Epistemological Beliefs, Mathematical Problem-Solving Beliefs, and Academic Performance of Middle School Students

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Abstract

This study examined the structure of middle school students' general epistemological beliefs and domain-specific mathematical problem-solving beliefs by asking whether the 2 belief systems are related and whether they predict students' academic performance. Over 1,200 seventh- and eighth-grade students completed an Epistemological Questionnaire, the Indiana Mathematical Belief Scale, and the Fennema-Sherman Usefulness Scale. Based on regression analyses, beliefs in quick/fixed learning (i.e., that learning is fast and instinctual) and studying aimlessly (i.e., studying without strategy) were significantly related to beliefs about effortful math, useful math, understand math concepts, and math confidence. Furthermore, path analysis suggested that both general and domain-specific epistemological beliefs predicted academic performance as measured by solving mathematic problems and overall grade point average.

Beliefs about the nature of knowledge and learning, or epistemological beliefs, have been linked to numerous aspects of academic learning, particularly among college and high school students. For example, the more college students believe that knowledge is simple, the less likely they are to comprehend academic text, monitor their comprehension, and use sophisticated study strategies (Schommer, 1990; Schommer, Crouse, & Rhodes, 1992; Schraw, Dunkle, & Bendixen, 1995). The more high school students believe in quick learning, the more likely they are to earn a low grade point average (Schommer, Calvert, Gariglietti, & Bajaj, 1997). And the more high school students believe in the innate ability to learn, the more likely they are to devalue education (Schommer & Walker, 1997). There is little doubt

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that epistemological beliefs are critical factors to be considered among older students. What are students' epistemological beliefs before high school? And do epistemological beliefs of younger students relate to other aspects of students' cognition? The research reported in this article extends inquiry in this area by identifying middle school students' epistemological beliefs and examining the relations between these beliefs and beliefs about mathematical problem solving.

Most studies of epistemological beliefs have involved older students. For example, in the mid-1950s, Perry (1968) interviewed and surveyed college undergraduates. He concluded that undergraduates enter college believing that knowledge is simple, certain, and handed down by authority. By the time they reach their senior year, many students believe that knowledge is complex, tentative, and derived through reason and empirical evidence.

Many of Perry's followers studied personal epistemology by focusing on a single dimension. For example, Kitchener and King (1981, 1989) studied how students justify knowledge. Their epistemological model, called the Reflective Judgment Model, describes a seven-stage developmental path. Early in development, students believe that reality is concrete and knowledge is absolute. Seeing is believing, and there is little need for justification. Midway through this developmental path, students believe there is a different reality for everyone, and one person's opinion is as good as another's. In the final stages of development, students acknowledge a tentativeness in knowledge, yet they also realize that not all knowledge is of equal credibility. Reason and evidence can help discern the quality of knowledge.

Other researchers have investigated epistemological beliefs independently from Perry's work. For example, Dweck and her colleagues (Dweck & Bempechat, 1983; Dweck & Leggett, 1988) studied young children's beliefs about intelligence. Dweck's theory suggested that some children believe that the ability to learn is fixed at birth and that the purpose of an academic task is simply to document their intelligence. When faced with a difficult task, these children tend to display helpless behavior. In contrast, other children believe that the ability to learn is improvable over time and with experience and that the purpose of an academic task is to improve their intelligence. When faced with a difficult task, these children tend to try different strategies and persist in their efforts to learn.

Schoenfeld (1983, 1985) has also studied epistemological beliefs independently of Perry's work. Through observations and interviews with high school students as they were solving mathematical problems, Schoenfeld concluded that part of the problem-solving process is influenced by students' beliefs about the nature of mathematical knowledge and learning. For example, he observed that students who did not engage in successful problem solving appeared to believe that mathematics problems should be solved in 10 minutes or less, that mathematicians are gifted individuals, and that as students they must rely on mathematicians to give them basic formulas and proofs.

Schommer (1990) proposed a reconceptualization of epistemological beliefs that synthesized much of the earlier research on personal epistemology. She suggested that epistemological beliefs be conceived as a system of more or less independent beliefs. By system she meant that more than one belief composed personal epistemology. By more or less independent, she meant that these beliefs could, but not necessarily would, develop in synchrony. Originally, Schommer hypothesized five beliefs, including beliefs about the structure of knowledge (ranging from isolated bits to integrated concepts), the stability of knowledge (ranging from certain to evolving), the source of knowledge (ranging from handed down by authority to derived from reason and evidence), the speed of learning (from quick or not at all to gradual), and the ability to learn (ranging from fixed at birth to improvable).

Schommer (1990) constructed a questionnaire that assesses four of these hypothesized beliefs: structure of knowledge, stability of knowledge, speed of learning, and ability to learn. This factor structure was replicated with other college students and with high school students (Schommer, 1993; Schommer et al., 1992, 1997). Other researchers have uncovered related multidimensional structures using different epistemological belief instruments (Buehl, Alexander, & Murphy, 2002; Hofer, 2000; Schraw, Bendixen, & Dunkle, 2002; Wood & Kardash, 2002).

