Acquisition, development and maintenance of maths anxiety in young children

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Setting the scene

Now, we all know that a good understanding of maths concepts is an important part of our education and that a certain ability in the subject can define a person's career opportunities. As we move into a more technologically dependent world, there is high international competition, and mathematically brilliant minds are perhaps more important than ever. However, according to the official Programme for International Student Assessment (PISA) rankings (2015), the UK's performance in maths has fallen, with the UK dropping a position and is currently ranked 27th. In contrast, Singapore is ranked in first position and the UK has attempted to replicate how maths is taught in East Asian Countries. So, what's going on?

If you reflect upon your own classroom experiences of maths, you might perhaps recall thinking that the curriculum demands were excessive. Now place yourself in the position of a primary-school-aged child in 2018. This child now has to be able to understand Pythagoras' theorem, creating more pressure for the child and, in particular, their teacher. This pressure can create a perfect breeding ground for anxiety. With the curriculum facing consistent criticism for increasing the difficulty level in primary schools, it's perhaps easier to understand why some children who encounter small problems in the subject can start on a path towards maths anxiety.

Researchers are increasingly drawing attention to the classroom experiences in early education. As early as 1986, Skemp believed that maths anxiety developed at the age of 5–6 years in response to the classroom environment. He drew particular attention to the use of rote memorisation. This style of teaching maths prevents deeper learning of concepts and their wider application. It has also been suggested by Rossnan (2006) that maths anxiety can develop at any age and that fear is often linked to a child's first experiences of maths.

If a child's first experiences of something are not enjoyable, they're unlikely to look forward to it or aspire to make the most of it. In fact, it's highly likely that they will avoid it and eventually give up! We can all think of something that we have not started off enjoying and never gave full effort to. This can be the same with maths, and there may be other reasons for this too.

Other factors that have been theorised and evidenced by researchers include:

- Previous negative classroom experiences associated with teachers and rigid rules of maths (Hadfield & McNeil, 1994).
- Personality, in particular shyness and self-esteem (Hadfield & McNeil, 1994).
- Intellectual factors including attitude, self-doubt, confidence and viewing maths as unnecessary (Hadfield & McNeil, 1994).
- Strained relationships between students and teachers and being placed under pressure (Mata, Monteiro & Peixoto, 2012).
- Children having an awareness of an ability deficit (Erdogan, Kesici & Yuksel-Sahin, 2011).
- Acceptance of failure (Ashby, 2009).

To explore important factors in maths anxiety, research has focused on the numeracy[1] experiences of children aged 4–7 years. This is discussed in more detail later in the chapter, but it's important to highlight some of the key findings. The data, which is based on discussion groups with children, points towards other reasons as to why they may feel worried when working with numbers. These include:

- Children becoming aware of an intelligence hierarchy
- Fear of failure
- Dependence on friends and competing with peers
- Numeracy being used as a punishment

These factors suggest that the roots of maths anxiety begin in the classroom. However, the findings from this research with younger children cannot be directly compared with those of previous research. This is because maths anxiety research, until very recently, had not really considered the early years of education and had not used qualitative methods to gain direct insight with regard to feelings and experiences. This was an omission, as interviews and focus groups with children have recently shown that much can be found through discussions, and we'll explore this later in the chapter.

[1] Within this research, numeracy is referred to as the ability to reason with numbers using basic mathematical skills (e.g. addition, subtraction, multiplication) and applying these to everyday life situations. Math is referred to as the ability to use numbers and specialised operations in complex subfields (e.g. algebra, equations).

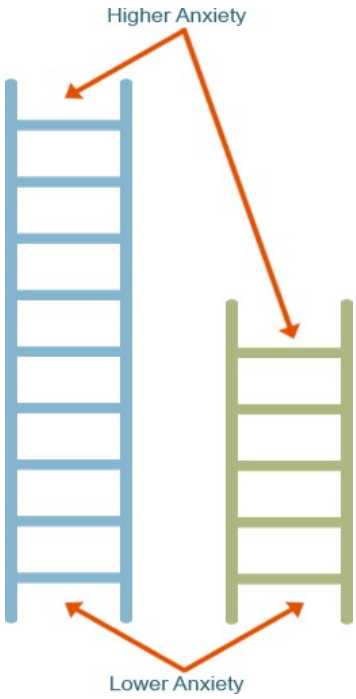
A closer look at influential factors

Maths anxiety is an emotional response that is often felt to greater extremes by those whose ability is already poor (Witt, 2012) and can lead to the avoidance of working with numbers. It is the perception of being incapable of learning and applying concepts that leads to flight responses. As well as withdrawal from maths, an individual may also experience feelings of guilt and particularly shame when faced with failure. Such emotions can reinforce the desire to avoid maths, so a vicious cycle ensues.

The avoidance of maths work has been described as the 'no-attempt' error (Chinn, 2012). This means that rather than placing effort in solving maths tasks, some simply do not try, or perhaps cannot. The no-attempt error relates to the internalisation of persistent negative feedback as a consequence of failure. Essentially, individuals blame themselves for their lack of success/ability, which relates to feelings of inadequacy (Mutodi & Ngirande, 2014). Such feelings intensify when confronted with and failing to complete complex maths problems (Ashcraft, 2002). Indeed, failure is a key maths anxiety factor that links with many others.

It is important to recognise that a person does not simply have or not have maths anxiety. At this point, try to think of anxiety as more of a ladder that ascends to higher anxiety (Figure 1) Each negative experience a person encounters in maths can be imagined as a step on the ladder, and naturally, a high frequency of negative experiences in the subject can lead to increased anxiety. Harari, Vukovic & Bailey (2013) believed that maths anxiety would emerge following a significant period of time in which a person has internalised failure and had largely negative experiences. However, we cannot say how many experiences lead to a higher level of anxiety. Bearing the previous point in mind, and to complicate matters further, consider each person's ladder has a different height. Thus, some can develop anxiety very quickly, whereas others may be more resilient and for them, it may take more negative experiences before they become highly anxious if they become anxious at all. In this sense, maths anxiety becomes a relative matter that is also defined by individual differences. This also explains observed differences in children's early maths experiences and performance.

