suggestion that Quick Learning and Fixed Knowledge are core dimensions of learning and instruction, a possible explanation for the differences is that gender differences exist in the nature of learning as they relate to the field of engineering.

In line with differences among engineering students, a third implication is that epistemological belief differences in Simple Knowledge exist between African American and European American engineering students. This finding was consistent with the King and Magun-Jackson (2009) study. A possible reason for this difference is that studies show that African American students demonstrate more variability than European American students in their pre-college preparation for the fields of science, technology, engineering, and mathematics (Collea, 1990; Good et al., 2001-2002; Lent et al., 2005; Perna et al., 2009). As a result, the African American engineering students, who are less prepared in high school mathematics and science than their European American peers, will be at a disadvantage when starting a college-level engineering program. To this end, their pre-college preparation for engineering studies may affect their ability to use higher-level cognitive processes, which have been correlated with beliefs in Simple Knowledge (Hofer & Pintrich, 1997).

The fourth implication of these results is that African American engineering college students attending HBCUs have the same academic experiences as the African American engineering college students at PWIs. For example, there were no differences in epistemological beliefs between engineering students at the HBCU versus the PWIs. According to Schommer-Aikins' (2004) embedded system model of epistemological beliefs, this finding indicates that the African American students perceive that the engineering classroom environment and interactions with others are similar regardless of the institutional type (e.g., HBCU, PWI). In the same vein, the results also indicate that all engineering programs, regardless of their racial composition, produce a classroom environment in which the psychosocial aspects that have typically been observed in HBCUs (e.g., faculty interaction, positive peer relationships) are not necessarily present in an engineering classroom environment.

Limitations and Recommendations

As with all studies, the current study has its limitations. These limitations include the failure to replicate Schommer's (1990) underlying 4-factor structure for epistemological beliefs, generalizability, and self-reported data. This study was the first to use exploratory factor analysis (EFA) to attempt to load engineering students' responses to the 63 Schommer Epistemological Belief Questionnaire (SEQ) items on to a 4-factor structure. However, this study failed to replicate Schommer's 4-factor structure. This was not unusual in that some studies (Qian & Alvermann, 1995) have found three-factor structures to represent data. And, other studies have found 4-factor structures that did not resemble the factors of Schommer's (1990) original study. More importantly, this study also supports the criticisms (DeBacker et al., 2008; Clarebout et al., 2001) that Schommer's instrument has methodological issues and that further research is needed to improve the instrument's internal inconsistency (Hofer & Pintrich, 1997; Schommer-Aikins, 2002).

The generalizability of this study is only applicable to engineering students with similar characteristics as the students in the two west Tennessee and one middle Tennessee universities. Also, this study is cross-sectional as opposed to being longitudinal; therefore, no assumptions about the epistemological development of engineering students can be concluded. Moreover, ethnicity was a limitation that affects the generalizability of this study. The largest ethnic groups in this study were European American and African American, respectively. The other groups were much less than half the size of both groups. As a result, one cannot assume that the findings of this study would be consistent cross-culturally. In agreement with Hofer and Pintrich (1997), there is a need to study epistemological beliefs within and across many different cultures and ethnic groups. This type of research would also be useful in engineering education as there is a need to attract more young minorities to pursue engineering fields in U.S. colleges and universities.

Finally, high school GPA was self-reported by each student; therefore, it is reasonable to question the accuracy of this data. Some students could not remember this information and left this item blank on their answer sheets. As a result, their data was eliminated from some of the data analysis. In addition, some students probably guessed their grade point averages. Guessing would also result in inaccurate findings in this study. In future research, it would be preferable to obtain examination scores and grade point average data directly from the records office of the university.

Contribution to Body of Knowledge

Currently, there are many initiatives underway to increase student enrollment in the fields of science, technology, engineering, and mathematics (STEM). One way to increase the enrollment of students in engineering is to recruit underrepresented minorities, such as African Americans, to major in engineering during college. To meet this challenge, engineering education researchers are contributing to these initiatives by focusing their research on five major areas, and one of these areas of interest is engineering epistemologies or what constitutes the nature of engineering knowledge and ways of engineering thinking.

