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Mathematics Anxiety in Preservice Teachers: Its Relationship to their Conceptual and Procedural Knowledge of Fractions

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The objective of the present study was to examine the relationship between mathematics anxiety and the procedural and conceptual knowledge of fractions in prospective teachers. Thirty-two preservice teachers enrolled in an elementary mathematics methods course were administered the Revised Mathematics Anxiety Rating Scale (RMARS, Baloğlu, 2002). Procedural and conceptual knowledge of fractions was assessed with a validated paper and pencil test (Saxe, Gearhart, & Nasir, 2001) and with four additional problems created by the researchers. Results indicated that as mathematics anxiety scores increased, scores on the validated measure of procedural knowledge of fractions decreased. The same relationship was found between the RMARS and the validated measure of conceptual knowledge. The findings provide some insight on the cognitive and pedagogical factors associated with mathematics anxiety in the preservice teacher population, underscoring the importance of facilitating their proficiency in both mathematical procedures and concepts.

There is renewed emphasis on the role of mathematical content knowledge in the teaching of elementary mathematics. A growing body of research underscores the importance of teachers' subject-matter knowledge, not only with respect to the ways teachers reason about mathematics teaching (e.g., L. Ma, 1999; Osana, Lacroix, Tucker, & Desrosiers, 2006; Wu, 1997) and what they do in the classroom (e.g., Ball & Bass, 2000; Ball, Hill, & Bass, 2005), but also with respect to their students' performance (e.g., Hill, Rowan, & Ball, 2005; Osana, Lacroix, Rayner, Pitsolantis, & Ing, 2008). Clearly, the findings from these studies have serious implications for the education of preservice teachers (Ball et al., 2005).

We contend that the levels of teachers' anxiety about mathematics may play an important role in the interplay between knowledge and practice. This claim is based in part on studies demonstrating that mathematics anxiety is more commonplace in elementary education majors than students in other fields of study (Baloğlu & Koçak, 2006; Bessant, 1995; Hembree, 1990; Kelly & Tomhave, 1985). For instance, Hembree's (1990) meta-analysis demonstrated that, compared to other university and high school students, the highest levels of mathematics anxiety were found in university students who were enrolled in a mathematics methods course and who were majoring in elementary education. Perhaps more importantly, some scholars have argued that teachers who are anxious about mathematics may spend less time in the classroom teaching the subject and may impart negative attitudes about it to their students (e.g., Trice & Odgen, 1986; Vinson, 2001). Because Kelly and Tomhave (1985) proposed that the prevalence of mathematics anxiety in preservice teachers was a consequence of their mathematical background and insufficient understanding of the subject matter, it is possible that preservice teachers' mathematics anxiety and mathematical knowledge are not entirely distinct constructs but rather share a mutual relevance.

In line with this reasoning, we argue that the relationship between preservice teachers' mathematics anxiety and mathematical knowledge warrants investigation. Specifically, our aim in conducting the present study was to assess preservice teachers' procedural and conceptual knowledge of fractions and to examine the relationship between those forms of knowledge and the prospective teachers' reported mathematics anxiety.

Mathematics Anxiety

The research investigating mathematics anxiety dates back over 20 years. Richardson and Suinn (1972) published the first article examining the psychometric properties of mathematics anxiety, whereby a measure of mathematics anxiety (i.e., the Mathematics Anxiety Rating Scale) was developed and tested. In that article, mathematics anxiety was defined as "feelings of tension and anxiety that interfere with the manipulation of numbers and solving mathematical problems in a wide variety of ordinary life and academic situations" (p. 551). Despite the simplicity of this definition, mathematics anxiety appears to be multidimensional (Bessant, 1995), and Kazelskis (1998) recently identified six distinct, but related, dimensions of mathematics anxiety: test anxiety, anxiety about numeracy situations, worry, positive affect toward maths, negative affect toward maths, and maths course anxiety.

As a consequence of the complexity of mathematics anxiety, research in this area has addressed a variety of related topics. Specifically, researchers of mathematics anxiety have investigated its origins (Bowd & Brady, 2003; Brady & Bowd, 2005; Harper & Daane, 1998; X. Ma & Xu, 2004; Trujillo & Hadfield, 1999; Uusimaki & Nason, 2004; Widmer & Chavez, 1982); the factors associated with mathematics anxiety (Ashcraft, 2002; Bessant, 1995; Sloan, Daane, & Giesen, 2002); the cognitive (Ashcraft & Kirk, 2001; Ashcraft, Kirk, & Hopko, 1998; Faust, Ashcraft, & Fleck, 1996; Hopko, Ashcraft, Gute, Ruggiero, & Lewis, 1998), affective (Cooper & Robinson, 1991; Wigfield & Meece, 1988), and behavioural consequences of mathematics anxiety (Meece, Wigfield, & Eccles, 1990; Turner et al., 2002); as well as methods to reduce individuals' mathematics anxiety (Harper & Daane, 1998; Sloan, Vinson, Haynes, & Gresham, 1997; Vinson, 2001).

