IS MATHS ANXIETY A ROBUST CONCEPT THAT SHOULD BE TAKEN SERIOUSLY BY PRACTITIONERS IN SCOTLAND?

Jamie Wilson.

Dissertation submitted in part fulfilment of the requirements for the degree of:

Master of Education (Educational Studies)

University of Glasgow

30/08/2018

Acknowledgements:

I would like to acknowledge and thank everyone who encouraged and supported me through this dissertation and through the entirety of this Masters degree.

Firstly, I would like to thank Dr. Robert Doherty for the advice and guidance he has given me in his role as dissertation supervisor and for his help in securing my Higher in Tech Studies 18 years previously.

I would also like to thank my family for their time and support with particular thanks to my dad and brother for the time spent proofreading and talking things through with me.

Finally, I would like to thank my wife Gina for putting up with me through this whole process during which she gave birth to our first child, Lukas Wilson Kelly. This dissertation is dedicated to them.

Summary:

This dissertation explores the concept of maths anxiety to establish if there is a robust definition with enough evidence to accept that it truly exists. With reports that maths anxiety is an issue both in schools in Scotland (Scottish Government, 2016) and around the world (OECD, 2015) all evidence will be considered, however, for the context of this dissertation the main aim will be how practitioners in Scotland can address this issue. A rapid evidence assessment will be conducted examining relevant literature within an interpretivist paradigm. By looking at the origins of maths anxiety, it will be established what maths anxiety is said to be and what implications this has on individuals. It is commonly considered that maths anxiety is a two-dimensional concept with affective and cognitive factors. Despite this, many measures of maths anxiety establish a single maths anxiety score for an individual therefore implying unidimensionality and ignoring the two proposed dimensions of the concept. This causes difficultly in establishing a robust definition. Regardless of the existence of a robust definition it is widely reported that feelings of maths anxiety are related to poor performance in the subject. For this reason there have been many studies regarding how maths anxiety can be addressed and these suggestions will be discussed. The dissertation will conclude with discussion of the robustness of the concept of maths anxiety and suggestions of practical strategies for practitioners in relation to how to address this issue.

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1. INTRODUCTION:

In 2015 the Organisation for Economic Co-operation and Development (OECD) issued their report on "Improving Schools in Scotland" stating that students and teachers in Scotland have an issue with maths anxiety and recommended that this "warrants close attention" (2015:57). There has been a decline in Scotland's mathematics achievement in PISA surveys over the past decade and whilst it had previously been one of the leading countries, it is now ranked similar to the international average (OECD, 2015). With the concern that poor skills in mathematics are "a direct drag on the economy" (Scottish Government, 2016:26) and as part of a wider need to promote Science, Technology, Engineering, and Mathematics (STEM) skills (OECD, 2017) there is a current demand to identify and address the causes of this problem. With the OECD (2015) stating that maths anxiety can cause an achievement drop comparable to a year of schooling, the Scottish Government (SG) are keen to tackle the issue of maths anxiety (SG, 2016). As a mathematics teacher at secondary level, this is an important issue to understand, however, there are many questions to be answered. What is maths anxiety and how is it defined in literature? In order to answer this, it is necessary to understand how individuals claim to be affected by it and how this is measured. This will help to answer the next questions; is there enough evidence to accept that maths anxiety is a robust concept? It is said to be associated with poor performance (OECD, 2015; SG, 2016), is this an appropriate assumption? Regardless of whether it is established as a robust concept, there is a demand that teachers in Scotland "tackle" maths anxiety (SG, 2016) so the final question to answer will be how should practitioners address this issue? Suggestions on how to do this will be evaluated and discussed to develop practice and offer practical ideas on how this could be done. Alongside discussion of methods and methodologies, the rapid evidence assessment of prominent articles will answer these questions and consider if maths anxiety really is a robust concept that needs to be acknowledged and addressed by practitioners in Scotland.

2. RESEARCH DESIGN:

The journal "Vital Directions in Mathematics Education Research" (Leatham *et al.* (ed.), 2013) provided a collection of chapters from respected authors in maths education who suggested ways in which prominent issues in the field could be addressed. They avoided setting specific research questions and instead proposed broad overarching principles and frameworks to direct and support research. The contained article "Needed: Critical Foxes" (Kilpatrick, 2013) references Isaiah Berlin's (1953) notion of the fox that knows many things and the hedgehog that knows one big thing and calls for more "fox-like" research in maths education. It is suggested that there are many hedgehogs in maths educational research who have one idea that determines how they interpret things and governs everything that they do and whilst they make important contributions, there is a need for more foxes. It is stated that "Foxes are fascinated by the world's variety. Foxes do not have one big idea to cover everything but are eclectic instead. They are very pragmatic" (Kilpatrick, 2013:175). Kilpatrick's (2013) call is for "Critical Foxes" with an emphasis on the ability for research to be critical, both of itself and of other academic research. This call is supported by Boaler *et al.* (2013) who highlights the need that this critical research must have an impact on practice. Taking on board these suggestions my methods and methodologies will be discussed.

2.1 Theoretical position:

Waring (2012) states that there are four basic assumptions that underpin all research, ontology, epistemology, methodology and methods. The theoretical position taken for this research will be defined through the discussion of these assumptions before explicitly detailing the methods that will be used for the research.

Acknowledging that ontologies are our understanding of how the world is, we will accept here that "ontological positions can be seen to exist in a simplistic fashion along a continuum from left to right from realism to constructivism" (Waring, 2012:16). With the concept of maths anxiety based on emotional reactions and attitudes to maths, our position here has to be closer to the constructivism end of the spectrum where interactions with people and their environment are key. With the purpose of this study to review academic ideas and definitions of maths anxiety it is important that we consider that “researchers’ own accounts of the social world are constructions, … rather than one that can be regarded as definitive” (Bryman, 2008:19). Not only is the concept of maths anxiety based on personal experiences but the attempts to define it are based on individual’s understandings of these experiences. With epistemology concerning how we know the world, the corresponding epistemological position to this approach would be interpretivism (Waring, 2012), where knowledge is developed personally and socially through a process of interpretation. Ernest (1997) encompasses this interpretivist research paradigm as purposeful to examine features and circumstances behind a familiar case which can be used to serve as an example of something more general. The methodology used is thus “ideographic, dialectical and hermeneutical in nature” (Waring, 2012:16) meaning it should be interpretive, critical and discursive. This shall be achieved through a narrative that is driven by interaction between research and researcher.

The dissertation is written from my perspective as a secondary mathematics teacher with the purpose of challenging thoughts and practice. This further supports the use of this paradigm as a positivist approach assumes the role of the researcher as neutral (Lichtman, 2013) which would not allow the opportunity for personal experiences and interpretations. Bryman (2008) states that researchers can uncover surprising findings when an interpretivist stance is taken when compared to one that takes a stance external to the study. The interpretivist paradigm which is more naturalist than positivist provides the ability to capture more of the reality and complexity of the classroom experience (Ernest, 1997). Therefore, it is proposed here that this is appropriate to examine the concept of maths anxiety to inform practitioners and impact classroom practices. A caution on using this methodology is given, however, and must be considered:

> Although we may tentatively come to know the knowledge of others by interpreting their language and actions through our own conceptual constructs, we must acknowledge that the others have realities that are independent of ours (Ernest, 1997:30).

Having an awareness that the construction of knowledge gathered in the review of the literature is not based solely on the articles, but also on personal beliefs based on experiences, is an important part of the research process. The interpretivist stance lets the researcher provide “an interpretation of others' interpretations” (Bryman, 2008:17) and this is transparently acknowledged in the dissertation. It is also important to acknowledge that by considering all evidence the interpretivist paradigm does not exclude research that positions itself within another paradigm.

The interplay between researcher's opinion and the critical evaluation of literature takes us back to the discussion on Kilpatrick's (2013) call for more fox-like research. An interpretivist research paradigm is both an appropriate framework to study the concept of maths anxiety and also addresses the demand for more critical analysis of academic works that impacts practice in the field of maths education (Boaler *et al.*, 2013; Kilpatrick, 2013).

2.2 Methods:

The aim of the dissertation is to collect, review and synthesise the available literature on maths anxiety to inform practice and suggest further ideas for research. There are various appropriate methods that could be used to do this, however, a rapid evidence assessment is chosen here as the most suited for this study with the proposed methodology in the allocated timeframe. The purpose of a rapid evidence assessment is to “streamline traditional systematic review methods in order to synthesize evidence within a shortened timeframe” (Ganann *et al.*, 2010:1). A systematic review aims to synthesise a body of literature in a topic area to answer a specific research question, to address gaps in the literature or to inform for future research (Torgerson *et al.*, 2012). A rapid evidence assessment works towards the same aims, however, on a shorter timeframe, on a smaller scale and are often only worked on by a single researcher rather than by a team. It has been suggested that postgraduate students that used systematic review methods “gained a greater depth and insight into the subject they were researching” (Armitage and Keeble-Allen, 2008:103). Therefore, a form of systematic review is appropriate for this dissertation project and the aims of an achievable systematic review can be met by a rapid evidence assessment.