Figure 1: Maths anxiety ladder



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In the last 10 years, articles and reports have referred to a growing maths competency problem in the UK. This, coupled with research in the area suggests that a negative correlation exists between maths anxiety and performance in children and adults (Ashcraft & Kirk, 2001; Maloney & Beilock, 2012). Government statistics reveal that almost half of the English population only have primary school maths skills, with the chairman of BT describing poor numeracy as "the hidden problem that blights the economy and ruins individuals' chances in life." (Burns, 2012). It is also claimed that this is very much a British based issue.

Further, primary care providers (teachers and parents) can influence maths anxiety. The significant role that parents play has been well documented by research (e.g. Erden & Akgul, 2010; Gunderson, Ramirez, Levine & Beilock, 2012) and suggests that it is not only the classroom environment that contributes towards early maths anxiety.

Maths anxiety and emotional responses

To immediately emphasise the observed link between maths anxiety and achievement, Ashcraft and Moore (2009) stated that no other relationship is as troublesome. We often witness athletes

underperforming due to sports performance anxiety, and this is the same in maths. However, athletes are likely to receive support from sports psychologists, whereas students and others living with maths anxiety often do not understand their own thought processes (cognitions). Like athletes in their area of specialism, high levels of anxiety have been shown to impact on performance in maths (Maloney & Beilock, 2012) yet we know that athletes have an underlying ability, even when they underperform. This can be the same case for individuals with maths anxiety. Essentially, their anxiety can mask their true ability. This has been evidenced in research such as that of Sheffield and Hunt (2007) who reduced high levels of anxiety in students, coupled with a performance increase through a simple intervention. For young children who are immediately baseline assessed in reception, if they already have some anxieties, this may be mistaken for lower ability.

We now have a greater understanding of the thought processes involved in maths anxiety. Emotional responses can also range in severity from small frustration to overwhelming disruption, such as panic, paralysis and mental disruption (e.g. Tobias & Weissbrod, 1980) This would be the point at which a person begins to cry and possibly verbalise their feelings. These may be aimed at themselves, such as, 'I'm absolutely useless and everyone else can understand this except me'. This is not a response exclusive to children; indeed, many adults can be brought to tears by maths. This highlights the emotional element. In research, individuals with maths anxiety have demonstrated poor performance when solving maths problems, even though they perform as well as others in most thinking and reasoning tasks (Maloney & Beilock, 2012). Lundberg and Sterner (2006) consider that arithmetic performance is influenced by a number of motivational and emotional factors such as helplessness, depression, anxiety and self-esteem. Based on such findings, the emotional element of maths anxiety seems particularly influential and, again, points towards a clear disadvantage for the maths anxious.

Anxiety, achievement and brain mechanisms

In 2009, Luo, Wang and Luo conducted research with middle school US students in the U.S. and found that a negative correlation existed between maths anxiety and maths performance. The overall results demonstrated that those who had higher levels of maths anxiety performed poorly on maths tasks and that negative emotional elements were also apparent; the anxiety levels left learners in a cognitively passive state. Additionally, Lyons and Beilock (2011) have shown that when those with high levels of

maths anxiety simply anticipate a maths task, they show greater activity in a particular brain network – the frontoparietal network – that is involved in the regulation of emotion. So, if this is applied to a school setting, when an already maths anxious child thinks about the upcoming maths lesson, they can start to experience a negative emotional response.

In research with children aged 7–9 years, Young, Wu and Menon (2012) also found a link between maths anxiety and the amygdala – part of the frontoparietal network that regulates emotions. Specifically, within the highly maths anxious, the amygdala was found to be linked with cortical regions that process negative emotions and was particularly evident in relation to lower problem-solving accuracy. For those with low maths anxiety, brain regions involved with emotions showed greater deactivation, meaning that they experienced less of an emotional response to working with numbers and solving problems. They could therefore perform at a much higher level than those with higher anxiety. However, when those with high maths anxiety are taught strategies to regulate negative emotions, they are able to perform at almost the same level as the low maths anxious. This demonstrates that an emotional element is influential in maths anxiety but can be alleviated to reveal genuine ability.

Factors associated with children's maths anxiety

Until very recently, research has overlooked the early years of education and when maths anxiety may begin to develop. This might seem like quite a large oversight, but research has been able to suggest and point towards what can influence early attitudes towards maths. We'll now take a look at some of these important factors and later in the chapter some direct feedback from children aged 4–7 years will be considered.

A main point to consider is that children in early education can sometimes encounter negative evaluation from peers and teachers, particularly if the children consistently underperform in maths (Beck, 1989; Ashcraft & Krause, 2007). Evaluation anxiety is thought to be another individual factor associated with maths anxiety. Donaldson, Gooler and Scriven (2002) consider this to be inherent in human beings and is encapsulated by emotions such as embarrassment and ridicule. Potential negative consequences of evaluation can lead to responses such as avoidance, and negative evaluation is

considered to be a particular issue in early childhood (Beck, 1989). In relation to maths anxiety in children, Ashcraft and Krause (2007) suggest this is learnt in the classroom and consider negative evaluation by peers, and in some cases teachers, to cause embarrassment when publicly performing maths poorly (Hadley & Dorward, 2011). This increases their chances of developing a negative self-image (or attitude), which can impact on performance (Nicolaidou & Philippou, 2003; Dowker, Bennet & Smith, 2012). These negative thoughts will drain essential working memory capacity to the point that there is nothing left to devote to task completion. Haase, Julio-Costa, Pinheiro-Chagas, Oliviera, Micheli & Wood (2012) have found that when children with maths difficulties have self-assessed their ability and feelings, their performance often negatively reflects this. In contrast, children with a more positive outlook on their ability show higher performance. What's more, research has found that children with optimistic attitudes towards maths in primary school show higher performance later into their secondary education (Yates, 2002). The opposite was found for children with pessimistic maths attitudes in primary education. This indicates that early educational attitudes can remain consistent over many years and that a good start is important.