Mathematics Anxiety and Student Learning in Mathematics

In general, research has demonstrated that mathematics anxiety has relevant implications for student learning, inhibiting performance in mathematics courses (Vinson, 2001) and affecting future opportunities for engagement in mathematics (Meece et al., 1990). Indeed, Meece et al. (1990) found that seventh-, eighth-, and ninth-grade students who were highly mathematics-anxious and who demonstrated poor self-efficacy beliefs regarding their mathematical abilities failed to participate in opportunities that would otherwise develop and cultivate their mathematical education. Moreover, Lefevre, Kulak, and Heymans (1992) found that highly mathematics-anxious university students avoided study majors that involved either moderate (e.g., architecture and business) or high mathematics requirements (e.g., accounting and computer science), implying that the experience of mathematics anxiety may ultimately play a role in an individual's career choice (Widmer & Chavez, 1982).

The relationship between mathematics anxiety and performance has been a highly popular topic of study primarily because of the high average correlation between these two variables (i.e., r = -0.34) demonstrated in Hembree's (1990) meta-analysis. Moreover, X. Ma's (1999) meta-analysis also revealed a negative association between mathematics anxiety and performance (i.e., r = -0.27), and a U_3 statistic of 0.71 corresponded to this correlation. That is, on average, students who displayed a low level of mathematics anxiety outperformed more than 71% of the students in the high mathematics anxiety group. Although there clearly are several factors that are predictive of mathematics achievement, this research implies that students who lower their level of anxiety would likely increase their performance in mathematics and mathematics-related courses. From a pedagogical standpoint, then, a deeper understanding of the nature of this relationship has serious implications for teacher educators and educational researchers.

Research focusing on the link between mathematics anxiety and mathematical cognition has contributed significantly to the understanding of how mathematics anxiety is related to performance (see Ashcraft et al., 1998). For example, Ashcraft and Kirk (2001) suggested that highly mathematics-anxious individuals experience an on-line reduction in the availability of working memory resources during anxiety-evoking situations. The on-line reduction of working memory resources is particularly problematic in mathematical situations that call for the use of complicated procedures, illustrating why anxiety effects have been found only when more complex mathematics is required to perform the calculations (Faust et al., 1996). That is, compared to recalling mathematical information that tends to be automatic in nature (e.g., 2 + 2 = 4), more complex mathematical procedures, such as performing algorithms used to solve operations with fractions, place a heavier demand on an individual's working memory (Ashcraft et al., 1998). According to Eysenck and Calvo's (1992) processing efficiency theory, the working memory processes of highly anxious individuals may be impeded during anxiety-evoking situations, which then results in the direction of their attention to their intrusive thoughts and worries rather than to the task at hand. Unfortunately, this misdirection of attention reduces the capacity of working memory to concentrate efforts on recall and the implementation of necessary procedures, negatively impacting test performance (Miller & Bichsel, 2004).

The Relationship between Mathematics Anxiety and Conceptual and Procedural Knowledge

At first glimpse, one might argue that these research findings allow us to predict rather confidently a negative relationship between mathematical performance and mathematics anxiety in the preservice teacher population. We argue, however, that the existing literature on the relationship between anxiety and performance is not readily applicable to preservice teachers. For example, in studies where prospective and practicing teachers were requested to identify the source of their mathematics anxiety, none of the participants attributed his mathematics anxiety to difficulties in recalling mathematical procedures during anxiety-evoking situations (e.g., Trujillo & Hadfield, 1999; Uusimaki & Nason, 2004; Widmer & Chavez, 1982). Instead, inservice and preservice teachers reported that experiences with the types of mathematics instruction they had received during their mathematics method course was a key factor in their perceived levels of mathematics anxiety. In particular, they reported that instruction that was procedurally focused while at the same time lacking in conceptual support was a salient factor that played a role in the development of their mathematics anxiety (Bowd & Brady, 2003; Brady & Bowd, 2005; Harper & Daane, 1998; Trujillo & Hadfield, 1999; Uusimaki & Nason, 2004; Widmer & Chavez, 1982). This evidence suggests that high levels of procedural knowledge (presumably acquired as a result of procedural instruction, see Hiebert & Wearne, 1996) may have a role in increasing mathematics anxiety, contrary to the conclusions drawn from the psychological literature.

Another reason for not relying entirely on the results from the psychological literature to make predictions about preservice teachers is that the type of mathematical knowledge we are examining goes beyond performance on mathematical procedures, the only form of knowledge studied to date by cognitive psychologists with respect to mathematics anxiety. Participants in these studies were engaged in mathematical tasks whereby they were required to recall and carry out mathematical rules, or the step-by-step process typically performed to solve a given problem (Saxe, Gearhart, & Nasir, 2001). In contrast, our interest includes preservice teachers' mathematical knowledge for teaching, which is defined by Ball et al. (2005) as subject-matter knowledge that is specific to the practice of teaching mathematics and is characterised by a way of understanding the discipline with a view to assisting students in the development of their mathematical proficiency. The emphasis on teachers' conceptual knowledge in particular is critical because of the current focus on the development of children's mathematical understanding in present-day curricula, reform documents, and assessment initiatives (Hiebert et al., 1997; Kilpatrick, Swafford, & Findell, 2001; National Council of Teachers of Mathematics, 2000; Pellegrino, Chudowsky, & Glaser, 2001). We conclude that the relationship between preservice teachers' mathematics anxiety and their knowledge, including their procedural competence, is not well understood and may in fact be different in nature than that in other populations of students. We maintain, therefore, that the relationship between procedural knowledge and anxiety is difficult to predict for the preservice teacher population.

