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Epistemological Belief Congruency in Mathematics between Vocational Technology Students and Their Instructors

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Abstract

Three questions were addressed in this study. Is there evidence of epistemological beliefs congruency between students and their instructor? Do students' epistemological beliefs, students' epistemological congruence, or both predict mathematical anxiety? Do students' epistemological beliefs, students' epistemological congruence, or both predict mathematical performance? Over 200 vocational technology students and their instructors completed measures of beliefs about mathematical problems solving. The students also completed a measure of mathematical anxiety. Regressions indicated students' epistemological beliefs about time and understanding predicted mathematical anxiety, whereas both student mathematical epistemological beliefs about time and their congruency scores predicted mathematical performance. The implications of these is that mathematical instructors may need to explicitly teach their mathematical epistemology and provide students with classroom experiences to deepen their appreciation of these epistemological underpinnings.

Keywords: epistemological beliefs, epistemological congruency, mathematical beliefs, mathematical anxiety, vocational technology

1. Introduction

Beliefs about the nature of knowledge, epistemological beliefs, have been the focus of educational researchers for several decades. Beliefs such as knowledge is complex, knowledge in tentative, knowledge is useful, and knowledge acquisition is time-consuming have been linked to comprehension, metacomprehension, and valuing of schooling (Schommer & Walker, 1995). Although much research has investigated epistemological beliefs in general, the past two decades have seen researchers urging the investigation of domain specific beliefs (Buehl & Alexander, 2005). Furthermore, with rare exception (Fruge & Ropers-Huilman, 2008), the congruency of faculty and students' epistemological beliefs has not been explored. Fruge and Ropers-Huilman define epistemological congruency (EC) as "the degree of similarity between students' and faculty members' beliefs about learning" (p. 121). They maintain that it is particularly critical to study EC at community colleges because of the importance of academic integration at these institutions in terms of retaining students. Hofer (2004) emphasized that a component of effective teaching is for faculty to filter their perceptions of instructional practice through their epistemological assumptions. Similarly, Grubb (1999) conducted a study of teaching effectiveness in which more than 250 community college classrooms were observed and found that central to good teaching was "a common understanding of what education is and what should go on in the classroom" (p. 360). Fruge and Ropers-Huilman contend that community college students may not engage in out-of-class activities so their in-class experiences may be especially influential in their decision to persist and graduate. The purpose of this study is to determine if students' mathematical epistemological beliefs, per se and/or the congruence of their mathematical epistemological beliefs with their instructor's would predict their mathematical anxiety and mathematical performance.

Perry (1968) was among the first researchers to investigate epistemological beliefs. He interviewed Harvard undergraduates from freshmen to seniors. He found freshmen were likely to believe that knowledge is simple, certain, and handed down by authority. However, seniors were likely to believe the knowledge is highly interwoven, fairly tentative, and is derived from multiple sources, such as reason and empirical evidence.

For many years researchers (e.g., Baxter Magolda, 1992; Kitchener & King, 1981) followed Perry's lead by investigating epistemological beliefs in general, as opposed to studying epistemological beliefs in a specific academic discipline. For example, Kitchener and King (1981) examined students' beliefs about the justification of knowledge. Known as reflective judgment, they hypothesized a development pattern from believing that knowledge is justified by direct observation to believing knowledge comes from reason and empirical evidence.

Other researchers (Schommer, 1990) followed Perry in the sense that they looked at domain general epistemological beliefs. However, they moved away from Perry's developmental and unidimensional model to conceptualizing a system of more or less independent beliefs. It was theorized that the complexity of epistemological beliefs could not be captured with the assumption of a single dimension. Hence, five beliefs were initially hypothesized to include beliefs about knowledge (certainty, structure, and source) and beliefs about learning (speed and improvability). Furthermore, it was theorized that these beliefs may not necessarily develop in synchrony. The potential of asynchronous development made it even more important to study each belief in the system.

