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MATHEMATICS COMPETENCY AND SITUATIONAL MATHEMATICS ANXIETY: WHAT ARE THE LINKS AND HOW DO THESE LINKS AFFECT TEACHER EDUCATION PROGRAMS?

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Abstract

The issue of mathematics anxiety and its possible links to mathematical competence have long been of concern to mathematics educators, particularly with the potential of the effects of mathematics anxiety to be transmitted from teacher to student. Hence it is in the interests of teacher educators to understand the nature of mathematics anxiety and connections that may exist between mathematics anxiety and mathematical competence. This study examines the connections between sitting a mathematics competency test and situational anxiety in a group of 47 pre-service teachers in their first year of study. Data were analysed by grouping the pre-service teachers into one of three groups based on their passing test score (a mark of 80 – 89% or a mark of 90% and above) or their having not sat the competency test. Results indicate that there were strong correlations between the three groups of pre-service teachers in their overall responses to the anxiety questionnaires. However, when data were considered in terms of situations (working in a group, taking a test, and teaching mathematics) and domains (somatic, knowledge, cognitive, and attitude), differences were evident. The implications of these results and the potential impact on teacher education programs are discussed.

Introduction

Mathematics anxiety has the potential to impact on pre-service teachers in two ways – in their willingness to develop mathematical competence and their willingness to use their mathematical knowledge when demonstrating competence or teaching. Mathematics anxiety may result in pre-service teachers not actively working to improve their mathematics understanding (Rayner, Pitsolantis, & Osana, 2009) or shunning mathematics activities (Isiksal, Curran, Koc, & Askum, 2009). Mathematics anxiety may affect results on mathematical achievement tests (Ashcraft & Moore, 2009) or interfere in successfully completing more complex problems (Hoffman, 2010). Teachers with mathematics anxiety may rely on textbooks that focus on basic skills and limit classroom discussion (Choppin, 2011), limit their selection of teaching strategies (Swars, Daane, & Giesen, 2007), and harbour doubts regarding their teaching ability (Gresham, 2008).

Swars, Smith, Smith, and Hart (2009) discussed the importance of identifying interconnections between the beliefs, attitudes, and knowledge that teachers have in regards to mathematics. Their research investigating the effects of their teacher education program found pre-service teachers related their personal understanding of mathematics to their beliefs in their ability to teach mathematics. In a strategy to avoid exposing their limited knowledge of the content of mathematics, many pre-service teachers may use textbooks and other pre-prepared commercial worksheets when teaching mathematics (Choppin, 2011). Aspects of the effects of mathematics anxiety on pre-service teachers is reflective of research with students. Ashcroft and Moore (2009) proposed that the avoidance of mathematics would also be evident in the classroom by students with mathematics anxiety not engaging with the content nor participating in class.

Mathematics anxiety can be viewed in terms of domains and in relation to different situations. Cavanagh and Sparrow (2010) proposed a construct model of mathematics anxiety that contained three domains - somatic, attitudinal, and cognitive - that could be used for measuring student anxiety when doing mathematics with others or taking a mathematics test. This model was further developed to incorporate a mathematical knowledge domain, and, with the addition of the situation of teaching

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mathematics, was used to investigate mathematics anxiety in pre-service teachers (Cooke, Cavanagh, Sparrow, & Hurst, 2011). Their findings indicated that pre-service teachers were more likely to indicate mathematics anxiety within the mathematical knowledge and cognitive domains. Later research incorporating a test for mathematical competency found the overall measures of mathematics anxiety cannot simply be used to predict the mathematics competency of pre-service teachers (Hurst & Cooke, 2012). This was in contrast to Ma and Xu's (2004) findings indicating a strong relationship of low mathematics achievement preceding later high mathematics anxiety. However, it may be that the relationship between mathematics anxiety and mathematics achievement may not be straightforward for pre-service teachers.