Although we know of no studies that have directly examined the relationship between mathematics anxiety and conceptual understanding in preservice teachers, it is reasonable to predict that their levels of mathematics anxiety would decrease as their conceptual understanding of mathematical topics increases. By incorporating concrete learning experiences during a mathematics methods course to enhance preservice teachers' conceptual understanding, Vinson (2001) found that the anxiety levels of the teachers was significantly reduced, even months after the course was completed. Although Vinson did not measure the degree of participants' understanding directly, individual interviews with the preservice teachers indicated that the concrete approach to teaching mathematics assisted them to acquire deeper understandings of the course material. Vinson claimed that these deeper understandings allowed the students to "see the mathematics" (Harper & Daane, 1998), thereby increasing their confidence and reducing anxiety.

Theoretical Framework

The overarching philosophical assumption we use in our research is one of constructivism, which, according to Perkins (1999), characterises learning as an active process of creating knowledge, often with others in a social context, so that it becomes personally meaningful (see also Bransford, Brown, & Cocking, 2000). We adhere to the theoretical framework proposed by Kilpatrick et al. (2001) to describe the learning objectives of school mathematics, which is in line with Perkins's view of constructivism. A variety of affective, cognitive, and social factors together interact in ways that foster a number of mathematical competencies in students, including conceptual and procedural knowledge as well as feelings and dispositions toward the discipline. These competencies are intertwined, indicating that they are related to and influence the development of each other over time and as a result of different forms of instruction.

With respect to mathematics anxiety in particular, research indicates that it stems, at least in part, from the type of mathematics instruction received in school, as early as the elementary level (Brady & Bowd, 2005). Instruction that does not foster students' *understanding* of mathematical topics would, according to theory and research evidence, lower their confidence in their mathematical ability, which would bear negative consequences for their performance in situations where their knowledge is being assessed (Bowd & Brady, 2003; Brady & Bowd, 2005; Harper & Daane, 1998; X. Ma & Xu, 2004; Trujillo & Hadfield, 1999). In turn, low mathematics achievement, particularly for boys (X. Ma & Xu, 2004), can develop the experience of mathematics anxiety, resulting in the avoidance of mathematics courses (Meece et al., 1990), perpetuating poor performance and exacerbating mathematics anxiety.

The theoretical framework on teaching and learning mathematics in general, and the research that speaks to the development of mathematics anxiety in particular, also applies to the study of teachers and their learning of mathematics. After all, preservice teachers themselves have been exposed to a wide variety of instructional styles and mathematical experiences throughout their educational careers, all of which contributed in a number of different ways to their knowledge of and feelings about mathematics. With the focus on the construction of both conceptual and procedural knowledge in teacher preparation (Ball, Thames, & Phelps, 2008), and with the key objective of developing and maintaining positive dispositions towards the mathematics they themselves will be teaching, it is evident that effective teacher preparation is predicated on a more thorough understanding of how these factors are related.

The Present Study

The primary objective of the present study was to understand the association between preservice teachers' mathematics anxiety and their knowledge of fractions, a topic in the elementary mathematics curriculum that is notorious for the challenges it provides teachers (Wu, 2001). Understanding the relationship between mathematics anxiety and preservice teachers' knowledge of mathematics is an important goal for two main reasons. First, research has indicated that teachers may have the greatest impact on their students' academic growth (e.g., Ball & Rowan, 2004). Added to that, teachers who experience mathematics anxiety may inhibit the use of positive practices for teaching mathematics (Vinson, 2001) and spend less time teaching content during mathematics lessons (Trice & Odgen, 1986), two outcomes that can impede student learning and performance. For these reasons, several researchers have suggested that mathematics anxiety often operates as a cycle, whereby mathematics-anxious teachers may induce anxiety in their students (Conrad & Tracy, 1992; Sloan et al., 2002; Vinson, 2001; Wood, 1988). This, in turn, can impede students' understanding of the subject and contribute to their avoidance of mathematics, thus limiting future career options (Lefevre et al., 1992; Widmer & Chavez, 1982). Hence, a reasonable solution to the problem of mathematics anxiety seen at the elementary level would be to prevent it at one of its sources – that is, addressing the problem at the preservice level promises to break the anxiety cycle that appears to be insidiously related to poor performance in mathematics (Ashcraft, 2002; Hembree, 1990).

Second, most opportunities for teachers to influence future instructional practice occur during their university education, before they formally join the teaching profession (National Commission on Teaching and America's Future, 1997). Thus, once in the workforce, teachers might find it particularly challenging to shake any affective discomforts they may experience toward mathematics and teaching the subject.

We can also justify our choice of the topic of fractions for our investigation of mathematics anxiety. To begin, the domain of fractions has been recognised as key in the elementary mathematics curriculum because it is related in important ways to other number concepts (Saxe et al., 2001). In addition, fractions may serve as a bridge between students' understanding of elementary mathematics and algebra (Behr, Lesh, Post, & Silver, 1983; Wu, 2001). In particular, Wu (2001) suggested that the topic of fractions helps students transition their mathematical perspective from the particular procedures and concepts addressed at the elementary level to the more general manner in which operations are performed in algebra. Third, fraction concepts have been identified as particularly complex to understand and teach in conceptually meaningful ways (D'Ambrosio & Mewborn, 1994; Saxe et al., 2001; Tirosh, 2000), suggesting that it is perhaps a topic that is likely to induce mathematics anxiety in prospective teachers. Finally, the decision to choose fractions was also based on the literature that suggests that individuals tend to experience anxiety when they are asked to perform complex mathematical procedures (Faust et al., 1996), which are necessary for operating on fractions in a variety of ways.