The multidimensional conception of epistemological beliefs has allowed researchers to uncover the unique effects of beliefs on specific aspects of learning and motivation. For example, the beliefs that knowledge is certain (unchanging) and that knowledge is simple (bits of unrelated facts) are linked to learners oversimplifying text summaries and drawing absolute conclusions from tentative text (Schommer, 1990). Belief that the ability to learn is fixed at birth is linked to learners displaying helplessness when faced with a difficult task (Dweck & Leggett, 1983). Belief that learning is quick or not-at-all is linked to learners' poor performance in reading and mathematics (Schoenfeld, 1983; Schommer, Crouse, & Rhodes, 1992).

The first several decades in the study of personal epistemology, epistemological beliefs were conceptualized and measured as if they were domain general (e.g., Perry, 1968; Kitchener & King, 1981). Domain generality was assumed more as a matter of convenience, rather than a conviction. In other words, for the pioneers in this field, it was necessary to work with some assumptions and let future researchers test those assumptions at a later date (Perry, 1968; Schommer & Walker, 1995).

Starting mid 1990s and beyond, researchers in educational psychology and human development began to test the assumption of domain generality (e.g., Hofer, 2000; Schommer & Walker, 1995). It seemed tenable that epistemological beliefs could vary by discipline especially when contrasting the hard sciences (e.g., science and mathematics) with the soft sciences (e.g., history and psychology). Overall, the results of a number of studies suggest that students' soft science epistemological beliefs may be more advanced than their hard science epistemological beliefs (Paulson & Wells, 1998; Schommer & Walker, 1995). However, the more classes students have in a particular discipline, the more advanced their beliefs are regardless of domain (Schommer & Walker, 1995). These findings have lead researchers to conclude that students have both domain general and domain specific beliefs. In the absence of domain specific knowledge, students are likely to rely on their domain general beliefs to guide their thinking (Hofer, 2000; Muis, Bendixen, & Haerle, 2006; Schommer-Aikins, 2004).

Meanwhile, researchers in mathematics education were conceptualizing mathematical epistemological beliefs as multidimensional in the 1980s. Schoenfeld (1983) conducted observations and interviews with high school students. His work uncovered beliefs that mathematic problems should be solved in less than a few minutes or the learner will never be able to solve them. Furthermore, only experts are privy to the understanding and generating of mathematical proofs due to their inherent giftedness.

Seeing a need to measure mathematical beliefs, Kloosterman and Stage (1992) developed a multidimensional scale to measure students' beliefs about mathematical problem solving. Among the beliefs measured were beliefs about time needed to understand mathematics, the conceptual nature of mathematics, the amount of effort needed to understand mathematics, and the usefulness of mathematics. Using this scale, researchers have found that these beliefs predict mathematical performance among high school students and college students (Schommer-Aikins & Duell, 2013; Schommer-Aikins, Duell, & Hutter, 2005).

Research has linked mathematical epistemological beliefs to specific concerns in mathematics education (Mtetwa & Garofalo, 1989). Believing that mathematics problems have only one answer is linked to learners' failure to search for multiple solutions. Believing that mathematics problems are solved by memorizing a step-by-step procedure rather than understanding deeper conceptual issues is linked to learners' failure to think creatively in the problem solving process. And the belief that learning is quick or not-at-all is linked to learners increase in mathematical anxiety as displayed with "no-attempt" responses (Chinn, 2012).

Domain specificity notwithstanding, the study of epistemological beliefs is critical in order to understand the complexity and subtlety of their effects. Educators may not be aware of these unspoken and sometimes unconscious beliefs because their effects are often intertwined with other variables and are likely to be mediated by more direct variables. For example, in a study with middle school children, researchers (Schommer-Aikins, Duell, & Hutter, 2005) found that beliefs in quick learning had indirect effects on grade point average. Specifically, belief in quick learning predicted poor reading performance and, subsequently, poor reading performance predicted lower grade point average.

More recently researchers (Schommer-Aikins & Duell, 2013) examined the direct and indirect effects of mathematical epistemological beliefs on college students' mathematical performance. Students completed the Kloosterman and Stage (1992) instrument. Then they were given measures of depth of processing mathematical text and answering mathematical story problems. Belief in the speed of learning mathematics had direct and, more importantly, indirect effects on students' mathematical performance. Specifically, belief that learning mathematics takes time directly affected students' depth of processing. Subsequently, students' depth of processing had a direct effect on mathematical performance.