First, this study contributes to the overall epistemological belief literature in that it expanded King and Magun-Jackson’s (2009) study and used Schommer’s (1990) Epistemological Questionnaire (SEQ) to quantitatively measure the epistemological beliefs of engineering students. As previously mentioned in the Methods chapter, it is difficult to quantify what individuals understand and think about knowledge. In an attempt to capture engineering students' beliefs about knowledge, the current study also contributes to epistemological belief literature in that it was the first to conduct exploratory factor analysis to determine whether the 63 SEQ items would replicate Schommer's 4-factor epistemological belief structure for an all-engineering student sample.

This study's design and results also contribute to the engineering epistemologies research in that a comparison of engineering students' epistemological beliefs across educational levels has not been examined prior to this study, except for King and Magun-Jackson's (2009) research. Furthermore, there have been no comparative analysis studies to assess the epistemological belief differences between African American engineering students attending Historically Black Colleges and Universities versus Predominantly White Institutions. This study could be extended and replicated to evaluate underrepresented minority students in engineering programs throughout the country, as Fleming (1984) demonstrated that comparative analysis results related to college students can vary by region of the country.

The findings of this study also suggest that engineering students' epistemological beliefs, at least their beliefs in Quick Learning, do indeed become more sophisticated as they progress through college. In addition, individual-level characteristics are influential as predictors of epistemological beliefs. These findings are important to engineering education because they can be used to understand students' perspectives as they relate to learning engineering concepts. Furthermore, engineering educators would be able to identify the specific parts of the engineering curriculum that would influence sophisticated or advanced cognitive processes (e.g., problem solving, critical thinking) in engineering students. In addition, the findings emphasize to engineering educators that African American engineering students' epistemological beliefs are not necessarily influenced by the campus racial composition. However, more research is needed in this area of comparative analysis, as this study was the first to examine epistemological beliefs of African American engineering students.

References

Accreditation Board for Engineering and Technology. (2007). *Criteria for accrediting engineering programs.* Retrieved November 12, 2007, from http://www.abet.org/Linked%20Documents-UPDATE/Criteria%20and%20PP/E001%2008-09%20EAC%20Criteria%2011-30-07.pdf

Allen, W. R. (1992). The color of success: African American college student outcomes at predominantly White and historically Black public colleges and universities. *Harvard Educational Review, 62*, 26-44.

Astin, A. W., & Astin, H. S. (1992). Undergraduate science education: The impact of different college environments on the educational pipeline in the sciences. Final report. National Science Foundation. Washington, D.C.: Government Printing Office. Retrieved June 30, 2010, from http://www.eric.ed.gov/ERICWebPortal/search/detailmini.jsp?_nfpb=true&_&ERICExtSearch_SearchValue_0=ED362404&ERICExtSearch_SearchType_0=no&accno=ED362404

Barker, S. A. (1998). The domain-generality of epistemological beliefs. (Unpublished master's thesis). Wichita State University, Wichita, Kansas.

Baxter Magolda, M. B. (1992). *Knowing and reasoning in college: Gender-related patterns in students' intellectual development.* San Francisco: Jossey-Bass.

Belenky, M. F., Clinchy, B. M., Goldberger, N. R., & Tarule, J. M. (1986). *Women's Ways of Knowing.* New York: Basic Books.

Berger, J. B., & Milem, J. F. (2000). Exploring the impact of Historically Black Colleges in promoting the development of undergraduates' self-concept. *Journal of College Student Development, 41*, 381-394.

Bohr, L., Pascarella, E. T., Nora, A., & Terenzini, P. T. (1995, January/February). Do black students learn more at historically Black or predominantly White colleges? *Journal of College Student Development, 36(1)*, 75-85.

Brown, M. C. (2002). Good intentions: Collegiate desegregation and transdemographic enrollments. *The Review of Higher Education, 25,* 263-280. doi: 10.1353/rhe.2002.0009

Butler, L. E. (1985). [Review of the book *Blacks in College,* by J. Fleming]. *Higher Education, 14*, 749-751.

Clarebout, G., Elen, J., Luyten, L., & Bamps, H. (2001). Assessing epistemological beliefs: Schommer's questionnaire revisited. *Educational Research and Evaluation, 7,* 53-77.