Methodology

The study was based within the constructivist ontology and the social constructionist epistemology (Crotty, 1998) as the area of interest was the pre-service teachers' self-reported anxiety. Two instruments were used. The first instrument was a three part questionnaire designed to measure pre-service teacher responses regarding their anxiety when thinking about working on mathematics in groups with others, thinking about taking a test in mathematics, and thinking about teaching mathematics (see Cooke, Cavanagh, Sparrow, & Hurst (2011) for a detailed description of the instrument). A four point Likert Scale was used for each of the 22 statements contained in each of the three parts. Pre-service teachers who strongly agreed or agreed with the statements within the questionnaires were indicating they felt anxious. When responses were scored, values of 1 and 2 respectively were allocated to the responses. Conversely, pre-service teachers who disagreed or strongly disagreed with the statements within the questionnaires were indicating they did not feel anxious. When responses were scored, values of 3 and 4 respectively were allocated to the responses.

The second instrument incorporated an on-line mathematics competency test (see the appendix for examples of the types of questions). The test was designed to address the pre-service teachers' conceptual understanding in mathematics. The pre-service teachers could sit the test once at any time during the semester to achieve the pass mark of 80%.

This paper addresses data collected for those students who completed the questionnaire and who registered for, and/or sat, the competency test (n = 57). Of these students, 15 registered for but did not sit the test, 10 achieved marks ranging from 40% to 78%, 16 achieved marks in the range of 80 – 89%, and 16 achieved 90% or above. The questionnaires for the 10 students who achieved marks within the 40% to 78% range were not viewed nor included in the analysis as it was believed that the range of marks for the number of students was large and this could make it difficult to interpret the results.

Research Questions

When pre-service teachers are considered by groups based on whether they attempted a mathematics competency test and, if they did, achieved marks in the 80 – 89% range or achieved marks 90% and above, what are the relationships between the average mathematics anxiety reported for the four domains over the three specified situations? Specifically:

1. Were there similarities between the levels of mathematics anxiety reported by the pre-service teachers who did not attempt the mathematics competency test and those who achieved marks in the 80 – 89% range or achieved marks 90% and above?
2. When the three situations are considered for each of the four domains, are there differences in the levels of mathematics anxiety reported by the pre-service teachers who did not attempt the mathematics competency test and those who achieved marks in the 80 – 89% range or achieved marks 90% and above?

Results

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Overall mathematics anxiety

The size and direction of the linear relationship between the average anxiety scores for the pre-service teachers who had not attempted the test and the pre-service teachers who had passed, either with a mark in the 80 – 89% range or 90% and above, for each situation for each a bivariate Pearson's product-movement correlation coefficient (r) was calculated. The bivariate correlations between the pairs of the three groups of pre-service teachers were strong and positive; between the average scores for the pre-service teachers who had not sat their test and the average scores for the pre-service teachers who achieved marks in the 80-89% range $r(10) = .847$, $p<.001$; between the average scores for the pre-service teachers that had not sat their test and the average scores for the pre-service teachers who achieved marks 90% and above, $r(10) = .925$, $p<.001$; and, between the average scores for the pre-service teachers who achieved marks in the 80-89% range and the average scores for the pre-service teachers who achieved marks 90% and above, $r(10) = .905$, $p<.001$.