In the study being reported, we test the effect of mathematical epistemological beliefs on both mathematical performance and a precursor variable, namely mathematical anxiety. The correlation between mathematical anxiety and various aspects of mathematical performance has been documented for decades. In a meta-analysis, Hembree (1990) found that high mathematical anxiety was correlated with low mathematical learning, mastery, and motivation. In 2008, the Final Report of the National Mathematics Advisory Panel (US Department of Education) recognized the relationship between math anxiety and performance, stating: "Anxiety about mathematics performance is related to low mathematics grades, failure to enroll in advanced mathematics courses, and poor scores on standardized tests of mathematics achievement" (p. 31). Also of concern is that mathematical anxiety has been found to correlate negatively with the likelihood of becoming involved in careers in science (Chipman, Krantz, & Silver, 1992).

Another complexity that has received little attention is the interplay of students' and their instructors' epistemological beliefs. To our knowledge, there is one study that has attempted to address the issue of epistemological belief congruency, which is defined as the degree of similarity between a student and his/her instructor's epistemological beliefs. Fruge and Ropers-Huilman (2008) cite the work of Tinto (1975, 1993) to provide the rationale for their investigation of epistemological congruency. Tinto has long claimed that students' retention is associated with their sense of academic and social connectedness to the institution. One specific phenomenon Tinto referred to was *incongruence*. Tinto defined incongruence as "a mismatch or lack of fit between the needs, interests, and preferences of the individual and the institution" (Tinto, 1993, p. 50). Fruge and Ropers-Huilman hypothesized that a critical point for congruency lies in the epistemological beliefs of instructors and students.

In a first attempt to study this issue Fruge and Ropers-Huilman (2008) assessed five domain general epistemological beliefs of community college students and their instructors. These beliefs included certain knowledge, simple knowledge, omniscient authority, quick learning, and fixed ability. Epistemological Congruency Scores were calculated by subtracting the students' scores from their corresponding instructor's scores. Students with high congruence and low incongruence were interviewed. Students with high epistemological congruence tended to accept any academic difficulties as their own responsibility and saw value in any additional assignments given in class. Students with low epistemological congruence found course work exceptionally challenging. They thought that if questions were based on more concrete scenarios they may perform better on exams. They would find themselves asking, "What does this have to do with anything?" (Fruge & Ropers-Huilman, 2008, p.125).

It is important that researchers continue to investigate the potential effects of epistemological belief congruency, since epistemological belief incongruency could lead to students' misunderstandings, poor performance, and increased dropout rate. Further, teachers may be hampered in teaching their students how to think and learn about mathematics by certain constraints, such as assessment and accountability demands of the larger society. When responding to these realities, there may be little opportunity for faculty to teach students how to think about mathematics (Hofer & Pintrich, 1997). It is particularly important to study epistemological congruency if it is an underlying factor in how effectively students learn mathematics and in their persistence in post-secondary education.

The study being reported addressed three overarching questions. Is there evidence of epistemological beliefs congruency or incongruency; specifically, do students' mathematical epistemological beliefs differ from their instructors'? When competing for prediction, do students' epistemological beliefs, students' epistemological congruence, or both predict mathematical anxiety? When competing for prediction, do students' epistemological beliefs, students' epistemological congruence, or both predict mathematical performance?

The study being reported follows the Fruge and Hulium's (2008) research with several new features. First, the participants were students from a vocational technology school. The study of epistemological beliefs among vocational technology school is scant. For example, Brownlee and her colleagues (Brownlee, Berthelsen, Dunbar, Boulton-Lewis, & McGahey, 2008) found the epistemological beliefs of students studying child care at a technology institute predicted their expectations of children's learning, the role of experts in the process of learning, and the nature of truth. Second, we examined domain specific epistemological beliefs, i.e., mathematical beliefs. This allowed students and instructors to focus their responses on a specific academic domain. Third, we examined the link between epistemological beliefs and epistemological congruency to an emotional response (mathematical anxiety) and to a measure of actual classroom performance.