Since 1990, research has shown that epistemological beliefs predict numerous aspects of academic performance among high school and college students. For example, beliefs in the structure and certainty of knowledge predict comprehension, metacomprehension, and interpretation of information among college students (Jehng, Johnson, & Anderson, 1993; Kardash & Scholes, 1996; Schommer, 1990; Schommer et al., 1992; Schraw et al., 1995). Beliefs about the speed of learning and the ability to learn predict comprehension, valuing of education, and overall grade point average for college and high school students (Schommer, 1990; Schommer et al., 1997; Schommer & Walker, 1997).

Because the majority of epistemological research has been carried out with older students, the research reported in this article focused on the personal epistemology of middle school students. We emphasize the contemporary notion of an epistemological belief *system*. As in the studies of older students and adults, we sought to identify the structure of middle school students' epistemological beliefs. Just as importantly, we wanted to determine if students' epistemological beliefs could predict other aspects of their cognition.

The study of epistemological beliefs has practical importance based on the premise that these beliefs play a role in other aspects of cognition, affect, and ultimately academic performance (Schommer-Aikins, 2002). Hence, to demonstrate the utility of epistemological beliefs among middle school children, it is important to show the link between epistemological beliefs and an outward manifestation of them. The challenge of this inquiry is that epistemological beliefs' powerful influence is likely hidden because many of their effects are indirect rather than direct (Schommer, 1994, 1998; Winne, Graham, & Prock, 1993). For example, epistemological beliefs (e.g., that knowledge structure equals isolated facts) may lead to an internal standard (e.g., learning completed equals ability to repeat facts), which leads to choice of study strategy (e.g., mindless repetition), which leads to what the instructor ultimately sees (an ability to repeat knowledge but an inability to understand or apply the knowledge). Support has been found for the idea that general epistemological beliefs about the speed and effort of learning relate to strategy use while reading text aloud (Kardash & Howell, 2000). Kardash and Howell's hypothesis tested in our study is that general epistemological beliefs affect students' domain-specific mathematical beliefs, which in turn influence students' mathematical ability.

Recently, De Corte and his colleagues (De Corte, & Op't Eynde, 2003; De Corte, Op't Eynde, & Verschaffel, 2002; Op't Eynde & De Corte, 2003) have urged those studying students' mathematical beliefs and performance to take a more systemic approach to their investigations. They noted that mathematics is part of a more complete system of classroom context, beliefs about self, and beliefs about the nature of mathematics. Another intriguing idea posed by De Corte et al. (2002, p. 306) is that "if epistemological beliefs, i.e., beliefs about the nature of knowledge and the processes of knowing, are essentially very fundamental and general in nature (Hofer & Pintrich, 1997), then mathematics-related beliefs may not be considered as epistemological beliefs as such, but rather be perceived as domain-specific manifestations of the general epistemological beliefs."

This statement is not without controversy. The existence of general and domain-specific epistemological beliefs is open to question. A more recent stance is that the issue of domain specificity/generality is not either/or (Buehl et al., 2002; Hofer, 2000; Schommer, 1994; Schommer-Aikins, 2002). Rather, the issue is how these different belief systems interact or whether they are systems within a system.

In the present study we examined epistemological beliefs in relation to other aspects of cognition and academic performance in order to provide a systemic framework of inquiry. Specifically, we examined the relation between students' general epistemological beliefs and their domain-specific beliefs about mathematical problem solving.

To understand mathematical problem solving, Kloosterman and Stage (1992) developed an instrument to assess beliefs about mathematical problem solving, the Indiana Mathematics Scale. The idea behind their work is that beliefs about problem solving are likely to influence willingness to engage in problem solving as well as the choice of strategies to use during the problem-solving process. Influenced by earlier researchers, Kloosterman and Stage identified six beliefs about mathematical problem solving that they believe are critical to the learner's motivation and strategy use. Five beliefs are assessed by their Indiana Mathematics Scale, which includes beliefs that mathematical problem solving (*a*) is time-consuming, (*b*) requires understanding, (*c*) involves more than step-by-step procedures, (*d*) involves word problems (not just calculations), and (*e*) can be improved with effort. They also field tested Fennema and Sherman's (1976) Mathematics Is Useful Scale, which assesses the degree to which students believe that mathematics is useful in their daily lives. In addition to generating psychometric properties for these instruments for use with high school and college students, they found that scores on the scales were related to mathematical performance and to success in college remedial mathematics classes.

In the study reported here we tested the hypothesis that general epistemological beliefs are linked to the mathematical problem-solving beliefs. Furthermore, links between these two systems of beliefs and students' reading, mathematical problem solving, and overall grade point average were examined.

We conducted analyses in several stages to examine the interrelations among these variables. First, historically, epistemological beliefs have been considered developmental in nature (Kitchener & King, 1989; Perry, 1968). That is, students' sophistication increased with age and experience. Whether the structure of students' beliefs is also developmental is unknown. Therefore, exploratory factor analysis was conducted on both the epistemological and mathematical beliefs measures to explore the number and nature of students' beliefs. Next, to examine the relations among epistemological beliefs, mathematical problem-solving beliefs, and academic performance, we calculated a series of regressions among all variables. Finally, to examine a potential causal chain of events, from epistemological beliefs in general, to mathematical problem-solving beliefs, and ultimately to academic performance, we conducted a path analysis.