These ideas relate to 'self-efficacy'; a theory that corresponds to social cognitive theory (Bandura, 1986). This is based on the idea that individuals will more likely engage in activities if they believe they have the capability to complete them. Self-efficacy can therefore be an outcome-dependent factor in a wide range of activities, including maths. When applying this theory to maths anxiety, some children have been found to have higher self-efficacy than their peers (Meece, Wigfield & Eccles, 1990). The effect of self-efficacy on maths was shown by Pajares and Graham (1999)who found that US children in Grade 6 with higher self-efficacy (UK age 10–11 years) were more persistent, interested and performed better at the end of the school year in comparison to children with lower self-efficacy. Thus, there is some evidence of self-efficacy as a key determinant of maths achievement. This also has an association with maths anxiety (Linder & Smart, 2010), such that those with higher self-efficacy are more likely to persist with maths, particularly when it becomes difficult. As described earlier, increasing difficulty in maths can be the point at which a person can start to experience and show more signs of anxiety – and this can happen in early education. Indeed, in research with children aged 9-11 years, Hunt, Bhardwa and Sheffield (2017) found systolic blood pressure increases when mental arithmetic

problems became more difficult; such reactivity was also shown to be related to self-reported maths anxiety.

Ashby (2009) found that children failed to understand the wider practicalities of maths and this can be linked to decreased motivation (Tella, 2007), negative attitudes, avoidance and lower performance. This is important, as motivation, task completion and seeking help are necessary for success but are badly affected by anxiety. In a questionnaire study, Anthony (2000) collected data from 92 undergraduate students and 26 lecturers to gauge agreement or disagreement with statements based on factors influencing success in maths. Poor performance was associated with students being uncertain of the skills required for maths courses or being unable to apply these appropriately. This revealed that the difficulties faced by adults relate to those identified in children and further suggests that anxiety may develop in early education and persist to adulthood. This highlights the importance of understanding the maths experiences of children. The consequences of low motivation in the early years can also persist into later education, as shown by Zakaria and Nordin (2008). By measuring students' maths anxiety in relation to achievement and motivation, they observed that low achievers often have high maths anxiety and reduced motivation, as well as lower performance.

So, to put this all together, maths anxiety in the later years can relate to low motivation in earlier educational years and may be the outcome of an apparent lack of understanding of the purpose of maths in the wider world. However, we cannot be certain of the causality of factors; we do not know whether maths anxiety is the cause or the effect. This again demonstrates the complexity of maths anxiety. Research has typically shown that higher levels of maths anxiety are linked to decreased performance. Yet in more recent research and showing the influence of motivation, Wang et al (2015) found that moderate levels of maths anxiety actually facilitate maths performance, but only when the learner has high motivation to learn, highlighting the role of individual differences.

Moving on, the avoidance of maths is another factor that can influence anxious responses and performance. Chinn (2012) found that if children perceive a maths task to be complex, this can induce anxiety and fear which is linked to task avoidance and what he called 'no attempts'. This is exactly what it sounds like: children simply don't answer a question because they see this as a better option than

providing an entirely wrong answer. Specifically, subtraction, multiplication and division place greater demand on working memory capacity, and children's avoidance of these more-complex tasks suggests that some may not have a positive belief in their ability (low self-efficacy) and may fear failure. Indeed, Chinn considered that many maths procedures are unforgiving of inaccurate memories. In light of this, it is important to remember that young children's memories are going through a development process and are restricted in how much information they can store in the short term (Croker, 2012). Some children may be better than others at storing and accessing the required information when doing maths, and is another point to consider.

Ramirez, Chang, Maloney, Levine and Beilock (2016) have explored the association between maths anxiety and achievement, with an emphasis on the problem-solving strategies that children employ. Young children use basic strategies, such as finger counting, but following repeated use, develop "problem–answer associations" (Ramirez et al., 2016, p. 84) such as understanding that 3 + 3 = 6. Building on this, children begin to use strategies such as retrieval, decomposition and reconstruction, which are suggested to be more-intensive working memory strategies (Ramirez et al., 2016). In terms of the relationship strategies have with working memory and anxiety, Ashcraft (2002) has previously shown that simple arithmetic does not require significant working memory processing, but more advanced problems, including carrying and borrowing operations place greater demand on working memory and increases anxiety. Higher levels of anxiety are associated with complex maths, such as algebraic equations due to the processes involved in order to achieve the correct solution.

Measuring maths anxiety in children: Self-assessment scales for older children

Despite the focus on adults, some research has attempted to measure the degree of maths anxiety experienced by older children. Suinn, Taylor and Edwards (1988) developed the Maths Anxiety Rating Scale for Elementary School Students (MARS-E). This consists of 26 questions (items) and uses a five-point Likert system. This means that there are five options that children can respond to for each item. The MARS-E was developed with 1,119 fourth (age 9–10, UK Year 5), fifth (age 10–11, UK Year 6) and sixth graders (age 11–12, UK Year 7) from six schools in the US. Children were asked to indicate the level of anxiety they experienced in certain situations, for example, when reading a maths chapter. The total score, indicating either higher or lower anxiety, was correlated with SATs scores. This suggests