Although it is suggested that full reviews offered greater depth and detail in their recommendations, it has been shown that overall conclusions do not vary greatly between rapid and full systematic reviews (Ganann *et al.*, 2010). This leads us to consider any potential limitations to this research method. Aside from the fact that the shorter timeframe leads to less depth than a full review, it is generally agreed that the process of streamlining articles to include and exclude can lead to bias in the review (Bryman, 2008; Ganann *et al.*, 2010; Arthur *et al.*, 2013). This limitation was discussed by Ganann *et al.* (2010) who stated the importance of future rapid evidence assessments to be transparent and explicit about their methods, methodology and the limitations and biases that could be introduced by this approach. Bryman (2008) supports this adding that biases are less likely to surface if explicit procedures are adopted. In order to address this potential for bias, the interpretivist methodology has been explicitly discussed acknowledging that my role as a secondary mathematics teacher will impact the study and the methods have been clearly laid out with article selection procedures to be discussed next.

The information retrieval process for the study consisted mainly of the searching of electronic sources and databases using key words and phrases, see table 1. Since in the UK mathematics is referred to as maths and in the US math, “mathematics”, “maths” and “math” all had to be considered to ensure all relevant studies could be identified. The University of Glasgow library and Google Scholar were the main databases searched and they led to other reliable sources such as JSTOR, Science Direct and APA PsycNET.

2.2.a. Table 1: Database search terms

Database search terms:			
maths anxiety	math anxiety	mathematics anxiety	test anxiety
number anxiety	math/s attitudes	math/s avoidance	math/s emotions
math/s anxiety history	math/s anxiety meta-analysis	math/s anxiety causes	consequences of math/s anxiety
math/s anxiety scale	math/s anxiety diagnosis	prevention of math/s anxiety	math/s anxiety cure

Whilst the search was exhaustive, a balance between identifying all papers and those which are particularly relevant was met as suggested by Athur *et al.* (2013). Without the assistance of a research team this task was completed by myself and the popularity of articles, in terms of how often they have been cited by others, was taken into account to assess their importance. There were two different types of articles to consider, those generated from primary research and those based on reviews of secondary sources. With a historical element to the study, no restrictions were placed on when articles were published, however, more recent studies received appropriate attention. Abstracts were used to decide on the relevance of articles and those articles of apparent relevance and quality were read and coded. Bibliographies were checked to identify more sources. Four general themes relating to maths anxiety rose from the study of the literature and articles were coded into one of the four categories for ease of analysis; causes, consequences, measures and prevention (see table 2). Whilst this helped with manageability, many articles addressed more than one of these themes as shown in table 2. Despite this, research evidence was somewhat reduced to enable more succinct analysis.

2.2.b. Table 2: Coding of relevant articles

Article	Article type	Causes	Consequences	Measures	Prevention
Adimora *et al.* (2015)	Research				✓
Alexander and Cobb (1987)	Research			✓	
Alexander and Martray (1989)	Research			✓	
Ashcraft (2002)	Review		✓		
Ashcraft and Kirk (2001)	Research	✓	✓		
Ashcraft and Moore (2009)	Review	✓	✓		
Ashcraft *et al.* (2007)	Review		✓		
Bai (2011)	Review			✓	
Bai *et al.* (2009)	Review			✓	
Baloglu (2010)	Research			✓	

Beilock (2008)	Research	✓	✓		✓
Beilock and Willingham (2014)	Review				✓
Betz (1978)	Research			✓	
Boaler (2013)	Review				✓
Boaler (2015)	Review	✓	✓		✓
Boaler (2016)	Review				✓
Buckley (2013)	Review				✓
Carey *et al.* (2017)	Research			✓	
Chinn (2012)	Research				✓
Dew *et al.* (1984)	Research	✓	✓		
Dossel (1993)	Review				✓
Dowker (2016)	Review	✓	✓		✓
Dreger and Aiken (1957)	Research			✓	
Finlayson (2014)	Review				✓
Foley *et al.* (2017)	Review	✓	✓		
Geist (2010)	Review				✓
Gough (1954)	Review	✓	✓		✓
Greenwood (1984)	Review	✓	✓		✓
Hembree (1988)	Research	✓	✓		✓
Hembree (1990)	Review	✓	✓		✓
Ho *et al.* (2000)	Research	✓	✓		
Hopko *et al.* (2003)	Research			✓	
Hunt *et al.* (2011)	Research			✓	
Jackson and Leffingwell (1999)	Research	✓	✓		
Jansen *et al.* (2013)	Research	✓	✓		✓
Kazelskis (1998)	Review			✓	
Kazelskis *et al.* (2000)	Review	✓	✓		
Levitt and Hutton (1984)	Research			✓	

Lyons and Beilock (2011)	Review	✓	✓		
Ma (1999)	Review	✓	✓		✓
Ma and Xu (2004)	Research	✓	✓		
Maloney and Beilock (2012)	Review	✓	✓		✓
Maloney *et al*. (2015)	Research	✓	✓		
Martinez (1987)	Review				✓
Metje *et al*. (2007)	Review				✓
Newstead (1998)	Review	✓	✓		
Nunez-Pena *et al*. (2014)	Research			✓	
O'Leary *et al*. (2017)	Review	✓	✓		✓
Plake and Parker (1982)	Research			✓	
Richardson and Suinn (1973)	Research			✓	
Rounds and Hendel (1980)	Research			✓	
Schonell (1942)	Review	✓	✓		
Scottish Government (2016)	Review				✓
Stuart (2000)	Review	✓	✓		✓
Suarez-Pellicioni *et al*. (2016)	Review	✓	✓		✓
Suinn and Edwards (1982)	Research			✓	
Suinn *et al*. (1988)	Research			✓	
Suinn and Winston (2003)	Research			✓	
Wang *et al*. (2015)	Research		✓		
Wigfield and Meece (1988)	Research	✓	✓		✓
Wood (1988)	Review				✓

2.3 Framework:

With meta-analyses on maths anxiety that follow the strict format that systematic reviews often abide to already available (Hembree, 1990; Ma, 1999), it is proposed that something different would be more useful here. In order to create a report that will engage practitioners and impact practice, a narrative synthesis that both combines my interpretations of the results of studies with influence from my experience as classroom teacher is suggested. This is supported as appropriate for the discussed methods of data collection and coding by Hammersley, (2002), Torgerson *et al.* (2013) and Booth *et al.* (2016). With Hammersley (2002) tackling criticisms that a narrative review is somewhat unsystematic by clarifying that considering relevant evidence and making valid and reliable judgements is a systematic process. Thus the narrative approach used to report this rapid evidence assessment style of systematic review is an appropriate and viable framework to use.

2.4 Summary:

To conclude this section we will consider a quote that exemplifies that the process of a rapid evidence assessment is more than merely synthesising data, it is:

> judging the validity of the findings and conclusions of particular studies, and thinking about how they relate to one another, and how their interrelations can be used to illuminate the field under investigation (Hammersley 2001:549).

The rapid evidence assessment process enables selection of quality articles within a manageable timeframe. Not only are the methods and methodologies discussed here appropriate to investigate the concept of maths anxiety they also respond to calls for more critical analysis of research in maths education (Boaler *et al.*, 2013; Kilpatrick, 2013). As a secondary mathematics teacher there will be an element of bias in the selection and analysis of articles, however, this is an important element of the interpretivist approach and will lead to a report that will inform my practice and also be accessible and relevant to other practitioners.

3. ORIGINS AND IMPLICATIONS OF MATHS ANXIETY:

Sister Mary Fides Gough wrote of the “disease” of Mathemaphobia in her 1954 article “Mathemaphobia: Causes and Treatments”. This fear and dislike towards mathematics was said to undermine confidence and destroy the chances of acquiring a knowledge of the subject (1954:290). Emotional responses to mathematics were considered even earlier by Schonell (1942) who believed “backwardness in arithmetic is due as much to emotional as to intellectual factors” (1942:81) and with this in mind, Dreger and Aiken (1957) wrote an article as “an endeavour to detect the presence of a syndrome of emotional reactions to arithmetic and mathematics” (1957:344). They set out to explicitly differentiate this from other anxieties and found that this was not related to “general intelligence” and that persons with high “number anxiety” achieved lower mathematics grades (1957:350). Since the 1950s the implications of emotional reactions towards mathematics have continued to be of academic interest. The prevalent name for this in current literature is maths anxiety. This is defined by Wood (1988) as “the general lack of comfort that someone might experience when required to perform mathematically” (1988:11) or by Ashcraft (2002) as “a feeling of tension, apprehension, or fear that interferes with math performance” (2002:181). This is said to be experienced in formal classroom/ test situations or encountered in everyday settings (Ashcraft and Moore, 2009).