Method

Participants

A total of 1,269 students from two middle schools in the Midwest participated in the study. Students were approximately equal in representation by gender (boys, $n = 587$; girls, $n = 657$; not reported, $n = 25$) and grade (7th, $n = 619$; 8th, $n = 644$; not reported, $n = 6$). Students were predominately white (86% European American, 5% African American, 5% Hispanic American, 3% Asian American, 3% Native American) and middle class (23% receiving free or reduced-price lunch).

Measures

Epistemological beliefs. A middle school version of an epistemological belief questionnaire (EB) was constructed using high school and college versions of an epistemological belief instrument (Schommer, 1990, 1993, 1998) as a guide. These original 63-item instruments assessed four epistemological belief factors including beliefs about (*a*) the structure of knowledge (ranging from isolated pieces to integrated concepts), (*b*) stability of knowledge (ranging from certain knowledge to changing knowledge), (*c*) speed of learning (ranging from quick learning to gradual learning), and (*d*) ability to learn (ranging from fixed at birth to improvable). Cronbachs alphas range from .63 to .85 for the college version and from .51 to .81 for the high school version (Duell & Schommer-Aikins, 2001). Validity is evidenced in the instruments' prediction of students' comprehension, metacomprehension, interpretation of information, and valuing of education (Kardash & Scholes, 1996; Schommer, 1990; Schommer et al., 1992; Schommer & Walker, 1997). The EB scale was revised to have fewer items and, if necessary, simpler expression of ideas to be more appropriate for middle school students. Details of EB scale development can be found in Schommer-Aikins, Mau, Brookhart, and Hutter (2000).

The middle school EB scale contains 30 items. Students respond on a Likert scale from 1 (strongly disagree) to 5 (strongly agree). Statements were written to assess students' beliefs about knowledge and learning (e.g., "If I can't understand something right away, I will keep on trying"). Items were written so that a less epistemologically developed individual would agree with about half the items and disagree with the remaining items. The order of items was randomized. About half of the items were reverse scored so that the higher the score, the less epistemologically developed the respondent.

Mathematical problem-solving beliefs. Students' beliefs about mathematical problem solving were assessed using the Indiana Mathematics Belief Scale (Kloosterman & Stage, 1992) and the Usefulness of Mathematics Scale (Fennema & Sherman, 1976), both developed for high school and college students. The original Indiana Mathematics Belief Scale measured five beliefs about mathematical problem solving: (*a*) I can solve time-consuming mathematics problems; (*b*) There are word problems that cannot be solved with simple, step-by-step procedures; (*c*) Understanding concepts is important in mathematics; (*d*) Word problems are important in mathematics; and (*e*) Effort can increase mathematical ability. The Usefulness of Mathematics Scale assesses the belief that mathematics is useful in daily life. Cronbach's alphas for these scales range from .54 to .84. Validity is evidenced in the instruments' prediction of students' mathematics scores and success in remedial college mathematics (Stage & Kloosterman, 1995).

The Indiana Mathematics Belief Scale contains 30 items, and the Usefulness of Mathematics Scale contains six items. Students respond on a Likert scale from 1 (strongly disagree) to 5 (strongly agree). Statements assess students' beliefs about mathematical problem solving (e.g., "Hard work can increase one's ability to do math"). Items were written so that a less epistemologically developed individual would agree with about half the items and disagree with the remaining items. Half of the items were reverse scored so that the higher the score the more epistemologically developed the respondent. We combined and randomly ordered the items for both instruments to form a single instrument that we refer to as the Mathematics Problem-Solving Beliefs Scale (MPSB). Items for the MPSB Scale were not revised because Kloosterman and Stage (1992) advised that these scales are appropriate for middle school and high school students. In addition, the Effort Can Increase Mathematical Ability Scale has been tested with seventh graders and has a generated reliability index that is almost identical to that of college populations (Kloosterman, 1988).

Academic performance. Three measures of academic performance were available from one of the participating schools: mathematical problem solving, reading, and overall grade point average. Both content-area tests were part of the Kansas State Assessment instruments developed by the University of Kansas and administered in January of each year.

For the problem-solving assessment, students were given two mathematical problems and asked to solve them, show their work, and explain the rationale behind their thinking. Four trained teachers applied a six-point rubric to score each student's solution: (*a*) 0 = no response, (*b*) 1 = inadequate response (e.g., contains major computation errors, focuses entirely on the wrong mathematical idea or procedure, shows copied parts of the problem with no attempt at a solution), (*c*) 3 = adequate response (e.g., omits parts or elements of the problem, contains computation errors, shows some deficiencies in understanding the problem), and (*d*) 5 = superior (e.g., is clear and unambiguous, communicates effectively, shows mathematical understanding of the problem's ideas and requirements).

