Student Attitude, Student Understanding and Mathematics Anxiety

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This paper reports on two of ten themes that emerged from a study of the impacts of a fraction teaching intervention on the mathematics anxiety and fraction competence of eight Year 8 students. The themes arose from multiple data sources and relate to Student Attitude and Student Understanding. The students identified practical, hands-on activities and group work as impacting positively on their understanding and their confidence in relation to fractions. The influence of improved understanding and confidence was also recorded as positively affecting student attitudes to fractions in particular and mathematics in general. The study highlights the connections between mathematics anxiety among middle school students and their existing understandings of and attitudes towards mathematics.

Recognised since the early 1970s, mathematics anxiety has been defined as "feelings of tension and anxiety that interfere with the manipulation of mathematical problems in a wide variety of ordinary life and academic situations" (Richardson & Suinn, 1972, p.551). It is regarded as multidimensional (Ma, 1999) having components relating to attitude, cognition and emotion that manifest in inclinations, thoughts, feelings toward mathematics. Each of these components is influenced by a range of other factors including teachers, parents and teaching (Dodd, 1992; Ma, 1999; Goldstein, 1999; Turner et. al, 2002). As well as being considered to have an attitudinal component, mathematics anxiety is also considered to be one dimension of attitude to mathematics (Ma & Kishor, 1997), and in that context can be considered as one end of a confidence-anxiety spectrum.

Hembree's (1990) meta-analysis of studies of mathematics anxiety amongst school students revealed that mathematics anxiety reaches its peak in Years 9 and 10 with Years 7 and 8 identified as significant in its development (Aiken, 1970; Hembree, 1990). These years are also recognised as a crucial period in the development of students' mathematical understanding: it is well known that rational number concepts, particularly fractions, present difficulties for many middle school students and that students' lack of competence with fractions is a major influence on their overall mathematics competence (Siemon, Virgona & Cornielle, 2001). It is, therefore, likely that both cognitive and affective factors play a role in the development of mathematics anxiety in the middle years. Ashcraft and Kirk (2001) explained that favourable attitudes and low mathematics anxiety allow an individual to enjoy and seek out mathematics experiences leading to increased mathematical competence. Conversely, poor attitudes and high anxiety are associated with avoidance behaviour and this leads to decreased mathematical competence. In addition, they found that "higher levels of mathematics anxiety are related to lower available working memory capacity" (p. 236). Their research indicated that whilst the anxiety exists, the student may find it difficult to focus their attention on the task at hand or may have distracting thoughts, which prevent them from engaging with the task further militating against the development of competence.

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In spite of the importance of the middle years, the majority of research on mathematics anxiety has involved adult students, often primary pre-service teachers. The study described here attempts to address that gap by focusing on Grade 8 students who experienced mathematics anxiety. The difficulties associated with fraction learning made this a suitable context in which to study relationships among students' mathematical understanding, mathematics anxiety and broader attitudes to the subject.

Alleviating mathematics anxiety and minimising the chances of its development are worthy goals in themselves and even more important given the impact of mathematics anxiety on students' abilities to learn the subject (Ashcraft & Kirk, 2001). To this end Dodd (1992) advocated, "The adoption of more personal and process-oriented teaching methods can help in solving this problem" (p. 296), and in a study of 1197 sixth grade students, Turner et al. (2002) found that "a perceived emphasis on mastery goals in the classroom was positively related to lower reports of avoidance". Avoidance is of course one manifestation of anxiety. It seems that when the emphasis is on understanding rather than on competition and ability, students make efforts to seek help or to improve their understanding, rather than avoid these situations. Uusimaki and Kidman (2005) recommended interventions that empower students to develop confidence as learners and highlighted the benefit of self-reflection and self-monitoring in reducing mathematics anxiety. Journal writing is a specific tool that has been used in efforts to reduce mathematics anxiety and has also been shown to increase student learning (Connor-Greene, 2000).