3.1. Two-dimensional concept:

Wigfield and Meece (1988) claim that there are two dimensions of maths anxiety, the affective and the cognitive (1988:210) and they are further supported by numerous other articles (Liebert and Morris, 1967; Hembree, 1990; Ma, 1999; Ho *et al.*, 2000; Ashcraft and Kirk, 2001). The affective component can be defined as the emotional response which is apparent in the very definition of maths anxiety, namely feelings of nervousness, tension, fear etc. The cognitive part is to do with the thoughts that those with maths anxiety experience, the most apparent example being the thought of worry. In their study of these two dimensions, Wigfield and Meece (1988) found that the affective emotionality factor correlated negatively to maths performance. Those measuring high levels of maths anxiety on an emotional scale performed poorer in a maths ability test situation than those with high scores on a cognitive – worry scale. The cognitive dimension scores, however, related strongly to the importance that students attach to maths and the effort that they put in. Thus maths anxiety could be seen to motivate individuals and lead to their improved performance. This will be further discussed when the connection between maths anxiety and performance is examined below.

A major cognitive consequence of maths anxiety that was proposed by Ashcraft and Kirk (2001) and Ashcraft (2002) is that the worry experienced by maths anxious individuals depleted working memory resources since attention is drawn to intrusive thoughts and worries. This led to difficulties in individuals when attempting maths questions that involved problem solving or more than one step. Beilock (2008) similarly studied this looking at links between strategies used to solve problems and working memory but found the opposite, that "pressure induced consumption of working memory should not disrupt performance" (2008:342).

"Highly math-anxious individuals are characterized by a strong tendency to avoid math" starts Ashcraft (2002) in his report examining the cognitive consequences of maths anxiety. His claim is widely supported (Hembree, 1990; Chinn, 2012, Maloney and Beilock, 2012; Buckley, 2013; Maloney *et al.*, 2015) and whilst it can mean the avoidance of maths on a day-to-day basis, it is commonly linked with the limiting of career choices and pathways. The number of students choosing to further study maths is a concern in Scotland and it is proposed that maths anxiety could be part of this problem (Scottish Government, 2016).

Whilst it appears that the concept of maths anxiety has generally been established to be made up of two dimensions, it is proposed here that the emotional affective side of maths anxiety seems to better define what maths anxiety is said to be. If we are to accept that maths anxiety is a fear and dread that one feels when experiencing maths, the cognitive side causes some questions to arise. If worrying about maths can lead to increased effort, then this would appear to contradict with another common consequence attributed to maths anxiety, that of avoidance. Wang *et al.* (2015) proposed that maths anxiety and maths motivation are two distinct factors stating that "some highly math anxious individuals are more avoidant in math, whereas others invest more effort and recruit more cognitive resources in math problem solving" (2015:1864). This adds to the complexity of the cognitive dimension of maths anxiety. With the above discussed studies showing further complications when looking at the effects of maths anxiety on working memory it suggests that it may be more appropriate to consider the emotional dimension of maths anxiety as more clearly defined. This is supported by Hembree (1990) who stated that maths anxiety "is a learned condition more behavioural than cognitive in nature" (1990:45).

3.2. Maths anxiety vs test anxiety:

Test anxiety has been studied since the 1950s claims Hembree (1988:47) who describes the evolution of the concept starting with a study that grouped students into two groups, low anxious and high anxious. When tested, the low anxious group outperformed the high anxious group. This evidence was used to support the idea that highly anxious students do poorer in tests than those with lower anxiety levels. This is a widely recognised definition of test anxiety (Liebert and Morris, 1967; Tobias, 1985; Hembree, 1988; Cassady and Johnson, 2002). In order to understand maths anxiety, it is important to be clear on its definition and therefore apparent similarities and differences between maths anxiety and test anxiety will be discussed to enable us to be clear on whether maths anxiety is a unique concept or whether it is just a subject specific subset of test anxiety.

Kazelskis *et al.* (2000) agree that there needs to be a clear distinction between the concepts of maths anxiety and test anxiety. By analysing the different ways in which each concept is measured they were able to bring into question their "seperateness" (2000:137). Their research established that the methods used to measure maths anxiety had a lot in common with those used to measure test anxiety. Finding one particular measure of maths anxiety that had 20% of its questions specifically relating to testing (2000:144).

> examples of such items include 'when taking maths tests, I usually …' and 'a maths test would scare me' or refer to 'taking an exam (quiz) in

a maths course' or 'being given a 'pop' quiz in a maths class

(Kazelskis *et al.*, 2000:144)

The interconnectivity of the two concepts here causes difficulty when trying to establish whether someone's anxieties are related to mathematics or to the testing environment. Kazelskis *et al.* (2000) reached the conclusion that "mathematics anxiety and test anxiety *may* be separate phenomena, but further conceptual and measurement differentiation appears to be needed" (2000:144). Whilst the scales used to measure maths anxiety will be discussed in greater detail later in this paper, this brief analysis has shown there are some difficulties in how these measures define maths anxiety.

Liebert and Morris (1967) wrote of "two classes of factors" that emerged from questionnaires used to identify test anxious individuals, "emotionality" and "worry". Cassady and Johnson (2002) are in agreement stating that there "is wide acceptance of the view that test anxiety is composed of two dimensions (traditionally referred to as emotionality and worry)" (2002:271). As previously discussed, these are the same two dimensions commonly used when defining maths anxiety. Ho *et al.* (2000) looked at the pattern of associations between the dimensions of maths anxiety and performance and compared them to that of test anxiety. They established that there is a clear difference here, with the affective dimension being the primary debilitator to maths performance whilst for test anxiety it was the opposite, with the cognitive factor that was found debilitate test performance more.

Hembree (1990) writes of anxiety being an "omnibus construct" and that test anxiety and maths anxiety are "subconstructs" (1990:33). His review aims to describe maths anxiety as fully as possible stating his belief that it has a "lack of independent identity" (1990:34). When comparing the two constructs he writes of their "parallel properties" namely, that they both relate to general anxiety, both affect performance and that this can be improved upon through relief of both constructs (1990:44). In relation to relief and treatments for these anxieties, his findings show that best relief is experienced from behaviour related methods and little result shown from cognitive treatment for both test and maths anxiety. However, despite the similarities, Hembree (1990) concludes that it is “unlikely” that maths anxiety is purely restricted to testing environments and writes of the “general fear of contact with mathematics, including classes, homework, and tests” (1990:45). This general fear of mathematics is an important part of the definition of maths anxiety so this establishes a difference between the two anxiety constructs.

Dew *et al.* (1984) hypothesized that if maths anxiety and test anxiety were related, then this would be particularly evident in a maths test like situation (1984:580). They believed that there were many unanswered questions regarding maths anxiety and their study aimed to further investigate these. They believed the relation of maths anxiety and test anxiety was an issue and as part of their study they examined physiological arousal of their participants (1984:580). It is regarded that test anxiety displays itself through physiological responses such as increased heart rate, nausea and feelings of panic (Hembree, 1988; Cassady and Johnson, 2002). Investigating if similar responses could be attributed to maths anxiety would therefore be a useful way to differentiate between the constructs. Through their research they established that “somewhat surprisingly, the math anxiety measures showed relatively little relation to physiological measures” (1984:582). This is another example that differentiates the construct of maths anxiety from test anxiety.

Further evidence to support that maths anxiety differs from test anxiety has been found by Tobias (1985) whose study examined test performances of test anxious students. It was found that the highly anxious students spent more time studying than their low anxious counterparts (1985:136). Whilst his study did not have any mathematics specific element to it, this test anxiety finding could be seen to contrast with a key consequence of maths anxiety - avoidance. Someone considered to be highly maths anxious would be expected to avoid doing mathematics rather than doing extra work as suggested by Tobias (1985). However, this contradiction was previously discussed when examining the apparent cognitive dimension of maths anxiety which was said to potentially motivate some maths anxious students to study more.

Clearly the concepts of test anxiety and maths anxiety are closely related. The need for robust definitions to differentiate one from the other is mentioned in numerous studies (Hembree, 1990; Kazelskis *et al.*, 2000; Carey *et al.*, 2017). Whilst this robust definition may not yet exist, Carey *et al.* (2017) claims that maths anxiety is distinct from other forms of its anxiety by its very definition that it is a response to *mathematics* in particular (2017:1). This idea is supported by Hembree's (1990) conclusion that maths anxiety is distinct from test anxiety as it includes all experiences of mathematics, not just those experienced in test situations. The fact that mathematics is an everyday part of life providing situations outside of a test environment where someone may experience feelings or worry defined as maths anxiety means we can accept that it is a distinct construct from test anxiety.

3.3. Suggested causes of maths anxiety:

It has been shown above that a key factor that distinguishes maths anxiety from test anxiety is that it can be caused outside of test situations and can be related to any and all experiences of mathematics. When reviewing the literature to find how maths anxiety relates to an individual's personal experiences of mathematics O'Leary *et al.* (2017) found "suggestions" of what maths anxiety could be related to; support from teachers and parents, methods of instruction and performance in mathematics (2017:3). Each experience will be examined and O'Leary *et al.*'s (2017) research will be used alongside prominent literature to establish whether there is support that maths anxiety can be caused by each of the three factors.