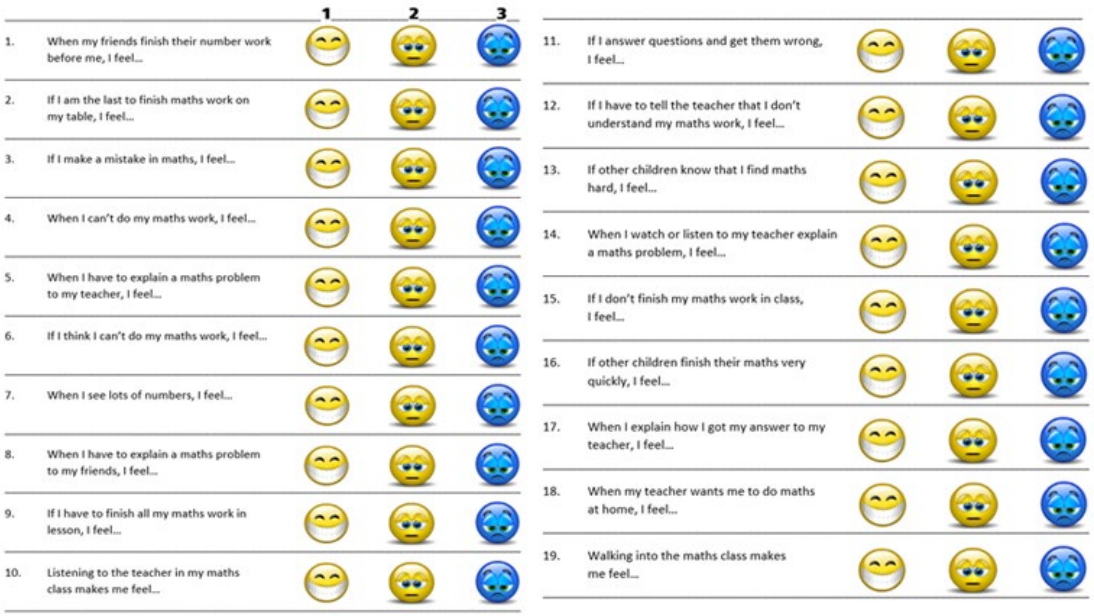
that children's self-assessment of anxiety score was reflected in their maths performance. Specifically, it was found that children had anxieties about maths tests and their performance in general. However, the age range that this scale focused on still overlooked the earlier educational years when anxiety may have already begun to develop. Moreover, maths test and general performance anxiety can potentially be the consequences of earlier negative experiences. To demonstrate this point, maths experts have discussed observing performance anxiety in much younger children when working in front of others (Petronzi, Staples, Sheffield, Hunt & Fitton-Wilde, 2018a). This implies that certain aspects of maths anxiety develop in the early years and can remain over time.

Chiu and Henry (1990) also developed a maths anxiety scale for children that consisted of 22 items: the Maths Anxiety Scale for Children (MASC). However, this again overlooks the earlier years of education. The MASC was developed with 562 children from fourth grade (age 9–10, UK Year 5) to eighth grade (age 13–14, UK Year 9) in the US. Like the MARS-E, children rated their level of nervousness in response to questions that considered, for example, their feelings when taking a maths test and when asked to make sense of maths questions. Children's self-assessment scores were compared against their maths results from the school term. The results demonstrated that children who scored highly on the MASC (higher maths anxiety) had lower achievement in maths and higher test anxiety. This clearly has implications in a school setting and shows how maths anxious children can be disadvantaged, particularly in test scenarios. Specifically, children were found to have concern with maths evaluation, learning maths and solving problems, as well as feelings of anxiety towards their teachers. While the findings were useful, the assessment scale overlooks several years of potential development of a negative attitude towards maths. In recent years, there have been some notable attempts to focus measurement on children's maths experiences, including Dowker, Bennett and Smith's (2012) measure of attitudes to maths for primary school children (aged 7 years and older) and the Modified Abbreviated Math Anxiety Scale (Carey, Hill, Devine, Szucs, 2017) for children aged 8-13 years.

Measuring maths anxiety in younger children

Researchers in the UK have developed a reliable self-assessment scale to be used specifically with children aged 4–7 years (Petronzi, Staples, Sheffield, Hunt & Fitton-Wilde, 2018b). The purpose of the Numeracy Apprehension Scale (NAS) is to support the assessment of children who may be showing signs of a negative attitude towards maths at an early age. This was the outcome of a project to develop a comprehensive understanding of how children experience day-to-day maths and what influences their experiences. Early identification can enable educators or primary care providers to intervene and support children in working towards a more positive attitude and success. The NAS was developed with 470 UK children and been to correlate with performance scores has been shown. More precisely, children who obtained a higher anxiety score on the scale typically demonstrated lower performance on a numeracy task.

Figure 2: Numeracy Apprehension Scale (Petronzi et al, 2018b)