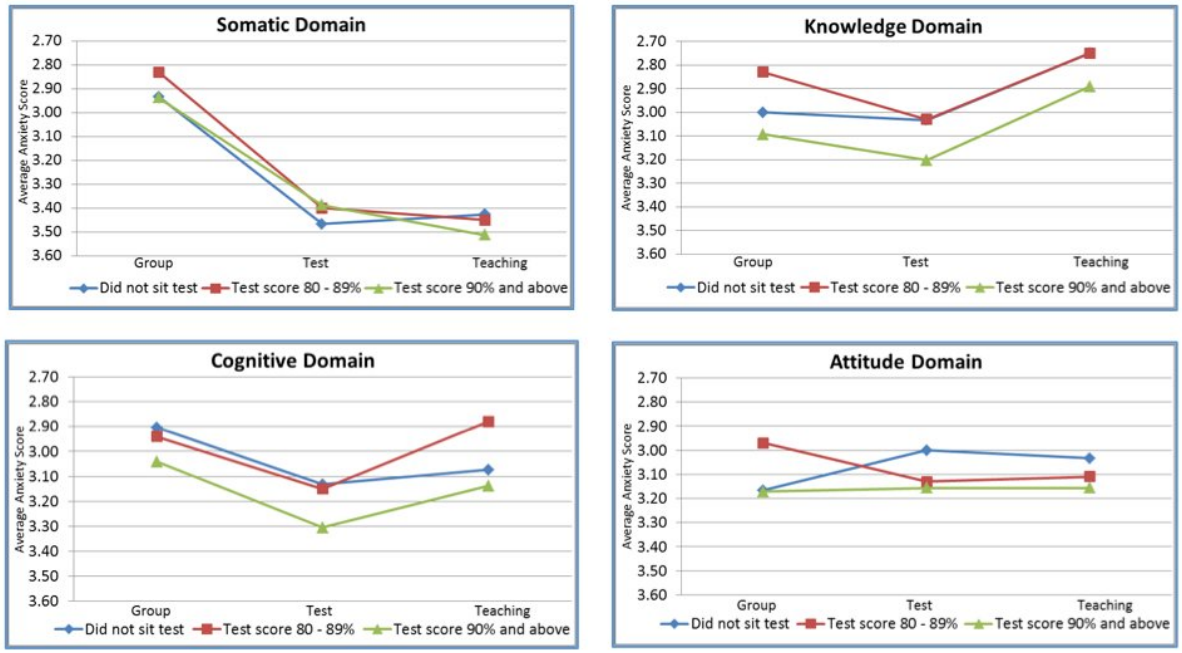

Figure 1. The average mathematics anxiety for the three groups of students for each situation by domain

Mathematics anxiety for the three situations for the somatic domain

Differences are evident when student anxiety scores are averaged for the pre-service teachers in each group and then graphed for each situation and each domain. As shown in Figure 1, the average anxiety scores for the three groups of pre-service teachers behave similarly over the three situations for the somatic domain. However, the results are very different from the other three domains, with the relationship between the three situations creating a markedly different shaped graph. In addition, the pre-service teachers had responded that they had lower average anxiety for the somatic domain for teaching as indicated by the higher average anxiety ratings for the test and teaching situations that were evident for the other domains.

Mathematics anxiety for the three situations for the knowledge domain

The graph for the average pre-service teacher anxiety scores for each group in the knowledge domain show a lower level of anxiety for pre-service teachers who had achieved 90% or above in the mathematics competency test, with the pre-service teachers who had not attempted the test and the pre-service teachers who achieved marks in the 80-89% range having average anxiety scores that were similar and lower, indicating higher anxiety, than pre-service teachers who had achieved 90% or above in the mathematics competency test. However, all pre-service teacher groups had the lowest average

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anxiety scores for teaching, indicating higher anxiety was reported. For the group situation, pre-service teachers who achieved marks in the 80-89% range had average anxiety scores that were lower, indicating higher anxiety, than pre-service teachers who had not attempted the test.

Mathematics anxiety for the three situations for the cognitive domain

The graph for the cognitive domain shared similarities with the graph for the knowledge domain. As with the knowledge domain, the graph for the average pre-service teacher anxiety scores for each group in the cognitive domain show a clear lower level of anxiety for pre-service teachers who had achieved 90% or above in the mathematics competency test. For the teaching situation, pre-service teachers who achieved marks in the 80-89% range had average anxiety scores that were lower, indicating higher anxiety, than pre-service teachers who had not attempted the test.

Mathematics anxiety for the three situations for the attitude domain

The average anxiety scores for the pre-service teachers who achieved marks in the 80-89% range were lowest (indicating higher anxiety) for the group situation, whereas the average anxiety scores for pre-service teachers who had had not attempted the test were lowest for both the test situation and teaching situation, indicating higher anxiety. The pre-service teachers who had achieved 90% or above in the mathematics competency test had very little difference in their average anxiety scores across the three situations.

Discussion

The findings of strong positive correlations for the mathematics anxiety reported for the domains and situations for the three groups of pre-service teachers shows that, overall, regardless of mathematical competency, the pre-service teachers responded similarly to the questionnaires. There was a slightly stronger correlation between the students who had yet to attempt the test and those who achieved marks of 90% or above than between either of these groups and the students who achieved marks in the range of 80 – 89%. This may be related to the pass mark setting of 80%, with the pre-service teachers interpreting marks within the 80 – 89% range as "just passing". The motivation behind the pre-service teachers not attempting the test could not be determined with the existing data, and it cannot be assumed that pre-service teachers have the mathematics competency sufficient to teach mathematics nor that they are personally competent in mathematics (Hamlett, 2010).