3.3.1. Support from teachers and parents:

The relation between maths anxiety and perceived level of support was found to be relevant only during high school by O'Leary *et al.* (2017). It was found that those purporting to receive lower levels of support had higher levels of maths anxiety. Possible reasons suggested for this not being an issue at Primary level is that support provided there is adequate or that, due to an increase in difficulty, more support is required at high school level (O'Leary *et al.*, 2017:10). It is believed that the class teacher is highly influential in establishing how students experience mathematics (Dossel, 1993; Stuart, 2000; Ashcraft *et al.*, 2007; Suarez-Pellicioni *et al.*, 2016). In particular, Ashcraft *et al.*, (2007) examined how exposures to failure in maths heightened maths anxiety levels in students.

> Maths anxiety does not derive from mathematics itself, but rather from the way maths is presented in school and may have been presented to school teachers when they were children.
>
> (Geist, 2010:29)

The quote from Geist (2010) suggests the notion that a teacher's own experience of mathematics in school could have influenced their own teaching. This is somewhat supported by Dossell (1993) who states that if a teacher has negative feelings towards a subject it is "likely" that these will be communicated to their students (1993:44). This seems speculative and more evidence could be required to firmly establish this, however, examining how parents' experiences of mathematics are passed on could help us with this.

"My father never could learn mathematics and I can't learn it either" is an example given by Gough (1954) to display what she terms "hereditary mathemaphobia" (1954:294). Similar sentiment is expressed by Suarez-Pellicioni *et al.* (2016) in their advice given that parents should not "transmit their own level of maths anxiety to their children" through statements such as "I've always found maths difficult" or "I've never been a maths person" (2016:17). A large-scale field study found that maths anxious parents did indeed pass on maths anxiety to their children which negatively affected their maths performance, however, this was only found to be the case when parents had frequently helped children with homework (Maloney *et al.*, 2015). The parents found to have maths anxiety that did not frequently help with homework did not seem to pass their anxieties on. Though it was concluded there is possibly a genetic link, the negative influence of helping with homework was attributed to parents sharing their experiences of mathematics using statements such as those listed above. Dossel (1993) warned that "parental involvement in the child's mathematical studies should be carefully monitored" (1993:44) which shows awareness of the potential negatives highlighted by Maloney *et al.* (2015). It is considered that parents can pass on negative attitudes about maths to children and instil ideas that their mathematics ability is genetic, in order to address this, it is essential to ensure positive aspects of mathematics work or achievements are highlighted (Suarez-Pellicioni *et al.*, 2016:17).

Personal experiences of learning mathematics are influenced by the support received through from both teachers and parents. It has been shown that the sharing of negative comments and beliefs regarding maths can lead to the development of maths anxiety. Both teachers and parents contribute to this development in similar ways and have to be conscious of their roles to ensure not to develop environments where maths anxiety can foster. The literature shows us how negative experiences of mathematics are passed to others and to address the problem of maths anxiety it is imperative that we learn from this and ensure that this hereditary cycle is broken.

3.3.2. Instructional methods:

Aside from the perceived levels of support received from teachers, another experience of mathematics that impacts someone's maths anxiety levels is the classroom experience based on instructional methods used. O'Leary *et al.* (2017) found little support to their hypothesis that those who had negative experiences of teaching and learning would report higher levels of maths anxiety. Establishing, however, that lower levels of maths anxiety could be related to generally good instructional practice rather than specific instructional methods, with the only exception being providing many examples. This will be further discussed in section five.

Jackson and Leffingwell (1999) also studied the impact teachers and their instruction methods used had on maths anxiety levels from "Kindergarten through college". In contrast with O'Leary *et al.* (2017), they found practices that were seen to foster maths anxiety. These were; expecting students to understand a new concept after seeing only one example, relying on worksheets without explaining content, getting students still unsure of a topic to provide answers to the whole class, inappropriately paced lessons and assuming familiarity of previous content without revisiting it (1999:584-585). The authors of the study accepted that there are several factors that contribute to maths anxiety and the purpose of highlighting these negative practices was with the intention of promoting the importance of teachers creating an environment through "positive attitudes and sound pedagogy" (1999:586). These ideas will be elaborated on and further examined when ideas of addressing maths anxiety in the classroom are discussed later.

Finlayson (2014) established that students were generally taught as if they have the same ability, at the same pace and with little consideration of individual learners' behaviours and needs. She believed that this led to teachers focussing on repetition as an important instructional method, rather than on helping students develop problem solving skills which in turn heightened maths anxiety in students (2014:101). Boaler (2016) agrees with this analysis, urging the need to "move away from fixed mindset grouping" (2016:176) pointing out the difficulty of communicating positive messages to students when they are in set classes. Whilst not exactly an instructional method, class setting impacts how maths is taught in schools and it is clear that this experience of maths teaching could have an impact on students' maths anxiety.

3.3.3. Performance in mathematics:

The link between maths anxiety and performance in maths is part of the definition of maths anxiety according to Suarez-Pellicioni *et al.* (2016), who stated that for some people dealing with maths "evokes an emotional response that disrupts their performance" (2016:4). This relation between performance in maths and maths anxiety was said to be the strongest of the experiences examined by O'Leary *et al.* (2017). Their research proposed that poor performance in maths contributed to higher levels of maths anxiety. A study by Ma and Xu (2003) reached the same conclusion that prior low achievement in mathematics led to higher levels of maths anxiety being established. This could be connected to what has been discussed already regarding support from teachers and the instructional methods used. Both situations highlighted the need for students to experience success as a means to ensure maths anxiety was not heightened. It could therefore be seen as a logical extension of this, that not experiencing success would potentially lead to development of maths anxiety. Hembree (1990) found that higher achievements in mathematics consistently reduced levels of maths anxiety and that treatment of high anxious students could improve their performance. This led him to conclude that maths anxiety caused poor performance further stating that there was no compelling evidence that poor performance was creating maths anxiety. However, the relationship between poor performance and maths anxiety is complicated. O'Leary *et al.* (2017) stated caution was required when interpreting their results posing the question: "is anxiety causing poor maths marks, or are the poor maths marks causing anxiety?" (2017:11). They did not attempt to answer this question in their study so other articles are required for further analysis.

Despite knowing Hembree's (1990) conclusion discussed above it is important to note that he had considered the same question as O'Leary *et al.* (2017). Is maths anxiety causing poor performance or is poor performance causing maths anxiety but Hembree (1990) also posed "or is the relation circular?" (1990:44). This idea has been labelled the reciprocal theory by Carey *et al.* (2016:4) and is supported in some other key studies (Ashcraft *et al.*, 2007; Jansen *et al.*, 2013; Foley *et al.*, 2017). Whilst this is refuted by Hembree (1990) it provides another interesting dimension to think about. After examining numerous studies Foley *et al.* (2017) concluded:

> math anxiety can impair maths performance by depleting working memory resources … [and] a poor grasp of basic math concepts may predispose students to develop math anxiety, partly in response to their math struggles. Thus, the relation between math anxiety and math performance is likely bidirectional (2017:54).

The mixed evidence available may suggest this bidirectional relationship, however, more research is required to provide greater understanding which is supported by Carey *et al.* (2016).

Whilst the aforementioned literature generally accepts the negative impact maths anxiety has on maths performance there is some research that shows that this is not always the case (Wigfield and Meece, 1988; Lyons and Beilock, 2011; Wang *et al.*, 2015). Alongside their performance, the value placed on mathematics contributed to their anxiety levels proposed Wigfield and Meece (1988). For example, a student who did not hold mathematics in high regard may perform poorly but not be bothered by this and therefore not experience anxiety. Those performing poorly that want to improve may be the ones that report higher levels of maths anxiety (1988:214). Similarly, someone performing at what would be considered a relatively good standard may not be happy with their performance and the desire to improve may contribute to feelings of anxiety. It was suggested by Lyons and Beilock (2011) that it was how students cope with their levels of maths anxiety that would impact their performance. Some highly maths anxious students were able to overcome their anxiety and perform well in maths tasks which led them to conclude that classroom practices should help students learn how to “marshal cognitive control resources” (2011:2109). Wang *et al.* (2015) support this and extended that some level of maths anxiety could actually be beneficial to some students. It was proposed that moderate levels of maths anxiety combined with high levels of motivation would drive students to work hard whilst also enjoying the subject (2015:1874).

The relationship between someone’s performance in maths and their levels of maths anxiety has been shown to be a complicated one. With evidence to support that poor performance causes maths anxiety and also to support that maths anxiety causes poor performance there is some acceptance that the relationship is bidirectional. Methods to address the problem of maths anxiety will be discussed later and it is essential to have an understanding of this relationship before these can be considered. It has also been shown that some levels of maths anxiety can actually be of benefit to students so this must also be taken into account.

3.4. Summary:

By looking at the origins and implications of maths anxiety it has been established that there are many complexities to the concept. It is important to now acknowledge the language used across the literature, with maths anxiety described by many as a concept and by others as a construct. Herein the language used will describe it as a concept which is more abstract and less concrete than a construct. Whilst it is suggested that the concept has both affective and cognitive dimensions, it has been shown that the affective part is more clearly linked to the definition that maths anxiety is an emotional reaction to mathematics. O’Leary *et al.*’s (2017) suggestions on the causes of maths anxiety help us to create a more established idea of how maths anxiety can manifest itself with examples that are particularly relevant in my role as a secondary maths teacher.