Cokley, K. (2000). An investigation of academic self-concept and its relationship to academic advancement in African American college students. *Journal of Black Psychology, 26*, 148-164.

Cokley, K. (2002). The impact of college racial composition on African American students' academic self-concept: A replication and extension. *Journal of Negro Psychology, 71*, 288-296.

Cole, R. P., Goetz, E. T., & Willson, V. (2000). Epistemological beliefs of underprepared college students. *Journal of College Reading and Learning, 31*, 60-72.

Collea, F. P. (1990). Increasing minorities in science and engineering. *Journal of College Science Teaching*, *20*, 31-41.

Committee on Science, Engineering, and Public Policy. (2007). *Rising above the gathering storm: Energizing and employing America for a brighter economic future.* Retrieved June 25, 2007, from http://books.nap.edu/catalog.php?record_id=11463#orgs

Cronbach, L. J. (1951). Coefficient alpha and internal structure tests. *Psychometrika*, *16*, 297-334.

Culver, R. S., & Hackos, J. T. (1982). Perry's model of intellectual development. *Engineering Education, 73,* 221-226.

Davis, J. E. (1995) College in black and white: Campus environment and academic achievement of African American males. *The Journal of Negro Education, 63,* 620-633.

DeBacker, T. K., Crowson, H. M., Beesley, A. D., Thoma, S. J., & Hestevold, N.L. (2008). The challenge of measuring epistemic beliefs: An analysis of three self-report instruments. *The Journal of Experimental Education, 76*, 281-312.

Dweck, C. S., & Leggett, E. L. (1988). A social-cognitive approach to motivation and personality. *Psychological Review, 95,* 256-273.

Fedler, R. M., & Brent, R. (2004). The intellectual development of science and engineering students. Part 1: Models and challenges. *Journal of Engineering Education, 93,* 269-277.

Fedler, R. M., & Brent, R. (2005). Understanding student differences. *Journal of Engineering Education, 94,* 57-72.

Field, A.P. (2005). *Discovering statistics using SPSS*. London, England: Sage.

Fitch, P., & Culver, R. S. (1984). Educational activities to stimulate intellectual development in Perry's scheme. *Proceedings ASEE Annual Conference, 2,* 712-717.

Fleming, J. (1984). "Role of Black and of White colleges in education Black students." *Blacks in College* (pp. 1-13). San Francisco, CA: Jossey-Bass Publishers.

Flowers, L. A. (2002). The impact of college racial composition on African American students' acadmiec and social gains: Additional evidence. *Journal of College Student Development, 43*, 403-410.

Good, J., Halpin, G., & Halpin, G. (2001-2002). Retaining black students in engineering: do minority programs have a longitudinal impact? *Journal of College Retention, 3,* 351-364.

Guay, F., Marsh, H. W., & Boivin, M. (2003). Academic self-concept and academic achievement: Developmental perspectives on their causal ordering. *Journal of Educational Psychology, 95,* 124-136.

Hofer, B. K. (2000). Dimensionality and disciplinary differences in epistemology. *Contemporary Educational Psychology, 25,* 378-405.

Hofer, B. K., & Pintrich, P. R. (1997). The development of epistemological theories: Beliefs abut knowledge and knowing and their relation to learning. *Review of Educational Research, 67,* 88-140.

Jehng, J. J., Johnson, S. D., & Anderson, R. C. (1993). Schooling and students' epistemological beliefs about learning. *Contemporary Educational Psychology, 18*, 23-35.

Kardash, C. M., & Howell, K. L. (2000). Effects of epistemological beliefs and topic-specific beliefs on undergraduates' cognitive and strategic processing of dual-positional text. *Journal of Educational Psychology, 92*, 524-535. doi: 10.1037//0022-0663.92.3.524

Kim, M. M. (2002). Historically black vs. White institutions: Academic development among black students. *The Review of Higher Education, 25*, 385-407. doi: 10.1353/rhe.2002.0019

Kim, M. M., & Conrad, C. F. (2006). The impact of historically black colleges and universities on the academic success of African American students. *Research in Higher Education, 47*, 399-427. doi: 10-1007/s11162-005-9001-4

King, B. A., & Magun-Jackson, S. (2009). Epistemological beliefs of engineering students. *The Journal of Technology Studies, 35(2),* 56-64.