When the results for the pre-service teachers were considered by groups based on whether they attempted the mathematics competency test and, if they did, whether they achieved marks in the 80 – 89% range or achieved marks 90% and above for each of the situations for the four domains, different patterns emerged. A comparison of the four domains shows that pre-service teachers from the three groups responded to the questions in a similar way for the cognitive and knowledge domains, with the average responses for all groups of pre-service teachers similar for the group and teaching situations (that is, higher average anxiety) and lower for the test situation (that is, lower average anxiety). However, the responses from the teachers in the group who achieved marks in the 80 – 89% range had the highest average mathematics anxiety for the group situation within the knowledge domain and the teaching situation in the cognitive domain. The responses for the three situations for the somatic domain, particularly the teaching situation, were different to the other domains, with the averages for the three groups of pre-service teachers being closer to the averages for the test situation rather than closer to the averages for the group situation. In addition, the results for all three groups of teachers followed very similar patterns with little difference between the averages. Finally, the third pattern emerged for the attitudinal domain, with pre-service teachers who achieved 90% or above on their mathematics competency test not differing in the average mathematics anxiety reported for the three situations.

The decrease in mathematics anxiety for the test situation in the knowledge and cognitive domains

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may reflect pre-service teacher perceptions of "thinking on their feet". If mathematics anxiety results in a reduction of working memory (Ashcraft & Moore, 2009), then students may feel more anxiety when they perceive a lack of opportunity to "re-do". In a situation where they have to "think on their feet", such as when they are discussing their work with their classmates or are teaching a class, they do not have the option to erase, rewrite, or retype an answer. This scenario reflects the avoidance of classroom mathematics activities by students with mathematics anxiety proposed by Ashcroft and Moore (2009).

The "immediacy" of completing mathematics activities in groups may connect to the potential of mathematics anxiety to impact on pre-service teachers and their own willingness to engage constructivist rather than traditional teaching practices (Swars et al., 2007), particularly if the teacher is "engaged in thinking about their students' understanding of the subject matter" (Ogan-Bekiroglu & Akkoc, 2009, p. 1177). Higher teacher mathematics anxiety could lead to less constructivist classroom practices that involve the shared control aspect of constructivism (Savasci & Berlin, 2012). These factors could be considered in terms of what Walshaw and Brown (2012) referred to as "collectivities on thinking and actions" (p. 196). Likewise, if the pre-service teacher is more anxious regarding working in groups and teaching, particularly within the knowledge and cognitive domains, it may affect their self-efficacy and, in turn, the pre-service teacher's willingness to consider teaching in an environment where students are encouraged to engage in discussions with each other and the teacher, as the pre-service teacher will need to be able to draw upon their knowledge in the discussions (Schunk, 2004).

However, it should also be noted that pre-service teachers are on the cusp between being a student and a teacher. This combination of the dual role may require teacher educators to consider both the pre-service teacher as a student and the pre-service teacher as a teacher. Reichwein Zientek, Yetkiner, and Thompson (2010) state "teacher training and professional development programs need to educate teachers on how to reduce mathematics anxiety levels" (p. 436), particularly in light of what they considered was the potential impacts of student mathematics anxiety on student achievement in mathematics. Focusing on the cognitive and mathematical knowledge domains would align with Martin and Marsh's (2008) consideration of academic buoyancy, as academic buoyancy could be more applicable to threats to pre-service teacher confidence, drops in motivation, and lack of engagement, just as Martin and Marsh noted occurred with students. In addition, they proposed that anxiety would be detrimental to academic buoyancy, though they considered that it "may trigger a 'fight' rather than 'flight' response" (p. 59). Incorporating Johnson and vanderSandt (2011)'s terminology, students may be more likely to "sweat" when thinking about completing mathematics tasks in a group situation than in a test or teaching situation.