In a university-level elementary mathematics methods course, we assessed a group of preservice teachers' procedural and conceptual knowledge of fractions and measured their level of general mathematics anxiety. In this study, we defined procedural knowledge as recalling and carrying out specified steps to solve problems involving the addition, subtraction, and multiplication of fractions. Conceptual knowledge was defined as understanding the mathematical principles that underlie these computational procedures (Hiebert & Lefevre, 1986). Our specific research questions were the following: (a) How is mathematics anxiety related to the preservice teachers' procedural knowledge of fractions? and (b) How is mathematics anxiety related to their level of conceptual knowledge of fractions?

Although the research reported by Ashcraft et al. (1998) and the results from Ashcraft and Kirk (2001) suggest an inverse relationship between mathematics anxiety and procedural competence in mathematics, data from preservice teachers indicate a potentially positive association between these two constructs. We thus maintain that the link between mathematics anxiety and procedural knowledge, particularly in the area of fractions, is not well understood in the preservice teacher population. As such, we were not able to predict a direction, either positive or negative, for this correlation. On the other hand, we predicted a negative correlation between the teachers' conceptual scores and their mathematics anxiety because of the research suggesting that the development of mathematical understanding leads to greater levels of confidence and lower levels of anxiety (Cooper & Robinson, 1991; Hiebert et al., 1997; Sloan et al., 1997; Vinson, 2001).

Method

Participants

Thirty-two preservice teachers enrolled in a four-year undergraduate teacher education program at a large urban university in Canada participated in this study. The participants were tested during the Winter 2006 session, at which time they were registered in the second part of a two-semester mathematics methods course. All participants took part on a voluntary basis and were not compensated for their involvement in the study. Those who participated formed 82.05% of the entire class.

The majority of the sample had completed at least 33 credit hours in the teacher education program prior to registering for the course. The participants ranged in age between 21 and 49 years and some of the participants had already completed at least one teaching internship in the program. The means and standard deviations for age, grade point average, and number of post-secondary mathematics courses completed at the time of testing are presented in Table 1.

Table 1
Means and Standard Deviations of Demographic Variables According to Gender (N = 32)

Variable	Female (n = 26)		Male (n = 6)	
	M	*SD*	*M*	*SD*
Age in years	27.42	8.05	26.5	3.39
Current GPA	2.92	0.27	3.00	0.00
Number of previous mathematics courses	2.42	2.04	4.80	1.48

Measures

Mathematics anxiety. We assessed the participants' levels of mathematics anxiety using the Revised Mathematics Anxiety Rating Scale (RMARS, Baloğlu, 2002), an instrument designed to measure course-related mathematics anxiety in undergraduate and graduate students. In completing the 20-item RMARS, the participants were asked to judge the amount of anxiety typically experienced during various situations involving mathematics, such as studying for a mathematics test, buying a mathematics textbook, and listening to another student explain a mathematical formula. Judgments about mathematics anxiety on the RMARS are made by selecting the response on a 5-point scale (ranging from 1, "*not at all,*" to 5, "*very much so*") that most accurately reflects the amount of anxiety typically experienced by the respondent during the described mathematical situation. A confirmatory factor analysis showed that the 20-item RMARS fit the theoretical model well (Normed Fit Index (NFI) = 0.90; Non-normed Fit Index (NNFI) = 0.90; Comparative Fit Index (CFI) = 0.92; Incremental Fit Index = 0.92; Root Mean Square Error of Approximation = 0.07).

Knowledge of fractions. We assessed the participants' procedural and conceptual understanding of fractions with a paper-and-pencil test referred to here as the Knowledge of Fractions Assessment (KFA). The KFA was developed and used by Saxe et al. (2001) to assess upper elementary students' procedural and conceptual knowledge of fractions. The test consists of two subscales, one that measures procedural knowledge of fractions and the other conceptual knowledge of fractions (see Saxe et al., 2001). Saxe et al. conducted a confirmatory factor analysis to substantiate the notion that each test item measured procedural or conceptual knowledge, and not both. Results of the confirmatory factor analysis demonstrated strong support that the two sets of items are indices of independent areas of competence. Specifically, for the posttest the confirmatory factor analysis indicated that all fit indices were high (NFI = 0.984, NNFI = 0.985, CFI = 0.994). Similarly, for the pretest, the best fit indices were high (NFI = 0.981, NNFI = 0.979, CFI = 0.992). Cronbach's alpha indicated internal consistency for each scale. For the conceptually orientated scale, the indices were 0.73 (pretest) and 0.83 (posttest); for the computational scale, the indices were 0.86 (pretest) and 0.87 (posttest).

Given that the participants in the present study received instruction on elementary-level fractions content, we believe there was a clear rationale for using Saxe et al.'s (2001) assessment. Furthermore, preservice teachers' conceptual difficulties with fractions that have been demonstrated in previous research (Ball, 1990; Tirosh, Fischbein, Graeber, & Wilson, 1998) suggested that their scores on the KFA would not achieve ceiling.