The Study

The study was designed to monitor in detail the impacts upon mathematics anxiety of a fraction teaching intervention. The research question of particular relevance to this paper was: In what ways is mathematics anxiety related to other aspects of students' attitudes to mathematics and their mathematical understanding?

Instruments

Mathematics Anxiety Questionnaire (MAQ). This 17-item questionnaire was adapted from that developed by Wigfield and Meece (1988) to include items about mathematics anxiety in relation to the topic of fractions as well as in relation to mathematics generally. Responses were sought on 5-point Likert scales ranging from "Not at all" to "Very much."

Fractions Tests. Two tests designed to cover the fraction understandings required at Year 8 level for all students in Tasmanian schools (Department of Education, 2007) were developed for use at the beginning (FT1) and end of the project (FT2). Both were designed in conjunction with the students' usual mathematics teacher. To minimise the possible impact of familiarity with the questions on the results of FT2, the items varied but a similar degree of difficulty was maintained. Rubrics describing levels of performance beyond correct answers were used to classify the students' understanding of each of addition and subtraction, fraction size, equivalence, mixed and improper fractions, and multiplication as low, medium or high, and also to provide an overall rating.

Interviews. Individual interview were conducted with each participant prior to the commencement of the intervention and again at the end. The initial interviews provided

insights into the students' prior experiences of learning mathematics, their knowledge of fractions, and attitudes to mathematics generally and fractions in particular. Questions asked participants to expand upon some of their responses to the MAQ and about their feelings while completing FT1. The second interview aimed to determine whether mathematics anxiety levels had changed and asked participants' about their perceptions of why this had or had not occurred. Informal group and individual interviews conducted throughout the intervention and were aimed at exploring the students' thinking about and developing understandings of fractions as well as their feelings about the topic. Questions included, "How did you feel about the lesson on fractions today?" and "Which part of the lesson did you enjoy most? Why".

Student journals. Each participant kept a journal throughout the intervention. The students were encouraged to reflect upon their feelings and ideas at the end of each lesson, initially with the aid of prompts upon which they could expand. Examples included, "Today I learnt" And "this made me feel …", and "I felt like this because …". The students were encouraged to let their feelings flow without worrying about spelling or expression.

Video-taped lesson observation. The intervention lessons were video-taped in order to record non-verbal indications of anxiety and understanding as they occurred.

Participants and procedure

The FT1 and the MAQ were administered, under the supervision of the class' mathematics teacher, to 40 students in two Year 8 mathematics classes in an independent boys' school. Based on the results, eight students who experienced the highest levels of mathematics anxiety, compared with the other Year 8 students at their school were selected to participate in the intervention. The pseudonyms Andrew, Bill, Colin, Darren, Evan, Frank, Gerry and Houston have been used for the eight students. Six intervention lessons commenced after initial individual interviews with each participant had been conducted. The lessons, conducted by the first author, made use of McIntosh and Dole's (2004) mental computation materials, and emphasised the development of conceptual understanding of fractions. Hands-on learning materials were used in order to assist students in visualising fraction sizes and locations of the number line and efforts were made to meet the individual learning needs of the students involved. The lessons involved manipulating cut-out shapes from paper, drawing shapes, working with fractions cards, rolling dice and playing fraction games. Collaborative work was an important feature of each of the lessons and was facilitated by seating all students around a central table. The lessons covered: basic concepts and representations; equivalence (two lessons); ordering; addition and subtraction; and multiplication and division. The FT2 and the MAQ were administered to the eight participants one week after the conclusion of the intervention and the final individual interviews were conducted after this.

A constructivist grounded theory approach applied in two phases (Charmaz, 2006) was used to code all of the interview data, video recordings of lessons, and student journal entries in order to identify themes (Burns, 2000, p. 441). Initial analysis involved open coding in a line-by-line fashion to identify emergent codes in each of the three data types. The data were then re-analysed using these codes to ensure they accurately reflected the data. Axial coding was then applied to make a more coherent and accessible interpretation of what was occurring (Charmaz, 2006). Axial coding provides answers to questions relating to conditions, actions

and consequences. Hence, "when, why, where, how come and by whom and how" and "what happens because of these actions" are the nature of the questions addressed by axial coding. Axial coding provides a thorough coverage of the recorded experience and "a frame for researchers to apply" (Charmaz, 2006, p. 61). To this end, themes or categories were developed. The construction of categories involved the examination of codes from each of the three data types. For instance, ten codes were grouped and categorised using the title, *Student Understanding of Fraction Concepts* (see Table 1). The codes assisted in providing a framework with which to work in an attempt to understand the implications of what was revealed.