4. MATHS ANXIETY MEASURES:

It is widely accepted that the measurement of maths anxiety is essential to understand and make attempts to reduce individuals' maths anxiety (Newstead, 1998; Hembree, 1990; McMorris, 2004; Bai, 2011). By evaluating the different methods used to measure maths anxiety over the years, how substantial the concept of maths anxiety is will continue to be examined. Attempts to measure maths anxiety have been documented for as long as the concept had been suggested to exist yet no common measure has been accepted. The following discussion examines how the scales have evolved over the years adding further insight into the idea of maths anxiety having more than one dimension.

4.1. Identification of "number anxiety":

The earliest published attempt to create a scale to measure maths anxiety was by Dreger and Aiken (1957) who adapted the Taylor Manifest Anxiety Scale (TMAS) as "an endeavor to detect the presence of a syndrome of emotional reactions to arithmetic and mathematics" (1957:344). The TMAS is a 50 question personality scale used to select experimental subjects that display manifest anxiety, that is anxiety caused without underlying psychological problems (Taylor, 1953). The questions are answered either true or false and "anxious items" are scored to give an overall manifest anxiety score. Dreger and Aiken (1957) used 47 out of the 50 TMAS questions and added three maths specific questions:

> 3. I am often nervous when I have to do arithmetic
> 9. Many times when I see a math problem I just "freeze up"
> 38. I was never as good in math as in other subjects
>
> (Dreger and Aiken, 1957:346).

A factor analysis was performed on these three questions, and whilst the caveat of how much can be taken from what they call a "little factor analysis" is given, we will go on to see that the results are consistent with other studies. Two factors were identified to arise; "negative math reaction" and "nervousness in the presence of math" (1957:347). These would appear to be consistent with the two dimensions of maths anxiety discussed earlier, the affective and the cognitive. Looking back at the three questions you can see that the first two clearly represent the affective dimension regarding emotional responses to maths and the third represents the cognitive with a question about thoughts. With the test providing a single score for anxiety levels, implying maths anxiety as a unidimensional concept, the existence of two contributory factors could cause for complications with the reliability of measurements. Whilst Dreger and Aiken's (1957) format of a self-report questionnaire is typical of how people have continued to attempt to measure maths anxiety, how these measures have developed since their scale was created will be examined as will the dichotomy between its two dimensions and its unidimensionality.

4.2. Maths Anxiety Ratings Scale (MARS):

Richardson and Suinn (1972) aimed to develop a scale to solely measure maths anxiety, as anxiety scales that are limited to specific situations were said to have "higher predictive value" than those with more diverse content. It was proposed that their Maths Anxiety Ratings Scale (MARS) could be used as a diagnostic tool, for treatment or for research. The scale consisted of 98 descriptions of situations that may arouse anxiety in an individual eg. "adding two three-digit numbers while someone looks over your shoulder" (1972:552). A Likert-type scale of 1 to 5 is attached to each situation for individuals to assess how anxious they would feel with 1 assigned to "not at all" and 5 being "very much". The sum of the values gives a maths anxiety score with a higher score reflecting high levels of maths anxiety which once again implies unidimensionality. The pioneering MARS was deemed to be both reliable and valid, and was once regarded as the best measure of maths anxiety (Dew *et al.*, 1993; Hopko *et al.*, 2003, Bai *et al.*, 2009; Bai, 2011). The scale has been revised numerous times to create new scales for various different reasons, such as the MARS-A for Adolescents (Suinn and Edwards, 1982) and MARS-E for Elementary school students (Suinn *et al.* 1988). A problem that many identified with the MARS was that it took too long to administer (Levitt and Hutton, 1984; Alexander and Martray, 1989; Suinn and Winston, 2003; Baloglu, 2010) which led to the creation of MARS-R, a Revised version of the scale (Plake and Parker, 1982). In order to reduce the number of items, Rounds and Hendel's (1980) factor analysis of the MARS was used which identified two dominant factors; feelings of anxiety in maths learning situations such as in tests or in the classroom and anxiety dealing with maths in everyday life. Similar to the factors identified in Dreger and Aiken's (1957) analysis discussed above. Ensuring a balance of questions that assessed each of these factors, the 98 item MARS was reduced to 24 items. The study concluded that the MARS-R was "highly related" to the full MARS with a correlation estimate of .97 (1982:556) and was thus accepted as an alternative to the full test. With similarly shortened versions created (Rounds and Hendel, 1980; Alexander and Martray, 1989), Suinn acknowledged the demand for a less time consuming maths anxiety measure and alongside Winston set out to create a Short Version, commonly known as the MARS-SV (Suinn and Winston, 2003). Their belief was that previous studies that had shortened the scale were promising, however had deficiencies, namely it was suggested that the sample groups used in each study did not include a broad enough group. The MARS-R was created using research with graduate students from a statistics course and another study had only used females. The MARS-SV was therefore created with the aim of improving on the "lack of representativeness" (2003:168) believed to be apparent in other studies and the "reasonably large" sample group chosen for their study was from an introductory psychology university course and balanced in terms of sex. 30 items were selected from the 98-item scale decided on thorough analyses of MARS in three articles; Alexander and Cobb (1987), Alexander and Martray (1989) and Rounds and Hendel (1980). The selection of the items was based on the two factors identified as "representing the core dimensions measured by the MARS" (2003:169) that of anxiety in classroom situations and anxiety in everyday life. Whilst the scales have been shorted once again we see the highlighting of two dimensions that are said to constitute maths anxiety.

4.3. Abbreviated Maths Anxiety Scale (AMAS):

The validity of factor structures of self-report measures were a concern for Hopko *et al.* (2003) who proposed that the many available scales to measure maths anxiety may not represent the emotional experience of individuals. They set out to create a "briefer and more parsimonious" maths anxiety scale using a "large representative sample", to evaluate its consistency then assess it with a replication sample (Hopko *et al.*, 2003). Undergraduate students of an unspecified course or courses were given the MARS-R and the results analysed. Ten items were initially identified as being more prominent for the measure of maths anxiety, however, it was decided that two questions were similar and could be combined. The result being the creation of the Abbreviated Maths Anxiety Scale (AMAS) consisting of nine items with the same Likert-type scale from 1 (low anxiety) to 5 (high anxiety) used in measures discussed previously. Testing the AMAS on a second sample allowed for further analysis and it was concluded that it was not only a valid measure but potentially superior when compared to the MARS-R (Hopko *et al.*, 2003). There are two factors that are identified by the AMAS, "Learning Math Anxiety" and "Math Evaluation Anxiety" (2003:181) which are slightly different terms that describe the two factors that have been identified in other measures. Evaluation has obvious connotations with thoughts and cognition and therefore links well to the cognitive factor of maths anxiety. The learning factor, however, seems more complicated and whilst it seems like it should fit with the affective dimension of maths anxiety, the description here seems much broader. These terms will be further analysed in the next sub-section. Hopko *et al.* (2003) concluded that the AMAS was valid and reliable and may be a useful tool to facilitate early assessment of maths anxiety.

4.4. Modified Abbreviated Maths Anxiety Scale (mAMAS):

The "need for an appropriate scale to assess maths anxiety in British children and adolescents" led Carey *et al.* (2017) to further develop the AMAS, creating the modified Abbreviated Maths Anxiety Scale (mAMAS) (2017). The language of the questions were changed to better reflect experiences in British schools, for example; "taking an examination in a math course" became "taking a maths test" and "being given a 'pop' quiz in math class" was changed to "finding out that you are going to have a surprise maths quiz when you start your maths lesson" (2017:3). The changes in language are certainly more appropriate for use in British schools and their study concluded the mAMAS was a valid and reliable measure of maths anxiety in children aged 8-13. In agreement with Hopko *et al.* (2003) they proposed it can be conceptualized using two subscales, that of “Learning” and “Evaluation” (Carey *et al.*, 2017). They concluded both that maths anxiety exists and that it could be measured.

4.5. Learning and Evaluation factors:

The common theme arising from analysis of the above scales is that there are two factors that constitute maths anxiety. The first being to do with school, classroom and testing situations which is apparent in both the questions asked in the surveys and how the data is split for analysis. From herein we will use the language of Carey *et al.* (2017) and refer to this as the Learning factor of maths anxiety. The second factor that arises could be viewed as any other experience of maths outside of a school environment, encountering mathematics in everyday life and how an individual uses their knowledge to do this. This is succinctly defined by Carey *et al.* (2017) as maths Evaluation anxiety. Albeit using different language, the above measures all split the measure of maths anxiety into these two factors; Learning and Evaluation. As previously mentioned, these measurement factors do not exactly match with the two dimensions said to constitute maths anxiety, the affective and the cognitive. Whilst the terminology used to label the factors is different, they all have their own merits and are appropriately proposed and justified by the article authors. Despite the measures of maths anxiety identifying two dimensions the output of these scales is a single maths anxiety score and therefore implies it a is unidimensional concept.