To the KFA we added two of our own items that were designed to measure the participants' conceptual and procedural knowledge of multiplication with fractions. Because the participants had received instruction on multiplying fractions prior to data collection, complementing the KFA with items that measured this knowledge made the fractions assessment more comprehensive. These items, which we have called the researcher-developed items (RD items), were placed after the KFA items and are presented in Figure 1. Item 18 addressed multiplication of a fraction and a whole number, and Item 19 addressed multiplication of two fractions. These two topics were part of the instruction, but were not assessed by Saxe et al.'s (2001) test.

Compute each of the following. For each equation, write a word problem that would put the equation in a real-world context.

18.1) $\frac{4}{7} \times 35 =$

18.2) Write your word problem here:

19.1) $\frac{5}{8} \times \frac{2}{3} =$

19.2) Write your word problem here:

Figure 1. Researcher-developed items assessing procedural and conceptual knowledge of multiplication with fractions.

Each of the RD items consisted of two subquestions designed to assess procedural and conceptual knowledge, respectively. To establish some degree of construct validity of the subconstructs of the RD items, we examined their correlations with the conceptual and procedural subconstructs of the KFA. The relationship between the RD procedural items and the KFA procedural items was not significant. The relationship between the RD conceptual items and the KFA conceptual items was significant ($r(30) = 0.36$, $p < 0.05$).

Procedure

The goal of the fractions instruction in the methods course was to develop the participants' mathematical knowledge of fractions that is unique to teaching (Ball et al., 2008). In particular, the fractions unit covered models of fractions (i.e., part-whole, quotient, and ratio models) in addition to operations with fractions (i.e., addition, subtraction, and multiplication). Throughout the lessons, the focus was on the fundamental principles that underlie fractions, such as partitioning and the relationship between parts and wholes, as well as on applying these principles to justify standard and nonstandard strategies for solving problems that involve addition, subtraction, and multiplication with fractions. At all points, physical and pictorial models were used, both by the instructor and the students, to solve a variety of fractions problems. Links were eventually made to manipulations with models and the symbolic representations of the operations.

Data were collected from all participants after the first three hours of fractions instruction, which spanned two class periods that were held one week apart. The instruction covered the conceptual underpinnings of fractions and operations with fractions (i.e., addition, subtraction, and multiplication) and was delivered by the third author, who is also the professor of the mathematics methods course at the university where the data were collected. The fractions unit in the course continued after the data collection took place and included additional topics, such as division with fractions. For logistical reasons, we were unable to collect data from the students once the entire fractions unit was completed.

Testing occurred at the beginning of the class period that immediately followed the first two class periods on fractions. After the informed consent procedure, the participants were given an envelope containing the following documents: (a) a short demographic questionnaire followed by the RMARS, and (b) the KFA and RD items. These two documents were printed on different coloured paper, allowing the administrator to clearly instruct the participants on which documents should be removed from the envelope and in which order. First, the preservice teachers were requested to complete the demographic questionnaire, followed by the RMARS, which began on the second page of the instrument. The participants were allowed a maximum of 15 minutes to complete the questionnaire and the RMARS.

Once the participants completed the RMARS, they were instructed to remove the remaining documents (i.e., KFA and RD tests) from the envelope, replace the completed RMARS in the envelope, and then complete the KFA and RD tests. The participants were given 45 minutes to complete the KFA and the RD items.

We decided against administering the KFA and the RMARS prior to instruction as pretest measures. First, we attempted to minimise the participants' awareness of their mathematics anxiety before instruction. Such awareness could have motivated them to seek assistance or information that may have, in turn, influenced their posttest performance. In addition, because of research evidence that points to preservice teachers' weak content knowledge in the area of fractions (Ball, 1990; Tirosh, 2000; Tirosh et al., 1998), we maintain that pretest data on the participants' fractions knowledge would not have yielded the variance necessary to detect meaningful relationships between their knowledge and mathematics anxiety.

Coding and Data Reduction

RMARS. Levels of mathematics anxiety were calculated by summing the participants' responses to the questions on the RMARS. Given the instrument's 5-point scale and the number of items that appear on it (i.e., 20), the minimum possible mathematics anxiety score is 20 and the maximum score is 100, with higher scores indicating higher levels of anxiety. None of the items on the RMARS required reverse scoring.

KFA and RD. The participants' responses to each item on the KFA, whether conceptual or procedural, was scored as either correct, earning 1 point, or as incorrect, earning 0 points. We used the same scoring procedure to score the responses to the RD items (i.e., two procedural RD items and two conceptual RD items). With respect to scoring the KFA and RD procedural test items, we considered only the final answer provided by a respondent; the method used to arrive at the answer was not taken into account.

We created a scoring key for some of the KFA and RD items because several questions could potentially elicit a variety of acceptable responses. For example, there are an infinite number of correct responses to the questions, "Write one fraction that is the same as 2/6" and "Write a word problem that would put 4/7 x 35 in a real-world context." The score key contained rules that would assist the coders to determine whether or not the responses to each of these items earned 0 points or 1 point. To illustrate, consider the problem, "Draw a picture to show how far John ran on two days if he ran 2/5 of a mile on Thursday and 3/5 of a mile on Friday." Full marks were assigned to responses that included a pictorial model with a clearly delimited whole equally partitioned into five parts, then showing two parts and three parts shaded or otherwise selected. Full marks were assigned to Item 18.2 (see Figure 1) if the response indicated a clear understanding that 35 was the size of the set or whole under consideration and that 4/7 of that number was to be found. For Item 19.2 (in Figure 1), full marks were awarded to responses indicating a clear and accurate understanding that a portion of an amount less than 1 was to be found.