2. Method

2.1 Participants

Two hundred and thirty-four vocational technology students participated in this study. The majority of students were Euro-American: Euro-American (*n* = 126); African American (*n* = 47); Latino/a (*n* = 21); Native American (*n* = 8); Asian American (*n* = 4), and the remainder reported "other" or chose not to report anything. English was the first language for the majority of students (*n* = 211). The majority of students were female: women (*n* = 136), men (*n* = 90), and no response (*n* = 8). Average age for students at this institution was between 25 - 29 years old. Students were enrolled in algebra courses ranging from pre-algebra to college algebra. Students were offered extra credit for their participation. Thirteen algebra instructors participated in the study. Seven instructors were male. The majority of instructors were Euro-American (*n* = 10); Latino/a (*n* = 1); Other (*n* = 1); No Response (*n* = 1).

2.2 Instruments

Mathematical epistemological beliefs were assessed using the Indiana Mathematics Belief Scale (Kloosterman & Stage, 1992) and the Usefulness of Mathematics Scale (Fennema & Sherman, 1976). These scales were developed for high school and college students. The development of these instruments is described in Kloosterman and Stage (1992). Their four scales with Cronbach alphas of .70 or higher that were used in this study. The scale titles and a sample item include: (a) I can solve time-consuming mathematic problems (TIME), e.g, "Math problems that take a long time don't bother me."; (b) understanding mathematical concepts is important (UNDERSTAND), e.g., "A person who doesn't understand why an answer to a math problem is correct hasn't really solved the problem."; (c) solving math problems takes effort (EFFORT), e.g., "By trying hard, one can become smarter in math."; and (d) mathematics is useful in daily life (USEFUL), e.g, "I study mathematics because I know how useful it is." Students responded to a 5-point scale from 1 (strongly disagree) to 5 (strongly agree). Kloosterman and Stage (1992) reported Cronbach alphas from .76 to .84 for these scales.

Mathematical epistemological congruency scores were calculated by subtracting students' scores from their corresponding instructors' scores. A positive score would indicate that the instructors hold a stronger belief that supports higher order thinking in mathematics.

Mathematical anxiety was measured with an instrument developed by Hopko, Mahadevan, Bare, and Hunt (2003). They constructed the Abbreviated Math Anxiety Scale (AMAS) using college undergraduates. The AMAS contains nine items which assess both anxiety about learning mathematics (e.g., "Starting a new chapter in a math book") and evaluation anxiety ("Taking an examination in a math course"). Students responded on a 6 point scale from 1 (Never Anxious) to 6 (Always Anxious). Cronbach alphas for this study were .84 for the learning math scale and .88 for the evaluation anxiety scale. Both convergent and divergent validity was established by Hopko, Mahadevan, Bare, and Hunt (2003).

The total number of high school mathematic classes taken served as a measure of prior knowledge. The final exam grade reported in percentages and the course grade reported in percentages for their algebra class served as measures of mathematical performance. The final exam was standardized across all sections of the mathematics courses. Ninety-four students granted us permission to use their scores in anonymous analyses.

2.3 Procedure

Survey booklets were compiled to assess mathematical epistemological beliefs and mathematical anxiety. The surveys were handed out the second week of classes by the course instructors. Participants completed the measures at home and returned the surveys over the following two weeks. The order of the surveys was counter balanced to avoid any order effect.

3. Results

Descriptive statistics and inter-item reliabilities were calculated for each measure. These data are shown in Table 1. Cronbach alphas were all at acceptable levels ranging from .73 to .89. Zero order correlations among all major variables are shown in Table 2 and Table 3. The average number of high school mathematic courses take was 2.65 (*SD* = 1.45 and range from 0 to 12). Course grades and final exam grades were available for 94 students. The average course grade for these students was 84.46% (*SD* = 11.09 and range from 54 to 95.50). The average final exam grade was 68.03% (SD = 18.61 and range from 8.00 to 100). Analyses of Variances (ANOVAs) were conducted to determine if there were significant differences in major variables between the different algebra classes. No significant differences between course sections were found for course grade, mathematical epistemological beliefs, or anxiety.