King, P. M., & Kitchener, K. S. (1994). *Developing reflective judgment: Understanding and promoting intellectual growth and critical thinking in adolescents and adults.* San Francisco: Jossey-Bass.

Lent, R.W., Sheu, H. B., Schmidt, J., Brenner B. R., Wilkins, G., Brown, S. D., Gloster, C. S., Schmidt, L. C., Lyons, H., & Treistman, D. (2005) Social cognitive predictors of academic interests and goals in engineering: Utility for women and students at historically black universities. *Journal of Counseling Psychology, 52,* 84-92. doi: 10.1037/0022-0167.52.1.84

Marra, R., & Palmer, B. (2004). Encouraging intellectual growth: Senior college student profiles. *Journal of Adult Development*, *11*, 111-122.

Marra, R. M., Palmer, B., & Litzinger, T. A. (2000). The effects of a first-year engineering design course on student intellectual development as measured by the Perry scheme. *Journal of Engineering Education, 89,* 39-46.

Marsh, H. W., Byrne, B. M., & Shavelson, R. J. (1988). A multifaceted academic self-concept: Its hierarchical structure and its relation to academic achievement. *Journal of Educational Psychology, 80*, 366-380. doi:10.1037/0022-0663.80.3.366

Muis, K. R. (2004). Personal epistemology and mathematics: A critical review and synthesis of research. *Review of Educational Research*, *74,* 317-377.

National Academy of Engineering (NAE). (2005). *Educating the engineer of 2020: Adapting engineering education to the new century*. Retrieved June 25, 2007, from http://books.nap.edu/catalog.php?record_id=11338#orgs

National Science Foundation (NSF). (1996, September). *Building diversity in the scientific workforce.* Report from the National Science Foundation Minority Postdoctoral Research Fellows and Mentors Annual Meeting. Arlington, VA: National Science Foundation. Retrieved June 23, 2010, from http://www.nsf.gov/pubs/1998/nsf9837/nsf9837.htm

National Science Foundation (NSF). (2006). *America's pressing challenge: Building a stronger foundation, a companion to science and engineering indicators.* Arlington, VA: National Science Foundation. Retrieved June 19, 2010, from http://www.nsf.gov/statistics/nsb0602/nsb0602.pdf

National Science Foundation (NSF). (2010). *Preparing the next generation of STEM innovators: Identifying and developing our nation's human capital.* (NSB-10-33). Retrieved October 19, 2010, from http://www.nsf.gov/news/news_summ.jsp?cntn_id=117713&WT.mc_id=USNSF_51&WT.mc_ev=click

Palmer, B., & Marra, R. M. (2004). College student epistemological perspectives across knowledge domains: A proposed grounded theory. *Higher Education, 47,* 311-335.

Pascarella, E. T., Edison, M., Nora, A. Hagedorn, L. S. & Terenzini, P. T. (1996). Additional evidence on the cognitive effects of college racial composition: A research note. *Journal of College Student Development, 37*, 494-501.

Pascarella, E.T., Smart, J., Ethington, C., & Nettles, M. (1987). The influence of college on self-concept: A consideration of race and gender differences. *American Educational Research Journal, 24*, 49-77.

Pascarella, E. T., & Terenzini, P. T. (1991). *How college affects students*. San Francisco: Jossey-Bass.

Paulsen, M. B., & Wells, C. T. (1998). Domain differences in the epistemological beliefs of college students. *Research in Higher Education*, *39,* 365-384.

Pavelich, M. J., & Moore, W. S. (1996). Measuring the effect of experiential education using the Perry model. *Journal of Engineering Education, 85*, 287-292.

Perna, L., Lundy-Wagner, V., Drezner, N. D., Gasman, M., Yoon, S., Bose, E., & Gary, S. (2009). The contribution of HBCUs to the preparation of African American women for STEM careers: A case study. *Research in Higher Education, 50,* 1-23. doi: 10.107/s11162-008-9110-y

Perry, W. G., Jr. (1970). *Forms of Intellectual and Ethical Development in College Years: A Scheme.* New York: Holt, Rinehart and Winston.