To test the reliability of our scoring, we randomly selected 20% of the fractions knowledge tests (KFA and RD tests combined) and the first two authors independently coded these tests using the same score key. The percentage of agreement was 97.06% and the Kappa coefficient was $r_k = 0.97$. Both values are considered excellent according to Cohen (1960).

The points received for correct responses were summed, creating total scores for each of the following: (a) the KFA procedural items; (b) the RD procedural items; (c) the KFA conceptual items; and (d) the RD conceptual items. Because the KFA contains a disproportionate number of items in the procedural and conceptual subscales (18 and 12, respectively), we converted the total scores of (a) and (c) to proportional values (ranging from 0 to 100) to obtain equally-weighted scores for each subscale. As there were two procedural RD subitems, the minimum score for the total RD procedural subscale was 0 points and the maximum was 2. The scores were converted to percentages. The same scoring procedure was used for the total RD conceptual subscale.

Results

Data Screening

There were a total of four missing values on three different items on the RMARS. In particular, two participants did not respond to Item 2 (i.e., taking the maths section of college entrance exam), and of those two participants, one also failed to respond to Item 10 (i.e., being given a "pop" quiz in a maths class). A third participant did not respond to Item 7 (i.e., thinking about an upcoming maths test one hour before). Given the relatively small sample size (i.e., $N = 32$), we chose to use mean substitution to replace missing values rather than to omit the data from the analyses. We elected to use this procedure because mean substitution is considered to be a conservative method; the researcher is not required to guess the missing values (Tabachnick & Fidell, 2001). In addition, mean substitution does not change the mean significantly for the overall distribution of the variable (Tabachnick & Fidell, 2001). Items on the KFA and RD that were not answered were scored as incorrect, assuming that in these cases, the participants were unable to answer the question correctly.

Descriptive Statistics

The means and standard deviations for the RMARS, both procedural measures, and both conceptual measures can be found in Table 2.

Confirming previous research on preservice teachers' knowledge of fractions (e.g., Ball, 1990; Tirosh et al., 1998), the observed pattern in these data reveals that the mean procedural score on the KFA was higher than the mean KFA conceptual score; a similar pattern was found for the RD subscales, which offers some evidence for the construct validity of the researcher-developed items.

Table 2
Means and Standard Deviations for RMARS and Measures of Procedural and Conceptual Knowledge of Fractions (N = 32)

Variable	*M*	*SD*
RMARS	54.49	15.80
Procedural Measures		
KFA Subscale	95.14	5.60
RD	73.44	42.09
Conceptual Measures		
KFA Subscale	78.64	16.52
RD	62.50	43.99

Note. RMARS = Revised Mathematics Anxiety Rating Scale. Minimum and maximum scores for the RMARS were 20 and 100, respectively. All other scores were converted to percentages.

The mean score for the RMARS was 54.49 (*SD* = 15.80). The RMARS scores ranged from a minimum of 22 to a maximum of 83. To describe the variability of the participants' RMARS scores, we created categories of low-mathematics-anxiety, medium-mathematics-anxiety, and high-mathematics-anxiety. The frequency and percent of participants within each of these categories are summarised in Table 3. Cut-off scores for categorising participants into the anxiety groups were determined empirically by the overall sample mean and standard deviation (Ashcraft & Kirk, 2001). The scores in the low-mathematics-anxiety group were less than one standard deviation below the overall sample mean (RMARS scores ranging from 20 to 38), the scores in the medium-mathematics-anxiety group were within one standard deviation above and one standard deviation below the mean (RMARS scores ranging from 39 to 70), and the scores in the high-mathematics-anxiety group were at least one standard deviation above the mean (RMARS scores ranging from 71 to 100). We found the majority of the sample in the middle anxiety category (72%), and 19% and almost 10% of the sample in the low and high categories, respectively.

Table 3
Frequency and Percent of RMARS Scores as a Function of Mathematics Anxiety Group (N = 32)

Group Category	Frequency or *f*
Low-mathematics-anxiety	6 (18.75%)
Medium-mathematics-anxiety	23 (71.88%)
High-mathematics-anxiety	3 (9.38%)

Note. RMARS = Revised Mathematics Anxiety Rating Scale.

Mathematics Anxiety and the Procedural and Conceptual Knowledge of Fractions

The intercorrelations among all fractions knowledge measures and the RMARS are presented in Table 4. The correlation between the KFA procedural scores and the RMARS scores was significant and negative ($r(30) = -0.48$, $p < 0.01$; $r^2 = 0.23$), indicating that preservice teachers with greater mathematics anxiety demonstrated significantly fewer correct responses to questions that required procedural facility with fractions. These results suggest that preservice teachers who experience high levels of mathematics anxiety may encounter difficulties solving fraction problems that emphasise computation, or conversely, that the computations create or enhance mathematics anxiety in prospective teachers. We did not, however, find a significant correlation between the RMARS and the RD procedural scores.

Table 4
Correlations Between Procedural and Conceptual Knowledge of Fractions and Mathematics Anxiety (N = 32)

Variable	1	2	3	4	5
RMARS	-				
Procedural Scores					
KFA	-0.48**	-			
RD	-0.32	0.23	-		
Conceptual Scores					
KFA	-0.49**	0.26	0.36*	-	
RD	-0.18	0.22	0.23	0.36*	-

Note. RMARS = Revised Mathematics Anxiety Rating Scale; KFA = Knowledge of Fractions Assessment; RD = Researcher Developed items.
*p < 0.05. **p 0< .01.