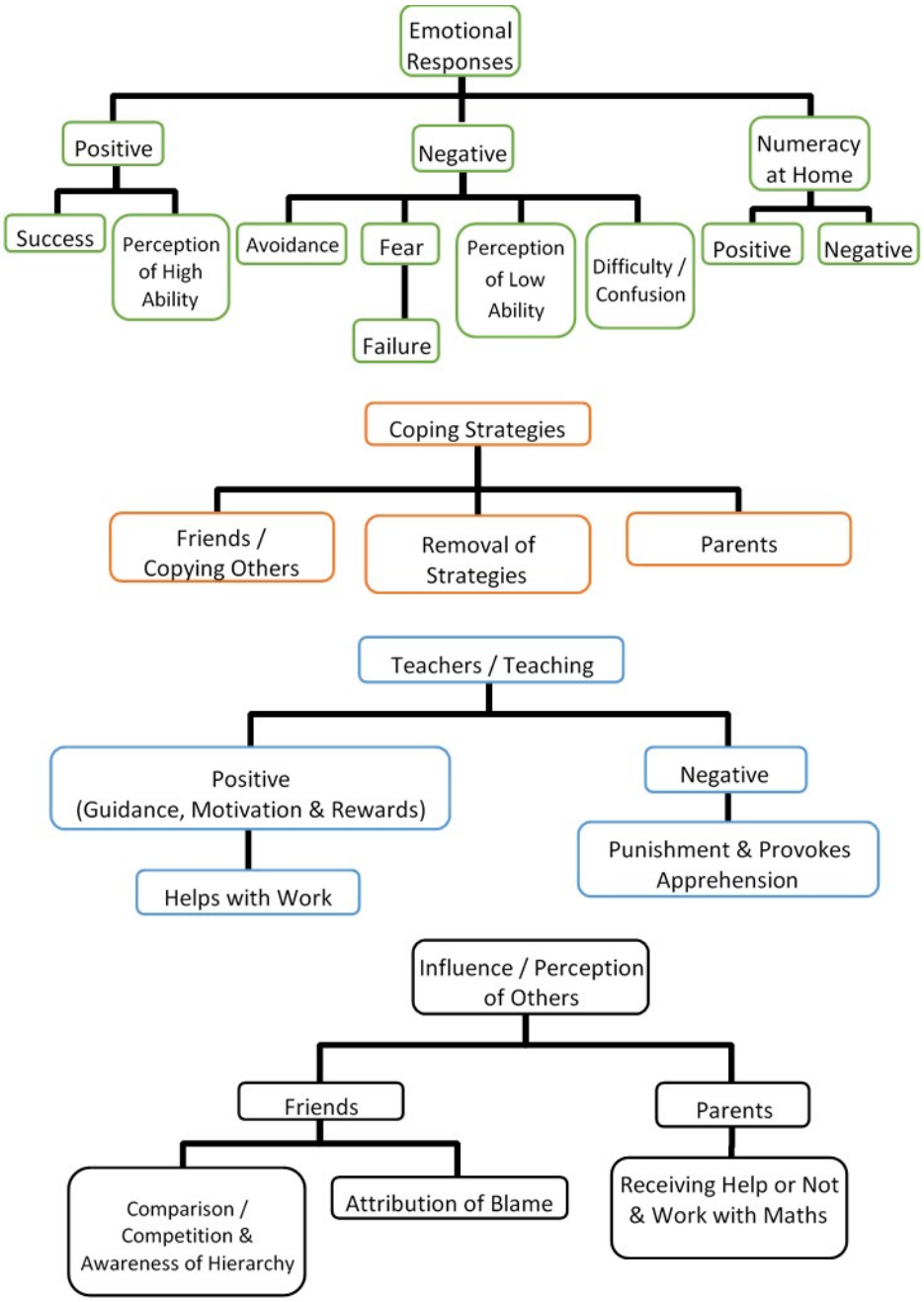
A significant premise on which the NAS was developed relates to assumptions that maths anxiety, a construct evidenced as relating to the experiences of older children and adults, is applicable to the experiences of younger children. It is therefore suggested that the term 'numerical apprehension' better describes the anxieties of children in early education. This is more representative, as at this educational stage, numeracy is taught in the classroom, rather than maths and research data suggests that maths anxiety is a subsequent and further developed issue, due to an association with complex mathematical procedures i.e. difficult multiplications, algebra and fractions (Ashcraft, 2002).

Maths anxiety in younger children: Feedback from 4-7 year olds

We now turn attention to the feedback provided by UK children aged 4–7 years (Reception, Year 1 and Year 2) who discussed their numeracy experiences and attitudes as part of a research project. This was an attempt to address our limited understanding of the origins of maths anxiety. Specifically, this research explored the factors that can shape children's attitudes towards numeracy as well as primary care providers' observations of children's attitudes and responses to working with numbers.

The research sample included children aged 4-7 years in reception (N=11), year one (N=18) and year two (N=12) at three primary schools in the United Kingdom, and parents (N=7), teachers (N=9) and maths experts (N=2). Insight was obtained from the use of focus groups. Four main themes emerged as being part of children's numeracy experiences and attitudes: (1) Emotional Responses; (2) Coping Strategies; (3) Teachers/Teaching; and (4) Influence/Perception of Others (Figure 3). For each factor, there was a clear difference in the comments made by children with a positive numeracy attitude and those with a negative attitude. It is noteworthy that children who showed a positive numeracy attitude did not make any statements in relation to punishment, avoidance, failure and fear. The following sections present findings from children and maths experts.

Figure 3: Four main themes of children's numeracy experiences



Theme 1: Emotional responses to numeracy

Young children's accounts of their numeracy experiences suggested a number of influential and interacting factors. In particular, emotions became a salient point and a difference became clear between those with negative and positive attitudes.

Success

Achievement in numeracy is an ambition and motivational force for a number of children and success promotes positive emotional responses. In particular, a sense of attainment and other positive emotions can be reinforced by reward systems that promote rivalry and clearly identify the most numerically competent children. In year one (UK age 5-6 years), children seem to have an awareness that enjoyment of numeracy results in doing more of it, making their own connections between attitude, quantity of work and performance. This suggests that those who enjoy the subject are higher achievers, in part, due to additional practice. Examples are provided here and also for subsequent themes that are discussed:

"Happy, because if you like doing numeracy, you'll have to do lots of it".

"I get a bit confident when I answer some right, then I do the same with the others".

High ability

Children independently recognise that positive emotions link to a sense of high ability, confidence and successful completion of numeracy work. A perception of high ability seemingly enables children to recognise limitations in their knowledge without suffering any negative emotional consequences and performance effects. This is supported by children expressing belief in their ability when faced with a high amount of maths work, evidencing greater resilience.

Worry/fear

Some children feel worried when presented with numerical tasks, typically believing that they lack the required level of ability – even at an early age. These worrisome thoughts place the child at risk of developing negative attitudes towards numeracy, and in relation to the hierarchy of needs (Maslow, 1943) will restrict a child in establishing safety in education and self-actualisation. Moreover, fear and perceived inability has an association with a fixed mind set (Dweck, 2006). For these children, attention diverts from work to focussing on worries and can inhibit working memory (Ashcraft & Krause, 2007) which results in a greater performance decline. Physiological anxiety is also associated with numeracy

apprehension, such as “feeling your heart beating so fast” and avoidance tactics present struggling children with the opportunity to conceal difficulties. In this scenario, a lack of motivation may develop through consistent low performance and a lack of enjoyment.

“Sometimes you’ve got like twenty answers and you think, how am I going to do this?”