Table 1. Descriptive Statistics for Overall Student Scores

Epistemological and Anxiety Variables	Mean	*SD*	Cronbach Alpha
Time	25.59	5.53	.82
Understand	29.11	4.41	.73
Useful	28.59	5.99	.87
Effort	29.16	5.09	.87
Amas	26.22	9.31	.89

Table 2. Zero-Order Correlations Among Major Student Variables

	TIME	UNDERSTAND	USEFUL	EFFORT	AMAS	EXAM	COURSE
UNDERSTAND	.51						
USEFUL	.61	.59					
EFFORT	.44	.42	.53				
AMAS	-.46	-.10	-.21	-.20			
EXAM	.17	.11	.13	.04	-.16		
COURSE	.22	.15	.07	-.12	-.21	.74	

Note. Correlations of .21 or higher are significant at the .05 level.

Table 3. Zero-Order Correlations Among Major Congruency Variables

	CTIME	CCONCEPT	CUSEFUL	CEFFORT	AMAS	EXAM	COURSE
CCONCEPT	.48						
CUSEFUL	.59	.52					
CEFFORT	.33	.07	.43				
AMAS	-.40	-.05	.21	.14			
EXAM	-.28	-.33	-.18	.02	-.16		
COURSE	-.28	-.30	-.09	.10	-.21	.74	

Note. Correlations of .21 or higher are significant at the .05 level.

To address the question: Do students' mathematical epistemological beliefs differ from their instructor's?, two-way ANOVAs were conducted. Status (student versus their own instructor) and Gender served as independent variables. Each mathematical epistemological belief served as the criterion variable in subsequent analyses. Table 4 shows the descriptive statistics for these analyses.

Table 4. Instructors' and Students' Mathematical Epistemological Beliefs Means and (Standard Deviations)

Epistemological Belief	Instructors		Students	
	Male	Female	Male	Female
TIME[1,]	32.90 (1.87)	32.55 (2.13)	24.26 (5.48)	26.18 (5.46)
UNDERSTAND[1]	28.44 (3.88)	28.43 (3.67)	27.90 (4.35)	29.61 (4.29)
USEFUL	34.46 (0.81)	34.65 (0.99)	27.35 (6.07)	29.33 (5.77)
EFFORT	33.22 (3.83)	32.29 (4.29)	28.82 (5.21)	29.22 (5.21)

[1]Significant main effect for Status (Instructors versus Students)

There was a significant main effect of Status for TIME: $F(1, 234) = 18.01$, $p < .001$, $\eta^2 = .07$. Instructors had higher scores than students. There was a significant main effect of Status for USEFUL: F $(1, 234) = 13.20$, $p < .001$, $\eta^2 = .05$. Instructors had higher scores than students.

To address the question: Do students' mathematical epistemological beliefs, students' mathematical epistemological congruence, or both predict mathematical anxiety?, a multi-level step-wise regression was conducted. AMAS scores served as the criterion variable. In the first stage, six student level predictor variables competed for entry, including prior knowledge, gender, TIME, USEFUL, UNDERSTAND, EFFORT. In the second stage, four course level variables competed for entry to explain the remaining variance, including TIMECONG, USEFULCONG, UNDERSTANDCONG, and EFFORTCONG. At each step of the analyses, the predictor accounting for the most variance entered. Only variables that were significant at the .05 level or better were allowed to enter the equation.

Three variables predicted AMAS scores, TIME, prior knowledge, and UNDERSTAND. TIME accounted for 21% of the variance: $F(1, 183) = 49.74$, $p < .001$, $R^2 = .21$, $b = -.78$. Prior knowledge accounted for an additional 8% of the variance: $F(1, 182) = 21.05$, $p < .001$, $R^2 = .08$, $b = -1.96$. UNDERSTAND accounted for an additional 2% of the variance: $F(1, 181) = 5.74$, $p < .02$, $R^2 = .02$, $b = .37$. The more students believed that they could complete time-consuming mathematical problems and the more classes they had in mathematics, the less anxiety they experienced. The more they believed that mathematics requires understanding, the more anxiety they experienced. Variance Inflation Factors were all lower than 1.5 and condition indices were are lower than 11 suggesting that multicollinearity was not a concern in this analysis.

To address the question: Do students' mathematical epistemological beliefs, students' mathematical epistemological congruence, or both predict mathematical performance?, two multi-level step-wise regressions were conducted with final exam grade and course grade serving as criterion variables in each subsequent analysis.