Kazelskis (1998) similarly identified the differences in how the dimensions of maths anxiety had been defined proposing that that these had not been sufficiently delineated. This led him to reach the conclusion that “a unidimensional approach cannot provide for adequate understanding of the construct” (1988:624). He suggested that different measures, measure different aspects of a complex concept and that single scores should “probably” be avoided. Attention should instead be paid to scores for individual factors within the measures. A potential question would therefore be whether an individual could be affected by one factor but not the other. Whilst this is not addressed in the above literature it is considered here that the factors are so closely related that even if an individual was shown to, for example, score higher in Learning anxiety than Evaluation then this would still have the desired effect of identifying anxious responses to maths. Whilst the two factors are useful for further analysis of the concept of maths anxiety, displaying signs of either could be argued to be evidence of an individual's maths anxiety and therefore a single score may be an appropriate representation. Dimensions identified as particularly interesting by Kazelskis (1998) were that of positive and negative affect towards mathematics which will be discussed in the next sub-section.

4.6. The Betz Maths Anxiety Scale (MAS):

Alongside their unidimensional representation of maths anxiety, all the measures discussed above share the fact that they are based on scores of negative affect toward anxiety levels. The Betz Maths Anxiety Scale (MAS) (Betz, 1978) was made up of ten questions on how an individual would respond in a situation with a four point Likert-type scale from 1 (almost never) to 4 (almost always). See appendix 1. Whilst the questions are similar in self-report style and cover both Learning and Evaluation items, what is different is that questions 1 – 5 are positively worded and 6 – 10 worded negatively so that both positive and negative affect could be measured. Scores are reversed for the positively worded questions so that an overall high score implies high levels of maths anxiety. This bidimensional scale was preferred by Bai *et al.* (2009) who felt that the inclusion of the positive affect of maths anxiety would help "to better understand the construct … so as to find better intervention strategies to reduce anxiety" (2009:187). They used the MAS to develop their own revised scale, the MAS-R (Bai *et al.*, 2009) and with the belief that the positive-affect items were too negatively worded they changed questions to be positively phrased. The MAS-R thus includes the following items; "I find math interesting" and "I enjoy learning mathematics" (2009:189). As was discussed earlier, the language used when discussing maths is important to ensure negative attitudes are not established so the inclusion of positively worded items seems appropriate. By measuring maths anxiety on a bidimensional scale of positive and negative affect items both those with high anxiety and low anxiety and said to respond well and is deemed to be an improvement of a unidimensional model.

4.7. Single-Item Maths Anxiety Scale (SIMA):

"On a scale from 1 to 10, how math anxious are you?" asked Ashcraft (2002:181). He used an unspecified shortened version of the MARS for his 2002 study but mentions that for "quick determination" the above single question could be used. He had found that the results of answers to this question correlated well with the scores from the MARS scores, however, he had only looked at a sample of "at least a half-dozen" (Ashcraft, 2002:181). Like many others previously discussed, Nunez-Pena *et al.* (2014) wanted to establish a quick and easy way to obtain valid and reliable scores of an individual's maths anxiety levels. They were interested by Ashcraft's (2002) suggestion and, alongside a short study of the value of single-item scales, set out to test the reliability and validity of the Single-Item Maths Anxiety Scale (SIMA). Using a much larger sample size than Ashcraft (2002), they administered the SIMA alongside the simplified MARS and some numerical tests to test maths performance. Results with the SIMA scale were consistent with the MARS and, in similarity with other more substantial measures, SIMA results showed that as maths anxiety levels increased, numerical achievement decreased (Nunez-Pena *et al.*, 2014). It was therefore concluded, with the caveat of the over representation of females in the sample group, that the SIMA was a useful measure to detect "students with high levels of math anxiety in large groups" (Nunez-Pena *et al.*, 2014:315). We can deduce from this that it is somewhat less reliable to identify those with low or moderate levels of maths anxiety and that more substantial tests would be required to identify these individuals. A potential problem not mentioned in the study is that subjects all completed both MARS and the SIMA scale. Whilst this is obviously essential to compare the sets of results it is proposed here that in completing the MARS, subjects are given the opportunity to reflect on how they feel when dealing with maths in various different situations. It is unfortunate that it is not stated in Nunez-Pena *et al.* (2014) the order in which the tests were completed as this is hugely relevant, since completing the MARS first, and thus reflecting on their anxiety levels in different situations, an individual would have a better understanding of maths anxiety and be better equipped to decide how maths anxious they are on the SIMA scale of one to ten. If, however, the SIMA scale was answered first then the results would be more indicative of the purpose of the scale, i.e. to create a quick measure of maths anxiety with no need for it to used alongside anything else.

4.8. Summary:

Each maths anxiety scale has been established and individually justified as a measure for maths anxiety by its author. These tests are generally agreed on as valid and reliable for the purpose the author has intended. What is clear over the years is the demand for a measure that is quick to administer and the results reliable to make a judgement over whether or not someone can be identified as someone who suffers from maths anxiety. All of the scales are based on self-report questionnaires so any conclusions reached could be viewed as essentially self-diagnosed. If this is indeed the case, then the argument for a single question asking how maths anxious an individual is, is strong. However, this has its problems. With valid arguments for positive affect questions the single question could be seen to be negative assuming all are somewhat maths anxious on a scale from one to ten. Another possible issue is that individuals will experience anxiety in different ways, one individual could regard themselves as highly maths anxious, however, could be generally anxious and not necessarily just in a maths situation. Individuals must be clear on what constitutes maths anxiety to ensure results are valid here. Whilst it is generally considered that maths anxiety is a multi-dimensional concept, reducing its identification to one self-assessment question the concept is reduced to a unidimensional one. Reflecting back on the previously discussed affective and cognitive dimensions of maths anxiety it is clear that the unidimensionality adds further complexity to the concept and adds further support for the need to fully understand and define maths anxiety.

5. PREVENTION:

Having firmly established some of the ideas behind the concept of maths anxiety and evaluated examples of methods used to measure it, our attention can now turn to strategies said to alleviate or reduce levels of maths anxiety in individuals. Claiming that "Scotland has a maths problem" the Scottish Government's (SG) (2016) Making Maths Count (MMC) group made suggestions in their final report on "tackling maths anxiety" (2016:12) in their section on improving confidence in maths. Addressing these concerns contribute to the of a wider global need to promote STEM skills (OECD, 2017).The suggestions made will be used to frame the evaluation of the prominent strategies found in research on how maths anxiety can be addressed. Whilst it is accepted here that no miracle cures exist (Martinez, 1987; Dowker *et al.*, 2016) we will examine how the SG (2016) suggestions support Greenwood (1984) and Dowker *et al.* (2016) that the prevention of maths anxiety being established is the best way to address the problem. It is stated that improving learner confidence is essential, so ideas of how to do this will be discussed before looking at their headline recommendation of the need to promote positive attitudes of maths using a "wide range of effective learning and teaching approaches" (2016:13). These ideas will be explored before addressing other suggestions prevalent in research to reduce maths anxiety, concluding with whether these are appropriate to tackle the problem in Scotland.

5.1. Improving learner confidence:

The SG (2016) believe that improving learners' confidence is essential to tackle the problem of maths anxiety in Scotland. Key to this message is the idea of promoting a growth mind-set approach which they describe as "encouraging learners to understand that their abilities are not fixed and they can improve their skills through effort and dedication" (2016:13). The concept of developing a growth mind-set was established and popularised by Dweck (1999) and was said to have "one of the biggest impacts on education of any research volume ever published" (Boaler, 2013). She wrote of two frameworks for understanding intelligence and achievement, a theory of fixed intelligence and one of malleable intelligence where intelligence can be cultivated through learning

(Dweck, 1999). Having a growth mind-set means believing in this theory of malleable intelligence and it is important to promote this in students as “it makes them want to learn” (1999:3), including those with low confidence in their own abilities. With maths anxiety shown to cause learners to want to avoid learning maths it follows logically that a method shown to increase motivation to learning would be useful in addressing this.

Boaler (2013) states that to make a true commitment to the promotion of a growth mind-set all aspects of teaching must be looked at and proposed a move away from the use of short closed questions which are marked correct or incorrect. It is reported that students see incorrect work as “indicators of their own low ability” (Boaler, 2013:149) and that instead, teachers must value mistakes and treat them as learning opportunities. This is supported by the SG (2016) who state that mistakes should be used as an “experience to embrace new challenges” (2016:13). Beilock and Willingham (2014) similarly address this in a discussion regarding the language teachers’ use when addressing students struggling with classwork stating that consoling a student with comments such as “not everyone can be good at these types of problems” (2014:32) gives the wrong message and instead teachers’ must express confidence that individuals have the potential for success. The messages teachers communicate to students through conversations and through learning tasks must be considered in order to establish a growth mind-set in a school (Boaler, 2013). It is proposed here that learner confidence can be improved on by encouraging learners to have a growth mind-set and thus understand that their ability is not fixed and can be improved on through effort. The purpose being that maths anxiety is less likely to foster, or be established, in individuals’ more confident in their own mathematical abilities. Whilst efforts to improve learner confidence are valued by Wigfield and Meece (1988) they “may not be enough to alleviate the strong negative affective reactions to math that learners experience” (1988:214) which adds support to consideration of other ways to alleviate or prevent maths anxiety.