Perry, W. G., Jr. (1988). Cognitive and ethical growth: The making of meaning. In A. W. Chickering (Ed.), *The modern American college* (pp. 76-116). San Francisco, CA: Jossey-Bass Publishers.

Piaget, J. (1932). The moral judgment of the child. New York, NY: Harcourt, Brace Jovanovich.

Provasnik, S., & Shafer, L.L. (2004). *Historically black colleges and universities, 1976-2001* (NCES 2004-062). U.S. Department of Education, National Center for Education Statistics. Washington, DC: Government Printing Office.

Qian, G., & Alvermann, D. (1995). Role of epistemological beliefs and learned helplessness in secondary students' learning science concepts from text. *Journal of Educational Psychology, 87,* 282-292. doi:10.1037/0022-0663.87.2.282

The research agenda for the discipline of engineering education. (2006). *Journal of Engineering Education, 95,* 259-261.

Schoenfield, A. H. (1983). Beyond the purely cognitive: Belief systems, social cognition, and metacognitions as driving forces in intellectual performance. *Cognitive Science, 7,* 329-363.

Schoenfield, A. H. (1985). *Mathematical problem solving.* New York: Academic Press.

Schommer, M. (1990). Effects of beliefs about the nature of knowledge on comprehension. *Journal of Educational Psychology, 82*, 498-504.

Schommer, M. (1993a). Comparisons of beliefs about the nature of knowledge and learning among postsecondary students. *Research in Higher Education, 34,* 355-370.

Schommer, M. (1993b). Epistemological development and academic performance among secondary students. *Journal of Educational Psychology, 85*, 406-411. doi:10.1037/0022-0663.85.3.406

Schommer, M. (1997). The development of epistemological beliefs among secondary students: A longitudinal study. *Journal of Educational Psychology, 89,* 37-40.

Schommer, M. (1998). The influence of age and education on epistemological beliefs. *British Journal of Educational Psychology*, *68,* 551-562.

Schommer, M., Crouse A., & Rhodes, N. (1992). Epistemological beliefs and mathematical text comprehension: Believing it is simple does not make it so. *Journal of Educational Psychology, 84,* 435-443.

Schommer, M., & Dunnell, P. A. (1994). A comparison of epistemological beliefs between gifted and non-gifted high school students. *Roeper Review, 16*, 207-210.

Schommer, M., & Walker, K. (1995). Are epistemological beliefs similar across domains? *Journal of Educational Psychology, 87*, 424-432.

Schommer, M., & Walker, K. (1997). Epistemological beliefs and valuing school: Considerations for college admissions and retention. *Research in Higher Education, 38*, 173-186.

Schommer-Aikins, M. (2002). An evolving theoretical framework for an epistemological belief system. In B. K. Hofer & P. R. Pintrich (Eds.), *Personal epistemology: The psychology of beliefs about knowledge and knowing* (pp. 103-118). Mahwah, NJ: Erlbaum.

Schommer-Aikins, M. (2004). Explaining the epistemological belief system: Introducing the embedded systemic model and coordinated research approach. *Educational Psychologist, 39*, 19-29. doi:10.1207/s15326985ep3901_3

Schommer-Aikins, M., Duell, O. K., & Barker, S. (2002). Epistemological beliefs across domains using Biglan's classification of academic disciplines. *Research in Higher Education, 44,* 347-366.

Seifert, T. A., Drummond, J., & Pascarella, E. T. (2006). African-American students' experiences of good practices: A comparison of institutional type. *Journal of College Student Development, 47,* 185-205.

Solorzano, D.G. (1995). The doctorate production and baccalaureate origins of African Americans in the sciences and engineering. *Journal of Negro Education, 64,* 15-32. doi: 10.2307/2967281

Southern Education Foundation. (2005). *Igniting potential: Historically Black Colleges and Universities in science, technology, engineering, and mathematics*. Atlanta, GA: Southern Education Foundation.

Tabachnik, B. G., & Fidell, L. S. (2007). Using multivariate statistics (5^{th} ed.). Boston, MA: Pearson Education.

Trautwein, U., & Ludtke, O. (2007). Epistemological beliefs, school achievement, and college major: A large-scale longitudinal study on the impact of certainty beliefs. *Contemporary Educational Psychology, 32,* 348-366.