Teacher training in using this rubric was conducted by the Kansas State Department of Education. The training consisted of workshops to explain what each category means as well as what each level of response would look like. Teachers were given sample responses to score and were required to reach a criterion of 80% or more agreement. For the state assessment, two teachers scored each student's solutions. If these two teachers disagreed, they resolved differences through discussion.

The following is an example of the type of problem students needed to solve:

> A heavy downpour of rain left a foot of mud on the ground. Each day Harry shoveled 3 inches of mud off of his sidewalk, but for the next 3 nights the rain added 4 inches of mud each night; the next 3 nights the rain added 3 inches of mud each night; the next 3 nights the rain added 2 inches of mud each night; and then for 3 nights the rain added 1 inch of mud each night. How many days did it take Harry to clear his sidewalk?

Once we had gathered the data and examined the distribution of scores, we transformed the rubric scoring into a four-point scale to allow a more level distribution of scores: (*a*) 1 = no response to inadequate response (n = 61), (*b*) 2 = weak to adequate response (n = 64), (*c*) 3 = good-quality response with a few minor errors (n = 84), and (*d*) 4 = superior response (n = 144).

Students' Kansas State Assessment reading scores were norm referenced. Reading comprehension was reported with normal equivalent scores (M = 50, SD = 21). Because the problems students solved involved reading, we used reading scores as a control variable in these analyses.

Procedure

To obtain maximum standardization in administration of these instruments, the beliefs assessments became an integral part of the schools' yearly Quality Performance Accreditation assessment process. Schools in Kansas are required to develop goals and show yearly progress toward those goals. Mathematics problem solving is a required goal. Hence, scores from the MPSB Scale were used as part of the school district's report to the state. School personnel were also willing to assess epistemological beliefs to determine if they affected student academic outcomes. Teachers administered these instruments along with other standardized measures for this yearly assessment and encouraged students to take all state assessments seriously.

To avoid student fatigue, we conducted assessments over 2 weeks. The EB and MPSB Scales were administered on different weeks, and order of scale administration was counterbalanced. Teachers were provided both written and oral instructions on how to administer the scales. Students were asked to give their true attitudes in responding to these scales and were assured there were no right or wrong answers. Rather, they were told that this was an opportunity to voice their own beliefs. Teachers gave quiet activities to students who finished the scales early so that other students could complete the scales undisturbed. On average, students took 15–25 minutes to complete the surveys.

Results

Factor Structure

Epistemological beliefs. To determine the middle school students' epistemological beliefs, we conducted an exploratory factor analysis on data from the epistemological questionnaire in a three-stage process. In step one, exploratory factor analysis was applied to the full EB questionnaire of 30 items. We used varimax rotation to maximize independence of factor scores. Examination of factor loadings and the scree plot indicated that four factors were a plausible fit. In step two, we ran an exploratory factor analysis again with all 30 items. This time we requested SPSS to generate four factors only. We then examined items that loaded highly on the four-factor structure. In step three, we ran the final exploratory analysis using only the 21 items that had high loadings in step two. Ultimately, these analyses generated four factors accounting for 40.35% of the total variance. The items and factor loadings are shown in Table 1. Factor titles and Cronbach's alpha scores, which served as a measure of internal consistency for items, were as follows: quick/fixed learning (.77), studying aimlessly (.55), omniscient authority (.55), and certain knowledge (.36). These titles are stated from the less mature point of view, which is consistent with earlier research.

Mathematical problem-solving beliefs. Because the MPSB Scale was originally developed for high school students, we needed to determine the factor structure for middle school students. Data from the MPSB Scale were subjected to exploratory factor analysis using all 36 items. We used varimax rotation to maximize the independence of the factor scores. Examination of factor loadings and the scree plot indicated that seven factors were a plausible fit. Because the default cutoff of an eigenvalue of 1 was met with the seven-factor solution, we did not conduct additional exploratory factor analyses. The seven factors accounted for 48.52% of the total variance. The items and factor loadings are shown in Table 2. Twenty-four items loaded onto this seven-factor structure. Factor titles and Cronbach's alpha scores were as follows: effortful math (.80), useful math (.80), persistence in math (.62), math confidence (.63), understand math concepts (.70), word problems (.62), and nonprescription math (.66). These titles are stated from the mature point of view, which is consistent with earlier research.

We took a conservative approach to these analyses. To be cautious in interpreting data, we retained belief factors that reached minimal psychometric standards in the following analyses. Therefore, factors with Cronbach's alphas of at least .55 and composed of a minimum of three items were used in the remaining analyses. These factors included quick/fixed learning, studying aimlessly, effortful math, useful math, math confidence, and understand math concepts. Correlations among these belief factors are shown in Table 3.