5.2. Good learning and teaching:

The SG (2016) recommendation of promoting positive attitudes through a wide range of learning and teaching approaches in order to address maths anxiety, sets out what "good learning and teaching" should emphasise (2016:14). It should; make connections between different aspects of maths, use varying representations, enable learners to explain their thinking and it is also suggested that some of the principles of mastery learning could be appropriate. There are already various studies that value the importance of how learning and teaching can address the issue of maths anxiety (Martinez, 1987; Metje *et al.*, 2007; Beilock and Willingham, 2014; Finlayson, 2014; Adimora *et al.*, 2015; Boaler, 2015, 2016; O'Leary *et al.*, 2017) and these will be examined alongside the SG (2016) suggestions.

5.2.1. Connections:

Connecting different aspects of maths is an example of good learning and teaching made by the SG (2016) that could alleviate maths anxiety. This can be done in a number of different ways. In his suggestions on "creating an anxiety-free math class", Martinez (1987) proposes using real objects such as fruit, pencils, textbooks etc. to teach arithmetic before using numbers and symbols which he sees as abstract. Also valuing the use of Cuisenaire rods, the abacus and manipulatable computer graphical representations of problems, he stressed the importance of students seeing and feeling problems to ensure confident understanding. Real life examples should also be used when possible to connect the maths being learned to situations students are familiar with, the goal being for students to understand "both the operations and the answers thoroughly" (1987:123). The key thing here would be using connections to ensure deep understanding of a topic or topics to ensure students are confident and do not feel anxiety.

Another way of using connections to deepen understanding and ensure confidence comes from Finlayson (2014) who interviewed maths anxious students about what strategies they used to build their self-confidence in maths. Making connections to previous knowledge and connecting easy problems to more difficult ones were suggestions made that could help alleviate maths anxiety in an individual. By highlighting individuals' areas of strengths and then building on them, it is argued that confidence is increased rather than potentially creating anxiety by treating content as completely new. These examples both demonstrate how making connections between different aspects of maths can contribute to addressing maths anxiety.

5.2.2. Vary representations:

It is suggested that using different representations of maths is another example of good teaching and learning that should be considered to address maths anxiety. An example of learning multiplication facts by Boaler (2016) uses flash cards of written questions, domino tiles, dice and rectangular grids that all represent equivalent answers. She proposed that learning these facts to understand multiplication both visually and spatially, brain connections are made which increases understanding of the real meaning of these multiplication facts. She compared the need to use different representations to the experiences in an English class where memorisation of words is not sufficient, it is being able to use them in different situations, talking, reading and writing where we would establish if a student has understood something. It is proposed that "representing mathematical ideas in different ways is an important mathematical practice, used by mathematicians and high-level problem solvers" (Boaler, 2016:187). This is said to be a good way to teach students maths facts along with ensuring a deep understanding of numbers and how they relate to each other. Maths anxiety is addressed here as the suggestions provide an alternative to the memorisation of maths facts that leads to anxiety and the "math crisis we currently face" (Boaler, 2016:38). Whilst ensuring deep understanding of mathematics should already be a goal in the teaching and learning of maths, it is proposed here that using different representations is a better way to do this than by memorisation.

5.2.3. Learners explain thinking:

In order to allow methods to be shared and discussed, teachers should be encouraging learners to explain their thinking, propose SG (2016). Finlayson (2014) believed that "knowledge is dynamic and changes with the experiences [learners] have" (2014:102) and that teachers should actively engage students with interactive student-centred classroom activities. The interactive learning environment suggested by Finlayson (2014) aims to remove maths anxiety from the classroom and fits with the SG (2016) suggestion that students should be encouraged to share their ideas "with the potential to contribute to everyone's learning" (Finlayson, 2014:110). Boaler (2015) values this idea adding that students explaining their work enables them to deepen their understanding and those listening may find a peer's explanation easier to understand than the teachers. Teachers should therefore "organise productive mathematical discussions" (Boaler, 2015:45) as talking is critical to learning maths to ensure learners get the depth of understanding they require. This does not, however, mean that talking about maths should happen all the time as it is suggested that it should be structured alongside time for pupils to work independently (Boaler, 2015). Allowing opportunities for learners to explain their thinking is thus proposed as a means to prevent the creation of maths anxiety and, once again, this is linked to ensuring learners build their confidence by ensuring a depth of understanding in maths.

5.2.4. Mastery learning:

Whilst the SG (2016) mention value in a "mastery approach" to learning maths, the caveat given is that it is not a "one-size-fits-all" approach and that we should therefore only consider some of the general principles. Notable suggestions are the following; embedding learning through practice of skills, drawing repeatedly on key concepts and skills to ensure "over-learning" and differentiated learning to support individual learners to achieve their best with no gaps in learning (SG, 2016). Mastery learning is similarly suggested to prevent maths anxiety by Martinez (1987) who places value in the fact that this approach reduces failings in maths and increases "the development of healthy and confident attitudes towards learning maths" (1987:123). He describes the approach as having no failures as pupils continue to work on a topic or skill until they achieve and demonstrate mastery in it. Learners moving on only once a skill is mastered would indeed ensure there are no gaps in a learner's knowledge, as stated by the SG (2016), however, Martinez' (1987) view is that students would be "self-pacing" (1987:123). With the SG (2016) version of mastery learning proposing that teachers provide differentiation it is clear there are differences when compared to the ideas of students completing a body of work at their own pace. With this model, maths anxiety would be prevented by ensuring confident learners with a deep understanding of topics, giving further support to the notion that learning and teaching strategies that ensure this will address the problem of maths anxiety.

O'Leary *et al.* (2017) agree with the SG (2016) that "generally good instructional practice" is related to lower maths anxiety but despite their hypothesis that those with negative experiences of instructional methods would correlate with higher levels of maths anxiety, they found their results to be inconsistent. In their study the only notable method shown to contribute to lower maths anxiety was that of providing many examples and practice tests (2017:11) somewhat similar to the mastery concept. This agrees with Metje *et al.* (2007) who stated that:

> after spending a significant amount of time doing several examples of, in principal the same mathematical problem, both with and without the students input, this fear for the subject could be lifted as the students experienced some success in solving the problem (2007:87).

Gough (1954) shares this view adding further the need to start with very simple problems then increase the difficulty gradually (1954:293) which has similarities to the ideas expressed above regarding making connections with previous learning. What is key here is the need for students to experience success to ensure that maths anxiety is not created/ heightened. Which adds support to the previously discussed idea that poor performance in the subject causes maths anxiety. With the need to ensure lots of examples are provided to ensure students experience success the potential problem here is the fine line between doing this and for examples becoming repetitive. There is a balance here that must be struck that provides ample opportunity for success whilst students are engaged positively in their learning. It is proposed here that the difficulty in ensuring this balance is met, or that the advice is somewhat contradictory, is why the SG (2016) only suggested using some of the principles of the mastery approach. Creating learning environments with instructional methods that keep this balance will minimise the development of maths anxiety in students by giving enough examples for students to be confident without disengaging students by being repetitive.

5.3. Classroom climate:

Something not mentioned explicitly by the SG (2016) is the importance of the teacher establishing a positive classroom climate to ensure the prevention of maths anxiety. This is supported by research (Martinez, 1987; Dossel, 1993; Stuart, 2000; Metje *et al.*, 2007; Beilock and Willingham, 2014; Finlayson, 2014; Adimora *et al.*, 2015) with descriptions of such a classroom being "a safe and friendly learning environment" (Metje *et al.*, 2007:87) and "an encouraging atmosphere where students feel safe taking risks, receive support when events intrude on learning and believe they can succeed if they put in the effort" (Adimora *et al.*, 2015:695). Classroom climate was a "major factor" in maths anxiety and this is created by the teacher through target setting, appropriate challenge of work and showing of empathy for the students (Adimora *et al.*, 2015). Dossel (1993) states more warmth is communicated to students alongside more differentiated performance feedback (1993:43). The teacher being positive about mathematics is essential, as is emphasising the correct parts of a students work rather than spending time highlighting errors (Suarez-Pellicioni *et al.*, 2016:16). Further supported by Stuart (2000) who writes of empowering students by focusing on their mathematical strengths rather than any weaknesses, similar to Dossel's (1993) suggestion to "attend to partial success and look at ways in which they can be made into complete successes" (1993:42). Beilock and Willingham (2014) stressed the importance of this too and urged teachers to be careful with what they say to students when they are having difficulties. The important general message to put across is that the work can be challenging, however, is achievable with continued effort rather than treating them like the work is unachievable to them. These ideas all correspond with previously discussed notions of the promotion of a growth mind-set and also relate to the general theme of ensuring a positive attitude to the subject.