“Sometimes I’m a little bit bored and then I want to get out”.

Failure

Failure in numeracy is a prospect that produces fear and critical self-evaluation in children. Constant apprehension about failing links to a decline in task completion. Thus, if a child consistently fails to complete work, their attitude towards numeracy may reflect this. Moreover, genuine ability may be masked by a focus on failure, with some visualising the negativity failure will bring, rather than the positivity of success.

“A bit ashamed if I got it wrong”.

“I always get it wrong”.

Low Ability

Some children genuinely have no confidence in their numeracy ability and although they attempt work, they may also have pessimistic outcome expectations. In this scenario, children seem to be aware of their specific weaknesses, and negative emotions intensify when these aspects are called upon in lesson, for example, multiplication. Furthermore, some children aspire to complete numeracy work competently, but often feel incapable of doing so. This shows that despite some children developing a low sense of self, their motivation and attitude can remain intact and there are opportunities for intervention.

“I’d work it out, but probably get the wrong answer”.

Difficulty/confusion

Children expressed significant emotional negativity when discussing experiences of attempting hard work. The difficulty of numeracy work is either met as a positive challenge by those who are secure with numeracy or as an obstacle by others. Anger and frustration was expressed towards difficult numeracy. In younger children, confusion was based on number recognition and representation and further contributed to negative attitudes to numeracy. Pressure was expressed as a consequence of confusion, and children were conscious that when they are unable to do the work, they fall behind others – also highlighting the competitive nature of the subject. A sense of being under pressure arose from a perception of the teacher or fellow pupils observing their struggle.

"When I'm writing the numbers I sometimes get them back to front and I don't really notice".

"Like if it's two, you say five because they look the same".

Theme 2: Coping strategies

Children uncomfortable with numeracy revealed methods they would employ to cope with numeracy lessons. Significant emphasis was placed on friends and how their help eased the pressure of the situation, whilst other children discussed co-developed tactics to achieve the correct answer without being 'found out'. This may explain how some children's discomfort with numeracy and low performance can remain unnoticed in the early school years. Additionally, when coping strategies were removed, apprehension became dominant. Parents acted as another coping strategy for some children and were utilised whenever numeracy became difficult; for others, though, this strategy was either not in place or was employed to a lesser extent.

Friends

Friends are a clear vessel of help in the classroom and typically have a positive impact on children's emotional responses. However, for some, having to accept help from peers caused negativity as this seemingly confirmed their inability to understand and complete the work. Others were able to recognise

that their lower ability was not ideal and could accept help in an attempt to learn from this, while others were simply happy to 'survive' the lesson. Demonstrating this survival approach, some children will identify those that are confident with numeracy and exploit this ability for their own needs - typically by copying. Indeed, a great deal of effort is placed on numeracy lesson 'survival' rather than attempting to complete the work itself.

"You just wait until they say the answer or you can just copy their work".

Removal of Strategies

When presented with the situation of numeracy strategies being disallowed (typically for testing scenarios) increased worry can arise in children who are most at risk of numeracy apprehension. Without their coping strategies, they may feel unable to attempt work and leave questions unanswered. Some children believe that when help is forbidden, their work will be wrong, and the teacher will be frustrated with them. Others have expressed concern about isolation from their friends when help is removed.

"Sometimes the teacher says you're not allowed to be helping people so you just carry on with your own work and it's kind of difficult and you can't really concentrate properly".

Parents

Highlighting the importance of numeracy support outside school, children secure in their ability typically receive help from parents and this facilitates their learning. Children with parents in a position to help with numeracy will be spared from feeling incapable and apprehensive, particularly when the difficulty level increases.

"If it was really hard, I would ask my dad to help me".

Theme 3: Teachers and Teaching

For some children secure with numeracy, teachers were regarded as the instructor who guided them through work and stated that listening to instructions results in work being correct, demonstrating their consideration of behaviour as a determinant of success. These children also take comfort knowing that the teacher is observing them and feel valued and supported. In contrast, observation causes apprehension for those uncomfortable with numeracy. Some children have also expressed happiness when explaining answers to the teacher as this provides an opportunity to demonstrate their knowledge. However, some children experience fear and apprehension in response to all aspects of their teacher's presence.

Theme 4: Influence/perceptions of others

It has been established that children's numeracy experiences are influenced by others and the child's perception of those persons being either a facilitator of work or a threat. A strong emphasis was placed on friends as a coping strategy in numeracy, with the high apprehensive relying heavily on their input to ease pressure and remain unidentified. However, other factors surfaced relating to friends, particularly competing with them, and attributing blame to them for failure. Though parents were also previously discussed as a coping strategy, more specific details were expressed by children and clearly influenced their approach and attitude to numeracy.

Friends: Comparison/competition and awareness of a hierarchy

Children who are secure in their numeracy ability may view the subject as a competition and regard fellow students as rivals. However, the findings suggest that numeracy is a subject that all children acknowledge as highly contested, yet those of lower ability are often unable to maintain the pace and work load of higher performing children. Indeed, by necessity, their focus is simply surviving each lesson. The competitiveness of numeracy results in negativity when children finish work after others and some children internalise the cause of their failure. The speed of which numeracy can be completed is a key factor, and for some, if answers are different to those of others, they typically assume that their work is wrong which exemplifies pessimistic attitudes (Yates, 2002).

"They might have got it right and we might have got it wrong".

Also revealing a sense of competition, children in year one and two (UK age 5-7 years) have indicated an awareness of an intelligence hierarchy established through numeracy. As an example, a child conceded that a group of children received more challenging work as they were "brainier" than others. This demonstrates how children in early education are already comparing themselves against the ability of others, using numeracy as the subject to define intelligence.

"I sometimes beat them, I just think it's a race".

"Rockets are more brainier than stars, so stars get different work from rockets".