With these belief factors in mind, we tested several hypotheses in the next stage of analyses. We hypothesized that the less students believed in quick/fixed learning (i.e., that learning should occur quickly and is related to ability rather than to effort), the more likely they would be to believe that mathematical problem solving requires effort, confidence, and understanding math. We also hypothesized that the less students believed in studying aimlessly (i.e., that studying does not involve strategy or effort), the more likely they were to believe that mathematical problem solving requires

TABLE 1. Factor Loadings of Items in Each Factor for the Epistemological Belief Scale

Questionnaire Item	Factor Loadings			
	Q/F	SA	OA	CK
Quick/fixed learning (Q/F):				
An expert is someone who is really born smart in something.	**.67**	−.01	.05	.07
If I cannot understand something quickly, it usually means I will never understand it.	**.62**	.19	.04	−.07
Working hard on a difficult problem only pays off for the really smart students.	**.61**	.17	.05	.04
Some people are just born smart, others are born dumb.	**.51**	−.02	.14	−.04
If I am ever going to be able to understand something, it will make sense to me the first time I hear it.	**.51**	.08	−.04	.00
Students who are "average" in school will remain "average" for the rest of their lives.	**.50**	.09	.18	.00
The really smart students don't have to work hard to do well in school.	**.48**	.07	.09	−.05
Successful students understand things quickly.	**.40**	−.18	−.06	−.05
If I can't understand something right away, I will keep on trying. (reverse scored)	**.35**	.28	.16	−.02
You will get mixed-up if you try to combine new ideas in a textbook with what you already know.	**.34**	−.05	−.05	−.02
Studying aimlessly (SA):				
If I find the time to re-read a textbook chapter, I get a lot more out of it the second time. (reverse scored)	.24	**.46**	.18	−.17
What students learn from a textbook depends on how they study it. (reverse scored)	.09	**.41**	.11	.13
You cannot learn anything *more* from a textbook by reading it twice.	.38	**.40**	−.07	−.15
The knowledge of "how to study" is usually learned as we grow older. (reverse scored)	−.07	**.38**	.08	.09
Getting ahead takes a lot of work. (reverse scored)	.02	**.36**	.17	.15
Learning something really well takes a long time. (reverse scored)	−.21	**.34**	.04	.07
A class in study skills would probably help slow learners. (reverse scored)	.10	**.33**	.10	.08
Omniscient authority (OA):				
If scientists try hard enough, they can find the truth to almost everything.	−.02	−.23	**−.57**	−.05
Scientists can get to the truth if they just keep searching for it.	−.12	−.25	**−.54**	−.03
Certain knowledge (CK):				
The only thing you can be sure of is that nothing is sure. (reverse scored)	−.10	.06	.04	**.45**
Today's facts may be tomorrow's fiction. (reverse scored)	.06	.20	.01	**.42**

NOTE.—In each column of factor loadings, items that were a part that factor are in bold print.

effort and understanding. Finally, we hypothesized that the less students believed in quick/fixed learning and studying aimlessly, the more likely they were to believe that mathematics may be useful. These hypotheses are consistent with findings from earlier research. For example, researchers have found that belief in fixed ability is related to failure to persist and to the belief that the purpose of studying is simply to document one's intelligence (rather than to learn) (Dweck & Leggett, 1988). The belief that learning occurs quickly or not at all has been related to strategy selection (Kardash & Howell, 2000) and reading comprehension (Schommer, 1990). Belief in fixed abil-

TABLE 2. Factor Loadings of Items in Each Factor for the Mathematical Problem-Solving Beliefs Scale

Questionnaire Item	Factor Loadings						
	EM	UM	MP	MC	UMC	WP	NPM
Effortful math (EM):							
Ability in math increases when one studies hard.	**.63**	.10	.09	.14	.07	.09	−.09
By trying harder, one can become smarter in math.	**.60**	.16	.14	.02	.14	.10	.04
I can get smarter in math if I try hard.	**.57**	.22	.13	.06	.08	.06	−.10
Working can improve one's ability in mathematics.	**.57**	.19	.10	.11	.14	.11	−.13
I can get smarter in math by trying harder.	**.53**	.03	.13	.03	.06	.02	−.01
Hard work can increase one's ability to do math.	**.50**	.17	.17	.08	.11	.05	−.05
I find I can do hard math problems if I just hang in there.	**.42**	.24	.13	.29	.17	.11	−.11
Useful math (UM):							
Mathematics is a worthwhile and necessary subject.	.31	**.57**	.16	.21	.15	.11	−.01
I study mathematics because I know how useful it is.	.24	**.49**	.07	.30	.03	.14	−.07
Studying mathematics is a waste of time. (reverse scored)	.20	**.44**	.25	.17	.31	.15	−.09
Mathematics has no relevance to my life. (reverse scored)	.25	**.43**	.26	.13	.21	.21	−.01
Mathematics will not be important to me in my life's work. (reverse scored)	.22	**.42**	.28	.08	.16	.18	−.09
Knowing mathematics will help me earn a living.	.31	**.42**	.12	.16	.17	.09	−.10
Math persistence (MP):							
If I can't do a math problem in a few minutes, I can't do it at all. (reverse scored)	.21	.22	**.56**	.19	.14	.15	−.02
If I can't solve a math problem quickly, I quit trying. (reverse scored)	.17	.21	**.44**	.33	.09	.12	−.06
Math confidence (MC):							
I feel I can do math problems that take a long time to complete.	.28	.10	.16	**.61**	.11	.09	−.05
Math problems that take a long time don't bother me.	.02	.19	−.01	**.59**	.04	.08	−.03
I'm not very good at solving math problems that take a while to figure out. (reverse scored)	.00	.06	.27	**.51**	.04	.12	.07
Understand math concepts (UMC):							
It's not important to understand why a mathematical procedure works as long as it gives a correct answer. (reverse scored)	.17	.16	.27	.13	**.57**	.20	−.07
Getting the right answer in math is more important than understanding why the answer works. (reverse scored)	.22	.16	.33	.04	**.47**	.19	.02
It doesn't really matter if you understand a math problem if you can get the right answer. (reverse scored)	.17	.22	.25	.04	**.41**	.24	−.01
Word problems (WP):							
Word problems are not a very important part of mathematics. (reverse scored)	.19	.18	.15	.11	.13	**.60**	−.03
Math classes should not emphasize word problems. (reverse scored)	.17	.13	.25	.17	.17	**.50**	−.13
Nonprescription math (NPM):							
Any word problem can be solved if you know the right steps to follow. (reverse scored)	−.37	−.09	−.10	−.03	−.03	−.07	**.64**
Any word problem can be solved by using the correct step-by-step procedure. (reverse scored)	−.33	−.12	−.04	−.05	.02	−.03	**.53**