Results

Data relevant to the research question that is the focus of this paper derived from the fraction tests, interviews, student journal entries, and the six video-taped lessons. Ten themes, *High confidence and positive attitude, Enjoyment, Improved understanding, Low confidence and self-doubt, Previous experience, Lack of understanding, Memory, Factors affecting learning, Teaching methods, and Teacher and Parental influence*, emerged from open-coding of the interview data. The journal entries gave rise to seven themes; *High confidence and positive attitude, Improved understanding, Enjoyment, Lack of confidence, Lack of understanding, Memory, Teaching methods,* and *Teacher and Parental influence*. The axial coding phase resulted in a total of 10 categories that reflected the themes from each of the three data types. The two categories that are relevant to this paper are shown in Table 1 along with codes from phase 1 that relate to them, and the numbers of participants who had at least one instance of each code in their interview or journal. For the video data the focus was on the classroom dynamics, rather than on individuals, so when codes for a participant occurred more than once within a lesson as a result of repeated verbal and non-verbal behaviour, all instances were counted and are included in the total number of occurrences. Counting the behaviour as it occurred indicated the prevalence or scarcity of particular behaviours across the lessons.

The *Student Attitude* category focused on behaviours representing attitudes towards mathematics. Most of the behaviours recorded were indicative of positive attitudes. However, in the pre-intervention interviews, only Andrew and Gerry talked about having a confident and relaxed attitude to mathematics. Both were relaxed throughout the intervention and achieved highly on both FT1 and FT2. By the end of the intervention, Andrew, Darren, Frank and Houston indicated confident and relaxed attitudes through their responses in the post-intervention interviews and specific mentions in their journal entries. When asked how his approach to fractions had changed after the intervention compared with before it, Andrew commented, "I don't really hesitate about it." In response to the same question, Frank commented, "I feel more confident with maths now … there's a better way to solve a problem without trying to rely on the teacher and get it right." Darren answered the same question by stating: "Knowing how to do fractions, I can help other people if they need help."

Anderson (2007) found in his study of Year 4, 5 and 6 students that there were "very few responses that show a positive attitude associated with a high anxiety" (p. 101), so it is not surprising that Andrew, Colin, Gerry and Houston, who were identified as having a *confident and relaxed attitude towards mathematics*, also showed a reduction in mathematics anxiety by the end of the intervention as measured by the MAQ. For instance, Andrew appeared relaxed

during the intervention lessons and participated willingly in all of the activities. He never appeared frustrated and always persisted calmly until he had completed each activity. When Andrew was asked to divide a circle into fifths and explain his drawings, he was able to explain clearly and confidently why each of his attempts leading up to the successful attempt did not work. He did not rely on the help of others and other students would sometimes look to him for help. Colin too, demonstrated self-reliance and confidence in his mathematical ability throughout the intervention lessons. When asked to show a third of a collection of cubes, Colin made the correct selection but then questioned whether he had counted correctly. When the other students did not support the answer, Colin continued to reconsider his choice and confidently asserted, "Yes, that is right." He did not give in to others' opinions but was confident with his own correct thinking.