Parental support

The assurance that parents can help children with numeracy at home can prevent panic and fear. Although secure with numeracy, children typically require assistance from parents when difficulty increases. This allows them to overcome issues immediately and without experiencing negativity. This is in contrast to children who do not receive much help at home. It is worth considering that as techniques and terminology have altered significantly in numeracy, the methods of some parents are now out-dated and meaningless to children, potentially confusing them further. The research showed that a child's comfort with completing numeracy at home resulted from their parents working with maths. This demonstrates the value of parents providing an intellectually stimulating environment in the household (Mazzocco, 2007).

Motivation and educational psychology theories

If we apply numeracy apprehension to motivational and educational psychology theories, such as Maslow's hierarchy of needs (1943) (Figure 4), early difficulties and negative self-evaluation impede children in achieving esteem and self-actualisation. Indeed, many children will struggle to surpass the 'safety' phase of their hierarchy of needs as their anxiety denotes a fear of working with numbers and is related to similar factors, such as failure. In the same way, children cannot achieve educational

stability and security when they are experiencing worrisome thoughts in a classroom setting. Although dated, this theory continues to inform new ideas around children's needs and education.

Figure 3: Maslow's hierarchy of needs

More recently, Dweck's (2006) Mindset Theory relates to children viewing their intelligence as stationary and effort as ineffective. Applying this theory, children who experience worrisome thoughts will avoid challenges as their failure highlights a lack of intelligence. In contrast, a growth mind set applies to children who regard intelligence as changeable and embrace numeracy challenges as a platform for improvement. We've seen evidence of this in children's feedback as they consider effort as entirely worthwhile.

Insight from maths experts

We've explored children's feedback, but let's now consider insight from maths experts obtained in the same study (Petronzi et al., 2018a). Working as university academics, the experts that took part had also taught and observed maths attitudes and behaviours in primary, secondary and further education. Their insight was obtained in interview settings which allowed for a detailed conversation about factors deemed influential in how children experience numeracy in early education.

Main findings

Pressure and numeracy in public

Maths experts discussed occasions where they had witnessed children being asked to solve numeracy problems in front of others, placing them in a negative pressure situation. Expanding on this, males were identified as being generally more confident when completing numeracy in front of others and being less affected by mistakes in comparison to females. This is in line with Devine, Fawcett, Szucs, & Dowker (2012), who found males to have more persistence and resilience following mathematical mistakes. Females were discussed as showing behavioural signs of anxiety in classrooms when attempting to avoid solving a numeracy problem in front of others (Mutodi & Ngirande, 2014).

"Males are generally more confident and also more confident at making mistakes".

Specifically relating to apprehension, a maths expert discussed the consequences for children who became overwhelmed with the pressure of numeracy, claiming that sudden reactions such as crying have been observed and are specific to the subject of numeracy.

"Crying, literally crying. I could say almost in no other subject, only in maths".

A maths expert expressed their own feelings of anxiety when teaching the subject, demonstrating an inherent anxiety associated with numeracy and when solving numerical or mathematic problems in front of others (Beilock, Gunderson, Ramirez, & Levine, 2010). The inherent nature of numeracy and negative public experiences may place some children at risk of developing aversive emotional responses to working with numbers, and will impact on their learning, ability and relationship with the subject (Ashcraft et al., 2007).

Difficulty of numeracy

Maths experts discussed the perceived difficulty of numeracy as contributing to the formation of how learners experience the subject, including why some seek to avoid work. Polarities in feelings towards numeracy are often apparent and reinforced with self-critical or positive evaluations, as we have seen from children's insight.

"If people actually begin to perceive it as being a hard subject,that will increase their anxieties"

The right or wrong nature of numeracy was also identified as a further issue of the subject that links to difficulty and apprehensive reactions (Chinn, 2012). Once anxiety develops, maths experts conceded that this can take some time to alleviate. Reflecting upon their experience in primary schools, the method of teaching numeracy procedurally was also discussed as contributing to a perception of difficulty and ultimately, apprehension.

Additionally, a proportion of the difficulty of numeracy may be attributed to the language used in the subject, particularly when children encounter worded problems (Ginsburg, 1977). Maths experts further discussed concepts, such as learning and working with the teen numbers, subtraction and division as being particularly difficult for children and causing a degree of apprehension (Chinn, 2012).

"Moving into teen numbers is a problem for young children and subtraction as an operation is also tricky for children. There's a similar issue with division".

Demonstrating that negative numeracy attitudes are being learned in the early years when some children encounter difficulty, maths experts revealed that undergraduate students' years bring with them established negative attitudes towards the subject.

Influence of teachers (negative)

Some teaching methods have been implicated as causing boredom and producing a lack of motivation, resulting in counterproductive behaviours such as talking with friends. Maths experts spoke of children encountering difficulties with incorrect numeracy terminology used by teachers who may not be confident with the subject. Thompson and Rubenstein (2000) also consider that teachers often forget that mathematical language is foreign to many students and identify issues with the vocabulary used in maths to convey the "surface structures" that help students form ideas as they progress to the "deeper structures" of maths concepts. Furthermore, maths experts believed that some student teachers underestimate the importance of being able to teach basic numeracy/maths and concept understanding in a primary school classroom (Uusimaki & Kidman, 2004).

Low sense of ability

Maths experts revealed some of the behaviours and attitudes of children who felt they were of low numeracy ability, which typically include disengagement from the subject and refusing to do the work. This demonstrates a pessimistic explanatory style and a decrease in persistence and assertiveness (Yates, 2002).

"There was a sense that they felt that they couldn't do it and therefore, weren't prepared to engage with it".

In these cases, children may have adopted the belief that if they do not engage with numeracy, they have not failed to complete the work, as they have chosen not to do it.

High sense of ability

Maths experts discussed the belief of ability as being a motivator to challenge the subject further (Pajares & Graham, 1999) and also claimed that the performance gap would increase between children who were secure with numeracy and those who were not.

"Maths is quite an intuitive area; if you have ability, you're quite keen to move on and challenge yourself".