With respect to conceptual knowledge of fractions, the relationship between the KFA conceptual and RMARS scores (see Table 4) was significant and negative ($r(30) = -0.49$, $p < 0.01$; $r^2 = 0.24$), offering support for the research hypothesis that preservice teachers with greater mathematics anxiety would demonstrate significantly less conceptual knowledge of fractions. Because our design did not allow us to determine causation, however, it may also be suggested that preservice teachers with a strong conceptual understanding of fractions demonstrated less anxiety towards mathematics. The RD conceptual scores, on the other hand, were not found to be significantly related to anxiety levels.

Discussion

Mathematics Anxiety and Preservice Teacher Education

In the present study, we investigated the relationship between levels of mathematics anxiety in preservice teachers and their procedural and conceptual knowledge of fractions. Using the data from a validated measure of fractions knowledge (Saxe et al., 2001), we found that mathematics anxiety decreased as scores on both the procedural and conceptual subscales of the fractions assessment increased. Previous research has shown that the characteristics and consequences of mathematics anxiety may be similar for preservice teachers in Australasia (e.g., Usimaki & Nason, 2004; Wilson & Thornton, 2005), indicating that the results of the present study are applicable to teacher preparation in other counties as well.

We use previous research in the area of mathematics anxiety to speculate on these findings. First, with respect to procedural knowledge, although we did not measure the participants' working memory (e.g., Ashcraft & Kirk, 2001; Faust et al., 1996; Hopko et al., 1998; Miller & Bichsel, 2004), the results from our study replicated the negative relationship between mathematics anxiety and mathematics performance involving complex procedures. As such, we suggest that the results lend partial support for the notion that, similar to undergraduate psychology students, preservice teachers may also experience an on-line mathematics anxiety reaction when required to perform complex mathematical procedures.

It is also possible that the negative association found between the procedural scores on the KFA and the level of mathematics anxiety may be attributed to a general avoidance of mathematics, which has been found in previous research to be related to mathematics anxiety (Hembree, 1990; Meece et al., 1990; Turner et al., 2002). In Faust et al. (1996), for example, participants who displayed high levels of mathematics anxiety answered mathematical problems as quickly as those with low anxiety. This finding contradicts the processing efficiency theory, which posits that high anxiety individuals require more time to complete the task because they have fewer working memory resources available to them (Miller & Bichsel, 2004). Faust et al. interpreted these results as an indication that highly mathematics-anxious individuals attempted to reduce the time spent engaged in the task and avoid the required mathematics, thereby forfeiting any checks on the accuracy of their answers. We speculate, therefore, that during anxiety provoking situations, individuals with mathematics anxiety may have difficulty remembering complicated mathematical procedures *and* may harbour the desire to avoid engaging with mathematics. These findings may in part explain the negative relationship that was demonstrated in the present study.

The negative relationship found between the participants' level of mathematics anxiety and their conceptual knowledge of fractions (as measured with the validated instrument) is consistent with studies that have demonstrated a reduction in preservice teachers' level of anxiety after completing a mathematics methods course that emphasised conceptual understanding of the content (Battista, 1986; Conrad & Tracy, 1992; Sloan et al., 1997; Vinson, 2001). A number of qualitative studies examining mathematics anxiety in preservice teachers have uncovered potential reasons for this finding. For instance, in Sloan et al. (1997), some preservice teachers reported in individual interviews that their mathematics anxiety could have been avoided altogether if the instruction they had received in elementary school mirrored the conceptually focused instruction they received during their teacher education. Furthermore, in Harper and Daane (1998), students reported that using manipulatives to "see" the mathematics assisted them to interpret mathematical concepts, which served to diminish their anxiety. These findings may be an indication that conceptually based instruction facilitates a more meaningful understanding of mathematics, and as an effect, moderates the teachers' experience with mathematics anxiety. In other words, preservice teachers do not fear what they understand, which may explain why a high conceptual understanding of fractions was related to low levels of mathematics anxiety in the present study.

The results of the present study add to the existing body of literature on the relationship between content knowledge and mathematics anxiety. Most notably, our study may be the first to directly examine the role of mathematical *understanding* in preservice teachers' mathematics anxiety, and vice versa. A more thorough examination of the relationship between anxiety and mathematical content knowledge is critical because of recent evidence demonstrating that teachers' knowledge of the discipline is predictive of student performance in mathematics (Hill et al., 2005). In particular, researchers and teacher educators concerned with improving the mathematical content knowledge of preservice teachers during their university education should consider the possibility that a majority of them experience a moderate degree of mathematics anxiety, and, as was found in our study, a few may even be highly mathematics anxious. Therefore, based on the relationship between mathematics anxiety and mathematical content knowledge, it is possible that preservice teachers' mathematics anxiety can interfere with goals of improving their mathematical content knowledge. Indeed, Ashcraft and Kirk (2001) concluded that individuals' working memory may be compromised during a variety of anxiety-evoking situations, such as attending and performing in a mathematics methods course. Based on this notion, Ashcraft and Kirk concluded that highly mathematics-anxious students may suffer from a lack of working memory resources during instruction, resources that are needed to attend to the instructional content.