Table 1
Categories Related to Student Attitude and Understanding

		No. students (*n*=8)		No. Instances
Category	Related codes	interviews	journal	video
Student attitude	Confident and relaxed attitude towards mathematics	4	4	-
	Focusing on getting high marks	1	-	-
	Desire to do better at mathematics	1	-	-
	Asking for help	-	-	4
	Carefully considering the mathematics before answering	-	-	1
	Becoming easily distracted	-	-	15
	Totals	6	4	20
Student understanding of mathematics	Finding difficulties with fractions	1	5	-
	Not enjoying mathematics because of lack of understanding	1	-	-
	Guessing the answer	-	-	10
	Trying repeatedly to complete the mathematics without achieving desired results	-	-	6
	Enjoying mathematics because of understanding it	2	2	-
	Improving knowledge of fractions	3	5	-
	Understanding mathematical concepts	-	-	27
	Raising hand to offer response	-	-	9
	Smiling or laughing	-	-	45
	Lacking mathematical understanding	-	-	18
	Totals	7	12	115

Gerry and Houston also seemed to have attained greater confidence in their mathematical abilities by the end of the intervention lessons. Gerry's responses on the second MAQ indicated that he felt more comfortable answering questions from the teacher and taking tests

and less worried about his ability, compared to others, on assignments. His relaxed but enthusiastic behaviour throughout the intervention and the improvement in his performance on FT2 compared with FT1 may have been influenced by his increased self confidence. Similar to Andrew, Colin and Gerry, Houston's responses on the first MAQ indicated that he valued doing well at school in general and in mathematics in particular. Perhaps consistent with Houston's desire to perform well at mathematics and the importance he seemed to place on the subject, was his response to the following item, which increased slightly from, "not at all" on the first MAQ, to "a little bit" on the second MAQ: Does it scare you to think you will be taking advanced high school mathematics?

Performance on FT1 and FT2 provided data on the students' understanding of fraction concepts. The overall ratings that achieved in the tests are shown in Table 2. Unsurprisingly, given the brevity of the intervention, the understanding of just two students improved sufficiently to change their level. Pre- and post-interviews, journals and the videoed lessons, all of which evidenced the category Student Understanding of Mathematical Concepts provided more nuanced insights.

Table 2
Participants' Overall Fraction Understanding Evident from FT1 and FT2

	Description of understanding	FT1	FT2
Low	Demonstrates little or no understanding of some of all of the following fraction concepts: addition and subtraction; size; equivalence; and multiplication.	Bill, Darren, Evan	Bill, Darren, Evan
Medium	Demonstrate some understanding of most of the following concepts: addition and subtraction; size; equivalence; and multiplication.	Gerry, Houston	
High	Demonstrates a solid understanding of all of the following concepts: addition and subtraction; size; equivalence; and multiplication.	Andrew, Colin, Frank	Andrew, Colin, Frank, Gerry, Houston

Students with high levels of fraction understanding, based on the results of FT1, seemed to have positive attitudes to mathematics and were also highly motivated. They demonstrated a focus on getting high marks and a desire to do better. According to Dodd (1992), a lack of confidence in his/herself is one of the major barriers to a student achieving in mathematics. Ashcraft and Krause (2001) acknowledged that favourable attitudes to mathematics and low mathematics anxiety allow an individual to enjoy and seek out mathematical experiences. Meece, Wigfield and Eccles (1988) found that if a student is expecting to achieve highly, they will experience less anxiety compared with a student who expects not to achieve well in mathematics. Unlike the low achieving students in this study who expressed a desire to do better, the high achieving students were proactive in their efforts to improve their performance. For example, they asked for help when they required it and they appeared never to be satisfied with not knowing. Clute (1984) found that having confidence in one's ability to do mathematics may mean having confidence to discover and explore and trust "his or her own methods of mastering the material" (p. 56). For instance, when asked to fold a circle into

thirds without drawing the thirds on the circle first, Houston asked, "Can you fold a circle into thirds? … I folded it into halves so that you had eight of them and then if you divided it into three, it won't work." The students with stronger understanding were also less likely to guess answers, but rather would carefully consider responses to mathematical questions. However, Bill and Evan, whose performances on the fraction tests were low, often showed avoidance behaviour. For instance, when asked to explain his answers, Evan often replied with statements like the following: "I don't have a clue"; "What if I haven't a clue where it is meant to be?"; "I don't know what to do!!" This finding is consistent with Ashcraft and Kirk's (2001) assertion, that poor attitudes and high anxiety support avoidance behaviour. Dodd (1992) indicated that when self-confidence in one's ability is low, performance is compromised and avoidance may result contributing to mathematics anxiety. In Lesson 3, students were each given a card with a fraction on it and asked to stand in an appropriate position along a number line at the board. Evan avoided engagement with the relevant ideas while appearing involved. When asked how he chose the position he had, he reacted quickly with, "I am just here because Colin told me to be."