Maths experts considered age seven to be the point that children become aware of their ability and attitudes towards numeracy, potentially determining their trajectory in the subject for the remainder of their education. However, this contradicts Mcleod (1993b) who considered ages 9 to 11 years to be the critical stage for the development of maths attitudes and emotional reactions. Additionally, it was discussed that those with a high sense of ability may not necessarily understand a concept immediately but have an intrinsic motivation to learn and find a solution.

Influence of parents (negative)

Maths experts discussed the role of parents in influencing how children experience numeracy and identified that many parents in the UK have faced difficulty in their own numeracy/maths experiences. They considered the possibility of negative attitudes being transferred to children (Gunderson et al.,

2012). Developing the idea of transference of attitudes, maths experts revealed experiences of parents stating that due to their own inability in numeracy, they knew their child would also have difficulties with the subject (Gunderson et al., 2012). If the child is aware that they are not expected to perform well, it was thought that they will respond according to this self-fulfilling prophecy.

"A lot of parents come into school and say; I wasn't good at maths so they're not going to be good at maths. The child listens to this".

Offering an alternative perspective, maths experts briefly considered the pressure placed on children to perform as having a detrimental effect. This may lead to self-consciousness about numeracy performance related to not meeting parental expectations (Yuksel-Sahin, 2008).

Comparison/Competition

Maths experts discussed children as comparing themselves against others in numeracy lessons and this would regulate how they perceived their own performance. Discussions revealed that when comparing ability, the children who have difficulty with numeracy begin to develop a negative self-perception (Erdogan et al., 2011) as they realise that other children are more secure with learning and doing numeracy. It also emerged that children who are secure with their numeracy ability may negatively perceive children who have difficulties, with one maths expert considering them to be patronising. When children who struggle with numeracy are aware of how they are negatively perceived by the more secure children, this is likely to further affect how they perceive themselves and their ability.

Fear/anxiety

Failure is a main component of the fear associated with numeracy. In some cases, children are unsure of what method to use and are fearful to write it down, with their uncertainty being further compounded by time restrictions (Wong & Evans, 2007). In other instances, in order for some children to hide their failings, maths experts had observed them sitting back in lessons and not attempting the work. In this case, the children have adopted the belief that numeracy work is beyond their ability and choosing not to work is more self-preserving than to be stigmatised as failing (Chinn, 2012). A fear of failure in

numeracy was also attributed to the right or wrong nature of the subject (Chinn, 2012). If experience has taught children to be fearful of wrong answers, they are unlikely to attempt their numeracy work and disengage with the subject. This disengagement can be evident through the remainder of their education.

Avoidance

Maths experts discussed in detail the numeracy avoidance behaviours that children have displayed. This is supported by previous research, in which a significant negative correlation was shown between being nervous about maths and the intention to take on more maths (Meece et al., 1990). An initial point was that those who enjoy the subject are eager to make the teacher aware of this (Petronzi et al., 2018a), whereas those that are not secure with their numeracy ability will attempt to hide their work. Maths experts stated that children with incorrect work will often cry and also discussed extreme behaviours - revealed by parents - that children would display at home to avoid doing numeracy work, e.g. tantrums, although these behaviours were not evident in the classroom. However, they revealed that some children would ask to go to the toilet when given numeracy work and others would simply begin to display negative behaviours and become disruptive as a form of avoidance. Avoidance will only serve to increase the gap in concept knowledge and performance between them and other children.

Chapter summary

Until recently, the extant literature on maths anxiety has given limited attention to the early years of numeracy education. Knowledge surrounding the onset of maths anxiety has therefore been limited with uncertainty of whether factors in the early educational years have an association with this. A number of factors may influence the development of apprehension and include: negative evaluation from peers and teachers; pessimistic attitudes; low confidence; low self-efficacy; a resignation to failure; worry relating to performance; reduced motivation and; avoidance of perceived complex tasks. Norwood (1994) and Hadfield and McNeil (1994) considered that maths anxiety is a product of multiple factors, rather than one influential cause; we support this.

The research findings presented in this chapter suggest that numeracy apprehension may develop as a precursor to maths anxiety. The findings indicate that children in early education can begin to develop worrisome thoughts about working with numbers and this can occur much earlier than once considered. The findings of Petronzi et al. (2017a) relate to only a single area within the UK and more widespread research would be beneficial. Nonetheless, it is necessary for future researchers to consider the multitude of potential influences on the development of numeracy apprehension and evaluate intervention techniques that are known to be efficacious with older children to minimise the development of numeracy apprehension at its roots. Moreover, novel approaches to promoting and maintaining positive attitudes to numeracy should be explored and measured in future research in the area.

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Appendix

NAME_____ Total Score_____

The Children's Mathematics Anxiety Scale UK (CMAS-UK)

The items in the questionnaire refer to day-to-day numeracy situations that may cause anxiety for children aged 4-7 years. For each item, children can place a circle around the face which describes how they feel in relation to the situation.

1. When my friends finish their number work before me, I feel...			
2. If I am the last to finish numeracy work on my table, I feel...			
3. If I make a mistake in numeracy, I feel...			
4. When I can't do my numeracy work, I feel...			
5. When I have to explain a numeracy problem to my teacher, I feel...			
6. If I think I can't do my numeracy work, I feel...			
7. When I see lots of numbers, I feel...			
8. When I have to explain a numeracy problem to my friends, I feel...			
9. If I have to finish all my numeracy work in lesson, I feel...			
10. Listening to the teacher in my numeracy class makes me feel...			

11. If I answer questions and get them wrong, I feel...			
12. If I have to tell the teacher that I don't understand my numeracy work, I feel...			
13. If other children know that I find numeracy hard, I feel...			
14. When I watch or listen to my teacher explain a numeracy problem, I feel...			
15. If I don't finish my numeracy work in class, I feel...			
16. If other children finish their numeracy very quickly, I feel...			
17. When I explain how I got my answer to my teacher, I feel...			
18. When my teacher wants me to do numeracy at home, I feel...			
19. Walking into the numeracy class makes me feel...