NOTE.—In each column of factor loadings, the items that were a part that factor are in bold print. See Kloosterman and Stage (1992) for the original scales.

TABLE 3. Correlations among Belief Factors included in Analyses

Factor	Q/F	SA	EM	UM	MC	UMC
Quick/fixed learning (Q/F)	. . .	.22**	−.39**	−.45**	−.29**	−.50**
Studying aimlessly (SA)		. . .	−.40**	−.33**	−.12**	−.27**
Effortful math (EM)			. . .	.59**	.30**	.45**
Useful math (UM)				. . .	.42**	.55**
Math confidence (MC)					. . .	.28**
Understand math concepts (UMC)						. . .

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

ity is related to students' appreciation of the benefits of education to one's future (Schommer & Walker, 1997).

Epistemological Beliefs as Predictors of Mathematical Problem-Solving Beliefs

To test these hypotheses, each MPSB Scale factor was regressed on two blocks of variables. First, because grade level has been associated with epistemological development (Schommer et al., 1997) and gender has been associated with mathematical performance (Reis & Park, 2001), these two variables were statistically controlled for by entering the equation in the first step. Second, we entered EB Scale factors into the equation using step-wise regression. That is, variables within blocks competed for entry, so that the variable that accounted for the most variance entered at each step. Only variables that were significant at the .05 level were allowed to enter the equation. Scores for each factor were sums of items that composed each factor. Table 4 presents the regression analyses.

As indicated by the negative *b*-weights, the less students believed in quick/fixed learning, the more likely they were to believe that mathematical problem solving is effortful and useful. Furthermore, they were more likely to believe problem solving requires understanding and to have confidence in their mathematical problem-solving ability. The amount of variance accounted for by this belief ranged from 10% to 25%.

Belief in studying aimlessly also related to mathematical problem-solving beliefs. The less students believed in studying aimlessly, the more likely they were to believe that mathematical problem solving is effortful and useful. The amount of variance accounted for was modest, ranging from 5% to 9%. Although the relation between studying aimlessly and understanding math was significant, the amount of variance accounted for (3%) was too small to consider meaningful.

Predicting Mathematical Problem-Solving Performance

To determine if general and mathematical beliefs predicted mathematical problem solving, we conducted a step-wise regression. Epistemological beliefs, mathematical problem-solving beliefs, and gender competed for entry. The variable accounting for the most variance entered the equation at each step. Two variables predicted mathematical problem solving—belief in quick/fixed learning and the belief that math is useful. The less students believed in quick/fixed learning, $F(1, 316) = 24.07, p < .01, R^2 = .07$, and the more they believed in useful math, $F(1, 315) = 5.20, p < .05, R^2 = .02$, the better they were at problem solving.

Relating Belief Systems to Academic Performance

To test the notion that epistemological beliefs and mathematical problem-solving beliefs relate to academic performance as part of a larger system of cognition, we conducted a path analysis relating academic performance to belief system. To avoid issues of multicollinearity, we used the significant predictors in the previous regres-

TABLE 4. Summary of Regression Statistics

Criterion/Predictor Variables	R^2 Change	b weight	Total R^2	Total F
Effortful math:			.25	127.97*
Grade	< .01	−.62		
Studying aimlessly	.16	−.48		
Quick/fixed learning	.09	−.22		
Useful math:			.25	131.33*
Gender	< .01	.63		
Quick/fixed learning	.20	−.31		
Studying aimlessly	.05	−.28		
Math confidence:			.12	54.93*
Gender	.02	−.72		
Grade	.02	−.42		
Quick/fixed learning	.12	−.14		
Understand math concepts:			.30	169.06*
Gender	.03	.89		
Quick/fixed learning	.25	−.20		
Studying aimlessly	.03	−.11		