U.S. Department of Education. (2005). The mission continues: Annual report to the president on the results of participation of historically black colleges and universities in federal programs, 2002-03. Washington, DC: U.S. Department of Education. Retrieved on June 10, 2010, from http://ed.gov/about/inits/list/whhbcu/edlite-rptstudies.html

Vuyk, R. (1981). Piaget's genetic epistemology as an interdisciplinary science. In *Overview and Critique of Piaget's Genetic Epistemology 1965 - 1980* (pp. 21-36). New York, NY: Academic Press.

Webster, A. F. (2002). *Comparing racial identity attitudes in African American teacher education students at a predominantly White university and a historically black university* (Doctoral dissertation, University of Memphis, 2002). Dissertation Abstracts International, 63 (5-A), 1715.

Wise, J. C., Lee, S. H., Litzinger, T., Marra, R. M., & Palmer, B. (2004). A report on a four-year longitudinal study of intellectual development of engineering undergraduates. *Journal of Adult Development, 11,* 103-110.

Wood, P. K., & Kardash, C. A. (2002). Critical elements in the design and analysis of studies of epistemology. In B. K. Hofer & P. R. Pintrich (Eds.), *Personal epistemology: The psychology of beliefs about knowledge and knowing* (pp. 231-260). Mahwah, NJ: Erlbaum.

Woolfolk, A. (2007). Cognitive development and language. In *Educational Psychology* (pp. 21-35). Boston, MA: Pearson.

APPENDIX A
Questionnaire
Second Draft
By Marlene Schommer-Aikins

Directions: There are no right or wrong answers for the following questions. We want to know what you really believe. For each statement circle the number on the answer sheet for the degree to which you agree or disagree.

Strongly Disagree				Strongly Agree
1	2	3	4	5

1. If you are ever going to be able to understand something, it will make sense to you the first time you hear it.

2. The only thing that is certain is uncertainty itself.

3. For success in school, it's best not to ask too many questions.

4. A course in study skills would probably be valuable.

5. How much a person gets out of school mostly depends on the quality of the teacher.

6. You can believe almost everything you read

7. I often wonder how much my teachers really know.

8. The ability to learn is innate.

9. It is annoying to listen to a lecturer who cannot seem to make up his mind as to what he really believes.

10. Successful students understand things quickly.

11. A good teacher's job is to keep his students from wandering from the right track.

12. If scientists try hard enough, they can find the truth to almost anything.

13. People who challenge authority are over-confident.

14. I try my best to combine information across chapters or even across classes.

15. The most successful people have discovered how to improve their ability to learn.

Strongly Disagree				Strongly Agree
1	2	3	4	5

16. Things are simpler than most professors would have you believe.

17. The most important aspect of scientific work is precise measurement and careful work.

18. To me studying means getting the big ideas from the text, rather than details.

19. Educators should know by now which is the best method, lectures or small group discussions.

20. Please skip this number.

21. Going over and over a difficult textbook chapter usually won't help you understand it.

22. Scientists can ultimately get to the truth.

23. You never know what a book means unless you know the intent of the author.

24. The most important part of scientific work is original thinking.

25. If I find the time to re-read a textbook chapter, I get a lot more out of it the second time.

26. Students have a lot of control over how much they can get out of a textbook.

27. Genius is 10% ability and 90% hard work.

28. I find it refreshing to think about issues that authorities can't agree on.

29. Everyone needs to learn how to learn.

30. When you first encounter a difficult concept in a textbook, it's best to work it out on your own.

31. A sentence has little meaning unless you know the situation in which it is spoken.

32. Being a good student generally involves memorizing facts.

33. Wisdom is not knowing the answers, but knowing how to find the answers.

34. Most words have one clear meaning.

Strongly Disagree				Strongly Agree
1	2	3	4	5

35. Truth is unchanging.

36. If a person forgot details, and yet was able to come up with new ideas from a text, I would think they were bright.

37. Whenever I encounter a difficult problem in life, I consult with my parents.

38. Learning definitions word-for-word is often necessary to do well on tests.

39. When I study, I look for the specific facts.

40. If a person can't understand something within a short amount of time, they should keep on trying.

41. Sometimes you just have to accept answers from a teacher even though you don't understand them.

42. If professors would stick more to the facts and do less theorizing, one could get more out of college.

43. I don't like movies that don't have an ending.

44. Getting ahead takes a lot of work.

45. Choose ‘1’ for your answer.

46. It's a waste of time to work on problems which have no possibility of coming out with a clear-cut and unambiguous answer.