But then, as Brown, Westenskow, and Moyer-Packenham (2011) found, mathematics anxiety does not automatically lead to mathematics teaching anxiety. This may indicate that teacher educators need to target mathematics anxiety and mathematics teaching anxiety differently, beyond the dichotomy of pre-service teacher as a student and pre-service teacher as a teacher. In addition, it may be a finer distinction where the domain and situation also need to be considered. Furthermore, as Brown et al. (2011) proposed in their study, there may need to be differentiation in how strategies to address mathematics anxiety are enacted as the different groups of pre-service teachers may respond differently (and negatively). However, mimicking Tirosh, Tsamir, Levenson, Tabach, and Barkai's (2011) discussion of the impact of teacher knowledge and teacher self-efficacy on classroom practice, teacher mathematics anxiety does impact on classroom practice (Choppin, 2011; Swars et al., 2007). As a result, teacher educators have no choice but to address mathematics anxiety within their teacher education programs. The question now is how to address these aspects of mathematics effectively for all of our pre-service teachers.

The effectiveness of addressing pre-service teacher mathematics anxiety through the provision of mathematics content courses has been noted (for example, Tooke & Lindstronm, 1998). Provision of such courses may help the pre-service teacher modify their beliefs about mathematics that can then feed into and affect their beliefs regarding how students learn mathematics and how they should teach

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mathematics (Beswick, 2012). If mathematics content courses are provided, appropriate assessment of the effectiveness of the professional learning needs to be built in as part of the course (Watson, Beswick, Caney, & Skalicky, 2005). However, more than mathematics content courses may be required, particularly to address negative beliefs pre-service teachers could have about their mathematical ability and the effects of their previous experiences as a student (Ogan- Bekiroglu & Akkoc, 2009). There may also be an effect created through the recall of prior mathematics experiences, both as a student within a mathematics classroom (Ma, 1999) and as a learner completing mathematical tasks (Beswick, 2011), which may contribute to mathematics anxiety

Conclusion

The research indicated that pre-service teacher average anxiety was similar within the knowledge and cognitive domains, with pre-service teachers who achieved marks within the 80-89% range for the mathematics competency test indicating higher mathematics anxiety than pre-service teachers who had not completed the mathematics competency test and pre-service teachers who achieved 90% or higher in the mathematics competency test. Apart from the attitude domain, all groups of teachers had higher mathematics anxiety for group and teaching situations than for test situations. This could indicate that the pre-service teachers were more anxious when faced with completing mathematics in a social situation where their lack of knowledge could be "found out", reflecting an avoidance of classroom mathematics activities (Ashcroft & Moore, 2009) and engagement in discussions (Schunk, 2004). In addition, the different patterns evident for the domains points to the conclusion there is an interrelationship between mathematics competency and the mathematics anxiety reported by the pre-service teachers across the three situations and within the four domains. To address this, it may be necessary for teacher educators to enact a two-level approach, considering both the pre-service teacher as student and the pre-service teacher as teacher. For the pre-service teacher as a student, providing mathematics content courses may address their mathematics competency (Ma & Xu, 2004) as well as their perceptions of what mathematics is (Beswick, 2012). In addition, this may provide mathematical learning experiences that enable pre-service teachers to experience positive mathematics learning environments where they successfully complete mathematics activities (Ma, 1999; Ogan- Bekiroglu & Akkoc, 2009). These experiences may elicit more positive responses to mathematics (Beswick, 2011) and result in academic buoyancy (Martin & Marsh, 2008). For the pre-service teacher as a teacher, building on successes with mathematical activities to develop experience engaging in mathematical discussions (Schunk, 2004; Walshaw & Brown, 2012) that provide foundations on which to base constructivist approaches rather than traditional teaching approaches (Savasci & Berlin, 2012; Swars et al., 2007) may address both mathematics anxiety and mathematics teaching anxiety (Brown et al., 2011).

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Appendix

Examples of the types of questions asked in the online mathematics competency tests.

1. An isosceles triangle has one angle of 80 degrees. What are the other angles?
2. I have fourteen hens and they have laid an average of 5 eggs over the week. If all of the eggs were to be stored, how many cartons holding a dozen will be needed to keep the eggs in?
3. Write the following number in digits – two hundred and thirty million, six hundred and seventy seven thousand, six hundred and four and twenty three thousandths.
4. A teacher had $32.85 left in his wallet after paying $92.75 cash to purchase classroom resources. How much cash did he have to start with?
5. The east paddock is a square paddock with sides of 3 km and the west paddock is a rectangle paddock with sides of 2.5 km by 800m.
    a. Which paddock has the larger area?
    b. Which paddock has the largest perimeter?
6. Which die would give you the best chance to toss a multiple of 3 – a six sided dice or a ten sided dice?