Two variables, TIME and TIMECONG predicted final exam grade. However, an analysis of VIF indicated the possible concern of collinearity in the model. To address this concern TIMECONG was regressed on TIME. This regression equation was used to create an unstandardized residual TIMECONGRESID by subtracting each individual's predicted TIMECONG score from their observed TIMECONG score to remove the variance associated with TIME. A multi-level step-wise regression was conducted with final exam grade serving as the criterion variable. In the first stage, six student level predictor variables competed for entry, including prior knowledge, gender, TIME, USEFUL, UNDERSTAND, EFFORT. In the second stage, four course level variables competed for entry to explain the remaining variance, including TIMECONGRESIDE, USEFULCONG, UNDERSTANDCONG, and EFFORTCONG. TIME accounted for 4% of the variance: $F(1, 89) = 7.90$, $p < .05$, $R^2 = .04$, $b = -.89$. The unstandardized residualized variable TIMECONGRESID accounted for an additional 13% of the variance: $F(1, 88) = 14.20$, $p < .001$, $R^2 = .13$, $b = -3.87$. The more students believe that they can complete time-consuming mathematical problems, the higher their final exam grade. The greater the difference between instructor and student in their beliefs about time to complete mathematical problems, the more poorly students performed on the final exam. In addition, the congruence in the instructor and the student about time to complete mathematical problems accounted for significant variance in final exam scores after the students beliefs were removed from the congruence scores. Following the residualization of TIMECONG, Variance Inflation Factors were all lower than 1.1, and condition indices were are lower than 9.5 suggesting that collinearity is no longer a concern in this analysis.

Two variables predicted course grades, TIME accounted for 8% of the variance: $F(1, 89) = 8.11$, $p < .05$, $R^2 = .08$, $b = .61$. UNDERSTANDCONG accounted for an additional 7% of the variance: $F(1, 88) = 7.519$, $p < .01$, $R^2 = .07$, $b = -.63$. The greater the difference between instructor and student in their beliefs about mathematical time-consuming, the more poorly students performed in the course overall. The more students beliefs were incongruent with their instructor that understanding mathematical problems is critical, the more poorly they performed in the course overall. Variance Inflation Factors were all lower than 1.2, and condition indices were are lower than 20 suggesting that multicollinearity is not a concern in this analysis.

4. Discussion

These results give new insights into the links between mathematical epistemological beliefs on student anxiety and student performance. The analyses revealed differences between the students' beliefs compared to the beliefs of their instructors. And the lack of congruency predicted lower mathematical performance.

Instructors held significantly stronger beliefs compared to their students in two out of the four mathematical epistemological beliefs that were measured. Instructors had stronger beliefs that mathematics problem solving takes time and is useful in the future. The finding that instructors held strong beliefs affirms the assumption of epistemological belief research, that these beliefs are deemed appropriate for higher level learning. The fact that students were significantly lower that instructors in their beliefs about mathematics problem solving can take time and is useful suggests that overall students come to the post-secondary classes with some doubt that problems that take less than a few minutes can be solved. And, at least for themselves, taking mathematic classes will not benefit them in the future. These beliefs can potentially, at the least, lead students to avoid investing time to solve problems and, at the most, lead students to avoid mathematic classes

The distinction between the students' own beliefs versus the congruency of their beliefs with those of their instructors had different effects. Students' own mathematical epistemological beliefs and prior knowledge predicted mathematical anxiety. The belief that they can solve time-consuming mathematical problems predicted less mathematical anxiety. Indeed, in Schoenfeld's (1983) work revealed that many high school students felt that if they did not solve a problem within a few minutes, then they were never going to be able to solve it. Hence, one interpretation of this finding is that when students believe not all problems are solved within a few minutes, that they will not become frustrated and anxious if they do not solve problems quickly. Rather they will view this as a normal pattern of learning.

In addition, the more students believed the understanding problem solving was a part of the problem solving process, the more anxiety they experienced. One interpretation of this is that for these students, understanding may have seemed onerous. Thinking that understanding is a part of the process suggests that mindlessly following a step-by-step process will not necessary lead to success. Hence, more mental engagement is needed. Future researchers might consider the relationship between need for cognition, belief in mathematical understanding, and mathematical anxiety.