47. You should evaluate the accuracy of information in a textbook, if you are familiar with the topic.

48. Often, even advice from experts should be questioned.

49. Some people are born good learners, others are just stuck with limited ability.

50. Nothing is certain, but death and taxes.

51. The really smart students don't have to work hard to do well in school.

52. Working hard on a difficult problem for an extended period of time only pays off for really smart students.

Strongly Disagree				Strongly Agree
1	2	3	4	5

53. If a person tries too hard to understand a problem, they will most likely just end up being confused.

54. Almost all the information you can learn from a textbook you will get during the first reading.

55. Usually you can figure out difficult concepts if you eliminate all outside distractions and really concentrate.

56. A really good way to understand a textbook is to re-organize the information according to your own personal scheme.

57. Students who are "average" in school will remain "average" for the rest of their lives.

58. A tidy mind is an empty mind.

59. An expert is someone who has a special gift in some area.

60. I really appreciate instructors who organize their lectures meticulously and then stick to their plan.

61. The best thing about science courses is that most problems have only one right answer.

62. Learning is a slow process of building up knowledge.

63. Today's facts may be tomorrow's fiction.

64. Self-help books are not much help.

65. You will just get confused if you try to integrate new ideas in a textbook with knowledge you already have about a topic.

Now, complete Part B on the answer sheet.

APPENDIX B

Background Information Form

1. What is your gender? (Circle one)

   A. Male B. Female

2. What is your ethnicity/race? Please select only one of the following.

   A. African-American/Black
   B. Alaskan/Pacific Islander
   C. Asian-American
   D. European-American/White
   E. Hispanic
   F. Native-American
   G. Multi-ethnic/racial
   H. Other

3. Is your native language English? (Circle one)

   A. Yes B. No

4. What high school grade point average applies to you? (Circle one)

   A. 1.0-1.5
   B. 1.6-2.0
   C. 2.1-2.5
   D. 2.6-3.0
   E. 3.1-3.5
   F. 3.6-4.0
   G. Don't Know

5. SAT Verbal score: ________ SAT Math score: _________

   ACT English score: ____ ACT Math score: _____ ACT Reading score: _____ ACT Science score: _____

6. What college grade point average applies to you? (Circle one)

   A. 1.0-1.5
   B. 1.6-2.0
   C. 2.1-2.5
   D. 2.6-3.0
   E. 3.1-3.5
   F. 3.6-4.0
   G. Don't Know

7. What is your level of education? (Circle one)

A. Freshman D. Senior

B. Sophomore E. Graduate (Masters)

C. Junior F. Graduate (Ph.D.)

8. In what engineering discipline is your major? If you have not declared a major, what do you anticipate your major to be? (Circle one)

A. Civil D. Electrical G. Other

B. Biomedical E. Engineering Management

C. Chemical F. Mechanical

9. Including this semester, how many courses have you taken in engineering? (Circle one)

A. 0-2 B. 3-4 C. 5-6 D. 7 or more

APPENDIX C

Dear Student:

You are invited to participate in a study of engineering students' beliefs and views toward various topics. You were selected as a possible participant in this study because you are a student enrolled in an engineering degree program.

If you decide to participate, you will be asked to complete two questionnaires regarding your views. There are no right or wrong answers. What is most important is that you answer with what you believe to be true. I ask that you complete all of the questionnaires without discussing their subject matter with anyone. On the average, it should take participants about 30 minutes to complete the questionnaires; however, feel free to take as much time as you like.

Any information obtained in this study in which you can be identified will remain confidential. Furthermore, your decision whether or not to participate will not affect your future relations with your instructor or The University of Memphis/Christian Brothers University. If you decide to participate, you may withdraw from the study at any time without affecting your status as a student.

You are under no obligation to participate in the study. Your completing and returning these questionnaires will be taken as evidence of your willingness to participate and your consent to have the information used for purposes of the study.