Throughout the intervention, students exhibited different behaviours as a result of their degree of understanding of the mathematics. A lack of fraction understanding was noted in relation to Evan a total of 11 times throughout the lessons, a greater number than for any other students. There were also fifteen recordings of students 'Becoming easily distracted and lacking engagement with mathematics'. Fourteen of these related to Evan and one to Bill. Both students were very low achieving according to both FT1 and FT2. Evan's reluctance to engage was evident in the first lesson to which he brought a basketball. During this lesson, he was often "spinning the ball in his lap". Hence, in conjunction with a lack of understanding and low achievement levels, Evan seemed to place little, if any, importance upon understanding the mathematical concepts, but rather focused on completing the task quickly and hoping to get the right answer. There were six times throughout the lessons where one or more students tried repeatedly to complete the mathematics without achieving desired results. According to Clute (1984), highly anxious and less able students of mathematics may prefer the expository approach to teaching rather than discovery lessons as they may lack the confidence to discover and explore. This may explain why Evan demonstrated behaviours that indicated he was anxious to give answers quickly, rather than understand the mathematical concepts.

Improved understanding was also linked to enjoyment of the subject. Frank commented in his journal at the end of Lesson 2, that "It made me feel that fractions were a lot simpler" and Frank said, "I've learnt many things that don't make me so anxious now." Bill wrote in his journal at the end of lesson three, "This activity made me feel fractions are easier than I previously thought." Five of the eight students recorded an improvement in their understanding of fractions in their journal entries. For example, Gerry wrote, "I think that this has given me more knowledge of fractions which will help me through the test of school." Similarly, Houston wrote, "From the six lessons I learned a lot. I could even say every lesson I understood something better or things got clearer for me."

Discussion and Conclusions

The research question of relevance to this paper was: In what ways is mathematics anxiety influenced by other aspects of students' attitudes to mathematics and their mathematical understanding? The findings showed that opportunities for hands-on and interactive work in a supportive and relaxing environment appeared to allow students improved understanding of mathematics, in conjunction with increased confidence in their own abilities. This feeling of empowerment enabled students to develop positive attitudes to learning mathematics. Students described the intervention lessons as "providing an easier way" (Frank) and improving existing understandings (Houston). Several linked cognitive and affective aspects of their experiences, connecting ease of learning with feelings of comfort (Evan) and enjoyment. The pre- and post-interviews revealed that six of the eight students showed increased in confidence and demonstrated a positive attitude by the end of the intervention And fewer students reported worrying about explaining mathematics to the class.

The findings suggest that it is important for teachers to be aware of both the cognitive and affective aspects of learning and teaching mathematics (McLeod, 1992). They illustrate that for many students, their limited existing understanding of a topic in mathematics or their feelings of inadequacy in the subject, may lead to poor attitudes towards mathematics. It appears necessary for teachers to become aware of individual students' existing understanding of a topic in order to meet students' learning needs adequately. Students also need to be encouraged by their teachers to be involved in their learning, shifting their focus from reliance on others to personal responsibility. Goldstein (1999) emphasised the importance of teacher support and encouragement to students' motivation to understand and achieve. This study used hands-on and interactive activities with students and this appeared to be helpful to this end. However, the type of hands-on work that is provided and the way it is implemented need to be framed appropriately in order to support the learning of individual students.

The findings show the interrelationships amongst student understanding, student attitude and mathematics anxiety. They confirm the wisdom of studying cognitive and affective aspects of learning and teaching together (MacLeod, 1992) and of adopting a holistic approach to engaging students with mathematics (Turner et al., 2002).

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