NOTE.—Boys were coded as 1, girls as 2.
*$p < .05$.

sion equation to represent general and domain-specific beliefs. Hence, belief in quick/fixed learning was the endogenous variable that we hypothesized would directly affect belief about useful math and all three measures of academic performance (mathematical problem solving, reading, and overall grade point average). We hypothesized that belief in useful mathematics would have a direct effect on two measures of academic performance—mathematical problem solving (research has indicated that students who believe mathematics is useful are more willing to take optional mathematical classes [Reyes, 1984]) and overall grade point average (because grade point average is derived from a number of classes involving mathematics, i.e., sciences as well as mathematics). Research has shown that both general and domain-specific beliefs have indirect effects on academic performance as well. Because reading comprehension is part of understanding the mathematical problem to be solved, we hypothesized that comprehension scores would predict both mathematical problem solving and overall grade point average. Figure 1 shows the path model. All paths were significant at a .05 level. Overall fit indices were at acceptable levels: $\chi^2 = 1.51$, $p = .22$, NFI = 1.00; CFI = 1.00; RMSEA = .04.

Discussion

Exploring the factor structure of middle school students' epistemological beliefs indicates that a multidimensional model is applicable. Although initially we found four domain general beliefs, we approached the data conservatively and continued analyses with the two strongest epistemological belief factors, quick/fixed learning and studying aimlessly. Because the multidimensional approach to middle school students' epistemological beliefs is in its infancy, we cannot assume that these two beliefs capture the personal epistemology of all middle school students. Refinement of the questionnaire could yield more epistemological dimensions in the future. This limitation notwithstanding, these two epistemological beliefs provide information that has not been revealed in previous research.

In earlier research with older students, beliefs in quick learning and fixed ability were more distinct because these beliefs often emerged as separate factors (Schommer, 1990). In contrast, the beliefs of the middle school students in this study about the nature of learning emerge as a single factor, quick/fixed learning. This developmental trend from undifferentiated to differenti-

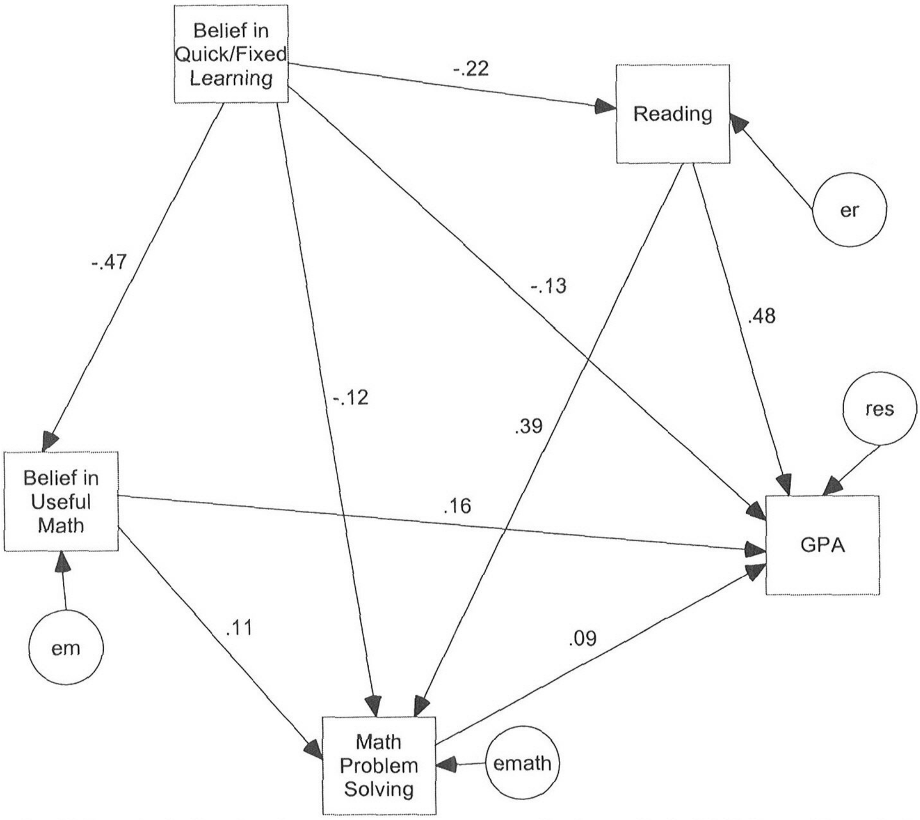

FIG. 1.—Path analysis showing the relations among a general epistemological belief, a mathematical problem-solving belief, and measures of academic performance. Standardized path coefficients are shown.

ated thinking is consistent with Wellman's (1990) conception of children's theory of the mind. He suggested that young children have a global theory of the mind. In contrast, adults conceptualize the mind as composed of distinct processes and components (Montgomery, 1992).