Both students' own mathematical epistemological belief and their congruency with their instructor served as predictors of mathematical performance. When the final exam served as the dependent variable, the congruency of belief that mathematical problem solving can be time-consuming in nature accounted for the most variance in predicting performance. The greater the difference between student and instructor, the worse students performed on the final exam. In addition, a smaller percentage of variance was accounted for in students' own beliefs in time-consuming problem solving.

When the course grade served as the dependent variable, the congruency of the belief in the value of understanding mathematical problems and students' own beliefs in time-consuming problem solving accounted for similar amounts of variance. The greater the difference between student and instructor and the less that students believed in time-consuming problem solving, the worse they performed in the course.

Overall, students' own epistemological beliefs predict anxiety. The fact that anxiety did not relate to lack of congruency with their instructors may reflect the notion that post-secondary students come to their class predisposed to a certain level of anxiety. Jackson and Leffingwell (1999) found that mathematical anxiety is generally formed after a negative experience with the content, an instructor, or both. Other factors may include limited experiences with mathematics, the modeling of discomfort with mathematics by others, lack of exposure to everyday applications, poor textbooks, and generalized test anxiety (Furner & Berman, 2003). These events could easily occur in grade school or high school. And these events may instill mathematical epistemological beliefs that increase anxiety.

Overall, both students' own mathematical epistemological beliefs and their congruency with their instructors predicted mathematical performance. These findings are consistent with previous research findings (Schoenfeld, 1983; Schommer, Crouse, & Rhodes, 1992; Schommer-Aikins & Duell, 2013; Schommer-Aikins, Duell, & Hutter, 2005) and continue to build the evidence that students' own beliefs about the nature of knowledge and knowing play critical roles in the learning process.

More importantly, these findings suggest that is it critical that instructors reveal their epistemological underpinnings in instruction. It is possible that instructors assume that post-secondary students already have a basic level of epistemological belief for mathematics. Or instructors may think that teaching the facts and theories are the main objectives of the course. Or in this assessment-driven academic climate, instructors may teach in such a way that the inadvertently communicate mathematical epistemological beliefs that do not intend. However, along with motivation and background knowledge, it appears that incongruent epistemological beliefs can be a roadblock to meeting the course objectives. Although it may seem self-evident, instructors may need to explicitly teach their adult vocational technology students that mathematics takes time, is conceptual, and is useful.

Another possible implication is the instructors need to do more than merely "say" their beliefs. Students may need to experience time-consuming problems that require deep understanding. Instructors can consider explicitly revealing the goal of such an activity and provide practice in a "safe" environment, such as students working in pairs or small groups on challenging problems that may take several days to understand and solve. Indeed, groups can share alternative solutions to the same problem and discuss why different solutions are appropriate. Such activities along with explicit discussions with the instructor are likely to enhance beliefs the problem solving require time and understanding beyond simple step-by-step processes.

This research provides evidence of the generalizability of the importance of epistemological beliefs. The majority of research on epistemological beliefs has focused on students in college, high school, and middle school. These results suggest that epistemological beliefs are relevant for vocational technology students as well. This demonstrates the pervasive influence of epistemological beliefs which are often unconscious yet serve as a guide to default habits of learning and thinking.

As is true of all studies, this work has limitations. Only one vocational technology institution participated in this study. Only a subset of the sample completed the anxiety ratio measure. Only students enrolled in algebra classes participated in this study.

Future research can address these issues and more. The theory of epistemological belief research would benefit from having participants from multiple institutions and a wide range of majors. Studies testing the effectiveness of explicitly teaching mathematical epistemological beliefs could reveal potential causal relationships between epistemological beliefs and mathematical anxiety and mathematical performance.

Future research can test the practical implications: intervention studies that incorporate epistemological components may be beneficial for both improving mathematical performance and increasing retention in mathematics courses. Ramirez and Beilock (2011) found that brief expressive writing assignments just before completing high stakes mathematics exams improved performance on the exam. Future research should study interventions that incorporate short expressive writing assignments with an epistemological focus throughout the course to determine the effect these interventions have on mathematical epistemological beliefs, anxiety, and course performance.

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