Law copyrights the questionnaires used in this study. Please do not duplicate them without expressed permission from Dr. Marlene Schommer-Aikins. Whether you decide to participate in this study or not, I would appreciate it if you would return all materials to your instructor so that they may be recycled.

You may keep this cover letter and explanation about the nature of your participation in this study and the handling of the information you supply.

If you have any questions about this research, you may contact me at 901-321-3282 or at bking1@memphis.edu. If you have any questions about your rights as pertaining to this research, please contact the Chair of the Institutional Review Board for the Protection of Human Subjects at 901-678-2533.

Sincerely,

Bethany King Robinson
Doctoral Student of Educational Psychology

APPENDIX D

THE UNIVERSITY OF MEMPHIS

Institutional Review Board

To: Bethany K. Robinson
Counseling, Educational Psychology & Research

From: Chair, Institutional Review Board
for the Protection of Human Subjects
Administration 315

Subject: Epistemological Beliefs of Engineering Students (E09-44)

Approval Date: September 10, 2008

This is to notify you that the Institutional Review Board has designated the above referenced protocol as exempt from the full federal regulations. This project was reviewed in accordance with all applicable statutes and regulations as well as ethical principles.

When the project is finished or terminated, please complete the attached Notice of Completion and send to the Board in Administration 315.

Approval for this protocol does not expire. However, any change to the protocol must be reviewed and approved by the board prior to implementing the change.

Chair, Institutional Review Board
The University of Memphis

Dr. S. Magun-Jackson

APPENDIX E

Institutional Review Board (IRB)

Research with Human Participants

Proposal Cover Sheet To Be Completed By The Student

Title of Proposal: Epistemological Beliefs of Engineering Students

Name(s) of Researcher(s): Bethany King Robinson

Name(s) of Faculty Sponsor(s): Dr. Susan Magun-Jackson , The University of Memphis

Office Phone Number: ______

Office Number: ______

CBU Box Number: ______

Email Address: ______

Material Below This Line Is To Be Completed By The Committee

Date Submitted to IRB: 9/19/08______

Date Approved by IRB: ______

IRB#: 103

Dr. Conrad Brombach Chairman	9/19/08 Date	✓ Approved	___ Approved with Changes	___ Not Approved
	See attached from The University of Memphis IRB Committee			
Dr. Rena Durr	9/19/08 Date	✓ Approved	___ Approved with Changes	___ Not Approved
Dr. Paul Haught	9/22/08 Date	✓ Approved	___ Approved with Changes	___ Not Approved

Alternate Members

Dr. Maureen O'Brien	Date	___ Approved	___ Approved with Changes	___ Not Approved
Dr. Rod Vogl	Date	___ Approved	___ Approved with Changes	___ Not Approved
Dr. Beth Nelson	Date	___ Approved	___ Approved with Changes	___ Not Approved
Dr. Scott Geis	Date	___ Approved	___ Approved with Changes	___ Not Approved

APPENDIX F

9122291414

Research and Sponsored Programs
Tennessee State University
3500 John A. Merritt Blvd.
Nashville, Tennessee 37209-1561

Office of the Vice President

To: Bethany A. King
bethanyking@hotmail.com
Dr. Susan Magun-Jackson
smgnjcks@memphis.edu
Dept.: Engineering

From:
Dr. G. Pamela Burch-Sims, Chair, Institutional Review Board

Re: Protocol #HS2009-2398

Date: Tuesday, January 19, 2010

The document listed below has been carefully reviewed and found to be in compliance with OPRR document title 45, Code of Federal Regulations part 46, the protection of human subjects, as amended by Federal policy, effective August 19, 1991. This project is **approved** as it presents minimal or no research risks to the pool of impending human subjects. Please make note, that any deviations in the administration of the protocol, accidental or otherwise should be reported to the IRB as soon as possible. The FWA for Tennessee State University is #FWA00000309, which is effective from September 23, 2008 to September 23, 2011.

"Epistemological Beliefs of Engineering Students"

This approval is valid for one year from the date indicated above. Continuation of research beyond that date requires re-approval by the Institutional Review Board.

Please contact me at 963-5661 or e-mail irb@tnstate.edu for additional information.