Our findings also point to the possibility that quality of instruction may play a more significant role in inducing mathematics anxiety than has been previously suggested. The results point to the importance of promoting proficiency in mathematical concepts as well as procedures in elementary mathematics methods courses, because inadequacies in both types of knowledge appear to be associated with enhanced levels of mathematics anxiety. While few would dispute the importance of emphasising mathematical concepts in methods courses (National Council of Teachers of Mathematics, 2000; Vinson, 2001) the present study provides additional reason to address procedural proficiency as well (e.g., Star, 2005). Overall, the type of instruction that students receive at both the K-12 and undergraduate levels, including the relative emphasis on conceptual and procedural mathematics, may play a larger role in the development of mathematics anxiety than originally thought, which underscores the need for further study.

In general, the results bring to light the complexities surrounding the relationship between mathematics knowledge and anxiety. On the one hand, evidence that these constructs are negatively related to one another is useful because it suggests that making mathematical concepts and procedures more accessible to students early on could perhaps serve to prevent the onset of mathematics anxiety. On the other hand, when the experience of mathematics anxiety is a "preexisting condition," improving students' mathematical knowledge can be challenging because of the deleterious role anxiety plays in the learning process (Ashcraft & Kirk, 2001). Thus, the negative relationship between these two constructs may have different implications for specific individuals, depending on the duration and even perhaps the level of mathematics anxiety experienced.

Limitations and Future Directions

While this study revealed several key findings, certain limitations should be considered. First, because of the design of the study and statistical analyses used, no conclusions based on causal relationships can be made. Nonetheless, the correlation statistics revealing the relationships between procedural knowledge of fractions and mathematics anxiety, and conceptual knowledge of fractions and mathematics anxiety, explained a significant portion of the shared variance between these variables as indicated by their medium effect sizes (Cohen, 1988). Second, because the sample was relatively small, an expanded sample should be examined and reanalysed in the future. Increasing the sample and assembling it from a wider pool would lend stronger support to the findings, perhaps making them more meaningful to other researchers and practitioners. Third, our demographic data appear to suggest that the prior experiences of males and females in mathematics methods courses are different (see Table 1), at least with respect to the number of males who enrol in teacher preparation and in the number of mathematics courses they take before they decide to become teachers. While our objective was not to examine gender differences, it is possible that for males and females, fractions knowledge and the nature of mathematics anxiety may be different. This raises the possibility that gender plays an important role in the relationship between these two constructs, but without further data, this speculation remains untested.

Finally, the present research examined preservice teachers' procedural and conceptual understanding strictly within the topic area of fractions. Because previous research has demonstrated that the effect of mathematics anxiety on performance is primarily associated with complex mathematics, it is likely that the relationship between procedural and conceptual knowledge and mathematics anxiety may vary across different mathematical domains. As such, investigating these relationships within a wider array of mathematical domains would provide a potentially more valuable contribution to the existing literature.

Further study is needed to reveal more precisely the reasons no relationship was found between the researcher-developed items and mathematics anxiety. One possibility involves the tentative validity and reliability of the RD items. Perhaps a larger number of items and more fine-grained rubrics would render the RD items more sensitive to teachers' knowledge. In particular, we speculate that the low number of RD items (i.e., two procedural RD items and two conceptual RD items) limited the variability of the data because it was only possible for participants to receive one of three different total subscale scores (i.e., 0%, 50%, or 100%) on the RD component of the fractions knowledge test. As a result, the distribution of scores for the RD procedural and conceptual subscales was not similar to the distribution of scores for the KFA procedural and conceptual items, respectively (see Table 2).

Qualitative methodologies would help to reveal more precisely the constructs that are measured by the RD items and the extent to which they may be related to anxiety or other affective elements of the preservice teachers' mathematical dispositions. Otherwise said, qualitative approaches could serve to enhance the quality of the knowledge measures (McLeod, 1994). Perhaps more importantly, however, detailed observations of the participants' behaviour as they solved the mathematics problems during testing would have allowed us to capture the degree of anxiety experienced by the participants in the context of problem solving. McLeod (1989) proposed that during problem solving, affect can diminish an individual's resources that would otherwise be used to focus on the task at hand. Results from studies that support McLeod's (1989) model (see Zan, Brown, Evans, & Hannula, 2006) may shed light on *why* highly mathematics-anxious individuals experience a reduction in working memory (McLeod, 1994). Thus, methodologies that would allow for on-line assessments of preservice teachers' anxiety would make the data more contextually meaningful; additional qualitative data, such as individual interviews or think-aloud protocols, would provide even richer descriptions and possible hypotheses for the reasons for preservice teachers' anxiety in the context of a mathematics methods course.

Given that our ultimate goal in understanding mathematics anxiety is fuelled by our desire to safeguard students from it,[7] we suggest that further research be conducted with inservice teachers as well. Indeed, based on the association between teachers' mathematical content knowledge and student performance (Hill et al., 2005), and the relationship found in this study between preservice teachers' mathematics anxiety and content knowledge, further study should highlight the role of anxiety in the knowledge and actions of practising teachers. That is, because of the negative relationship between mathematics anxiety and mathematical knowledge, it is possible that there may be a link between a teacher's mathematics anxiety and his or her ability to effectively use mathematical content knowledge during instruction. We propose that a teacher's weaknesses in mathematical content knowledge may not only hinder student performance, but may also be a source of the students' own mathematics anxiety.

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[7] We acknowledge the facilitative role that anxiety may play in the learning process under certain circumstances.

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