Additionally, our results generate an epistemological belief that is not evident among older students, namely, studying aimlessly, which suggests that some young students do not believe that learning is strategic. Rather, they view learning as a chance event. Ironically, if students receive an acceptable grade after engaging in haphazard studying, their belief in studying aimlessly can be strengthened. The belief in studying aimlessly seems to be consistent with one view of attribution theory, the view that success is related to luck (Weiner, 2000). If students believe that luck brings success, then they view learning as out of their control rather than as strategic and effortful.

Exploring middle school students' mathematical problem-solving beliefs again provides new insight into the minds of younger students. Although the factors generated from the analyses are similar to findings for older students, there are only four psychometrically adequate factors: effortful math, useful math, understand math concepts, and math confidence. Similar mathematical beliefs, such as self-confidence in math, perceived usefulness of math, and importance of math, have been obtained by interviewing young students (Kloosterman & Cougan, 1994; Kloosterman, Raymond, & Emenaker, 1996).

The fact that belief in quick/fixed learning is a predictor of all four mathematical problem-solving beliefs indicates the potential influence of this belief. This finding is consistent with past research showing that belief in quick learning, in particular, influences students' thinking in high school and college. For example, the more high school students believe in quick learning, the lower the grade point average they earn (Schommer, 1993; Schommer et al., 1997) and the more likely they are to display poor mathematical problem-solving strategies (Schoenfeld, 1983). The more college students believe in quick learning, the more poorly they comprehend, the less likely they are to monitor their comprehension of complex text accurately (Schommer, 1990), and the fewer cognitive processes they tend to exhibit when reading controversial text (Kardash & Howell, 2000).

The results of our study also suggest that both general epistemological beliefs and mathematical beliefs may play a role in students' problem-solving performance. Path analysis provides deeper examination of the interrelations between belief systems and academic performance. In the model we tested in this study, it appears that students' belief in quick/fixed learning leads to viewing mathematics as of little use. In turn, the less students believe mathematics is useful, the less likely they are to solve problems successfully. Believing in quick/fixed learning also implies a belief that the modus operandi of studying is to speed through the reading and solving of mathematics problems. All these cognitive and affective processes appear to lead to a lower grade point average. In short, our results support the hypothesis that belief in quick/fixed learning may guide students in their choice of problem-solving strategies and the amount of time they spend on solving mathematical problems (Schoenfeld, 1985; Schommer et al., 1992).

Both general epistemological beliefs and mathematical beliefs appear to influence mathematical performance and overall academic performance. Both systems of beliefs have direct and indirect effects. Furthermore, in our data a strong relation exists between general and domain-specific beliefs. Whether mathematical beliefs are a manifestation of general epistemological beliefs, as De Corte et al. (2002) proposed, remains to be examined in future research. What is more important is that researchers begin to understand how beliefs fit with and function among cognitive and affective characteristics of learners.

In summary, our findings have important theoretical and practical implications. First, middle school students' epistemological beliefs can be conceptualized as multidimensional. The dimensions are somewhat different from those of the beliefs of older students in that beliefs in quick learning and fixed ability are tightly woven in our sample. Belief in strategic studying, or lack thereof, is critical to middle school students' beliefs about mathematical problem solving.

The fact that epistemological beliefs are multiply linked to mathematical problem-solving beliefs suggests that general epistemological beliefs innervate students' thinking in specific academic domains. Consequently, this research suggests topics to investigate in the future, for example, the influences that reading teachers, science teachers, music teachers, or writing teachers have on students' general epistemology. In turn, how do general epistemological beliefs influence what students think about the learning or problem-solving process in various school subjects?

This research offers some thought-provoking ideas for the classroom teacher. For example, if middle school students have a strong belief in quick/fixed learning, they will assume that all assignments should be completed in a short amount of time. When faced with more challenging assignments, some students who focus on the quick belief may have a predetermined amount of time in which they study. When the time is up, they move to different activities. Other students who focus on the fixed belief and do not experience success immediately may cease to try because they assume that if they did have the ability, they would have solved a problem quickly, a notion that is consistent with Dweck's work (Dweck & Leggett, 1988). What this could mean for the teacher is that some students may need to be forewarned that a task will be challenging and time-consuming. Some students may need help and encouragement to put in the time and effort needed to complete the assignment with accuracy and understanding.

If middle school students have a strong belief that mathematics is not useful in their lives or future careers, they may resist spending time or effort needed to be successful at it. It may be helpful if teachers can make mathematics tasks instrinsically interesting and situate mathematics problems in middle school students' current interests, such as sports, music, and popular culture. In short, teachers can make mathematics fun and applicable to students' lives.

We see this research as only the beginning of understanding young students' epistemological beliefs. The middle school epistemological questionnaire, though useful at this point, may need to be revised so that more epistemological and mathematical belief factors are assessed by more items. Studies are necessary to understand the epistemological beliefs of students who are more culturally diverse. And research on how epistemological beliefs function as a part of a much larger system would be informative. That is, researchers should determine how epistemological beliefs are related to other aspects of cognition, such as problem solving, self-concept, motivation, study strategies, comprehension monitoring, cultural identity, and cognitive flexibility.

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