Whilst the SG (2016) does not explicitly mention classroom climate the learning and teaching ideas they suggest certainly would contribute to a positive classroom climate being established. The growth-mindset approach embodies the principles that learners can achieve their potential through effort, learn from mistakes and embrace new challenges which are all apparent themes in the description of what a positive classroom climate would look and feel like. It also seems apparent that good teaching and learning strategies such as those discussed would similarly be key to the creation of a positive classroom climate. It is therefore here proposed that the key method to prevent maths anxiety from being created in a classroom is through the establishment of a positive classroom climate. This could be done by using some or all of the methods suggested above, however, different strategies may be of more appeal to some teachers than others. The following quote perfectly sums up essential ideas for a positive classroom climate that would lead to the prevention of maths anxiety in individuals: “to learn math, students must want to learn math, feel good about learning math and be confident that they can learn math” (Martinez, 1987:125).

5.4. Behavioural vs cognitive:

Hembree’s (1990) meta-analysis of maths anxiety led him to conclude that cognitive treatments had little result and that instead behavioural-related methods provided the best relief of maths anxiety. Due to the scale and prominence of his research (cited in over 1500 articles) it is important to consider if this fits with findings here. Hembree (1990) studied “classroom interventions” such as efforts to improve student’s achievement, “heuristic versus algorithmic instruction” and different ways to present material and found that such changes were not effective in reducing maths anxiety (1990:42). Comparing this with above; SG’s (2016) recommendations for improving teaching and learning are all said to improve students’ achievements, heuristic approach would relate with the suggestions on the need for an interactive learning environment, algorithmic with mastery instruction and presenting material in different ways meaning self-paced, teacher led etc. It is quite clear then, that Hembree’s (1990) findings contrast with what has been proposed above. However, these methods are considered by Hembree (1990) as cognitive treatments. Whereas the SG’s (2016) suggestions, alongside their implementation as proposed here as part of a change in classroom climate, can be considered as cognitive-behavioural i.e. related both to worry and emotionality since there is an explicit attempt to change students' attitudes. Attempts to build self-confidence in maths, termed "cognitive modification" by Hembree (1990), was found to have produced a moderate reduction in maths anxiety levels (1990:43) which establishes somewhat potential success in the suggestions proposed here. His findings concluded that systematic desensitisation was the most successful treatment for maths anxiety. Whilst the proposals here do not suggest psychological treatments such as this, there are elements of the suggestions that relate closely to the procedure.

Systematic desensitisation involves creating a hierarchy of objects or events that create feelings of anxiety or fear, then address these fears sequentially starting with the one that induces the least anxiety to what was said to create the strongest feelings on anxiety. These are often addressed using relaxation techniques. In agreement with Hembree (1990) Richardson and Suinn (1973) found that no subjects experienced strong anxiety after treatment when faced with high hierarchy items and whilst some experienced moderate levels of anxiety this diminished notably on repeated presentation of the same items. Although both Hembree (1990) and Richardson and Suinn (1973) used relaxation techniques in combination with systematic desensitisation Hembree (1990), found comparable results when used with cognitive restructuring instead. Thus, the above ideas on building self-confidence could be equally as successful when used with systemic desensitisation without the need for relaxation techniques.

5.5. Summary:

It is important to take into account that whilst they are closely related there are differences between methods aiming to reduce levels of maths anxiety and those that aim to prevent its creation. Therefore, it is here proposed that whilst systematic desensitisation used with relaxation techniques can be successfully used to reduce levels of maths anxiety it is likely not the most convenient way for teachers to address the issue in the classroom. The suggested ideas of establishing a positive classroom climate may be more appropriate and realistic for classroom teachers but this would seem to focus more on the prevention of maths anxiety being established in an individual rather on reducing the anxiety one experiences. Although it is here proposed that the SG (2016) recommendations are appropriate as a means to tackle maths anxiety it is important to consider Hembree's (1990) findings that addressing this issue with behavioural methods is more successful then with cognitive ones. Which adds support to the previous discussion that the concept of maths anxiety is more affective than cognitive. We can therefore conclude that the emphasis must be on promoting self-belief and positive attitudes in mathematics which further supports the findings above that classroom climate is key in the drive to address the issue of maths anxiety in the classroom.

6. CONCLUSION:

For over 60 years the literature on maths anxiety has consistently defined it as an adverse reaction to experiences with mathematics. This emotional response causes individuals feelings of unease, dread and fear and a general dislike of mathematics. This can lead to avoidance of situations involving the use of mathematics and is also blamed for poor performance in the subject. With different ideas of whether it is a single or a multi-dimensional concept it has been established that it is considered incredibly complex with many academics offering different interpretations. Suggestions of affective and cognitive elements as well as theories of positive and negative influences add further intricacies and substantiates that there has been no definitive robust definition. Whilst there is no clear argument that can prove its tangible existence, there are substantial claims that individuals report feelings of anxiety when dealing with situations involving maths and this has been measured using a multitude of different scales. With both the OECD (2015) and the SG (2016) keen to acknowledge and address maths anxiety it is clear there is an acceptance that these reported feelings somewhat define the concept of maths anxiety. There is therefore an expectation for practitioners in Scottish schools to attempt to remedy the situation, regardless of whether or not teachers or psychologists can define or label individuals to 'suffer' from maths anxiety. It is thus concluded that whilst it cannot be accepted that maths anxiety is a robustly defined concept, there is evidence that individuals report having emotional responses to mathematics that is said to have an impact on their performance. Whilst it has been discussed that there are suggestions that some feelings of anxiety can have a positive impact (Wigfield and Meece, 1988; Lyons and Beilock, 2011; Wang *et al.*, 2015), it has been clearly established that the prevalent opinion is that these feelings have a negative effect and that this an issue that must be addressed (OECD, 2015; SG, 2016).

To ensure that practitioners are prepared to address the issue of maths anxiety, teachers must be fully trained on what the literature defines maths anxiety to be, how it is said to affect individuals and what strategies are suggested to alleviate or reduce it. This should form part of initial teacher training and is also essential to ensure current practitioners are fully informed if the SG (2016) demands of tackling this issue are to be met alongside addressing wider STEM concerns (OECD, 2017). Ensuring practitioners are fully informed should address the OECD (2015) claim that maths anxiety is an issue for both teachers and students. Highlighting the need to address maths anxiety to teachers should prepare them to help students with the issue and allow them to reflect and identify if it is an issue they themselves are faced with. As discussed previously, maths anxious teachers can pass their attitudes and anxieties on to students, so it is essential that teachers are given the opportunity to consider whether it is possible that they have feelings of anxiety that may impact their classes. Since there is no current concrete strategy to address the issue, there is opportunity for experimentation and future research could focus on how best this issue of maths anxiety could be addressed. What has been shown in the discussion is the importance for pupils to have positive experiences of mathematics to ensure that they do not have these feelings of anxiety. The idea of establishing a classroom climate where pupils are inspired, valued, nurtured and encouraged to succeed in mathematics without fear of judgement or of making mistakes has incredible merit, regardless of the tangible existence of maths anxiety as a concept. Whether maths anxiety, without a clearly established definition, is being used as an excuse in a bid to improve teaching and learning in order to raise attainment is another potential area for further research. However, addressing negative attitudes towards maths and establishing positive ones should be an important part of every maths teacher's job and teachers should be trained and structures looked at to ensure that this is happening. To finish, the following quote should be considered and reflected on:

> let us move together from the mathematics trauma and dislike that has pervaded our society in recent years to a brighter mathematical future for all, charged with excitement, engagement and learning.
> (Boaler, 2015:195)

7. REFERENCES:

Adimora, D. E., Omeje, J. C., Nwokennab, N. E., & Eze, U. N. (2015). Influence of Socio-Economic Status and Classroom Climate on Mathematics Anxiety of Primary School Pupils. *Procedia-Social and Behavioral Sciences*, 205, 693-701.

Alexander, L., & Cobb, R. (1987). Identification of the dimensions and predictors of maths anxiety among college students. *Journal of Human Behaviour and Learning*, 4: 5–32.

Alexander, L., & Martray, C. (1989). The development of an abbreviated version of the Mathematics Anxiety Rating Scale. *Measurement and Evaluation in counseling and development*, 22(3), 143-150.

Armitage, A., and Keeble-Allen, D. (2008). Undertaking a structured literature review or structuring a literature review: Tales from the field. *The Electronic Journal of Business Research Methods*, 6, 103-114, available online at www.ejbrm.com

Arthur, J., Waring, M., Coe, R., & Hedges, L. (2012). *Research Methods and Methodologies in Education*. London: SAGE Publications

Ashcraft, M. H. (2002). Math anxiety: Personal, educational, and cognitive consequences. *Current directions in psychological science*, 11(5), 181-185.

Ashcraft, M. H., & Kirk, E. P. (2001). The relationships among working memory, math anxiety, and performance. *Journal of experimental psychology: General*, 130(2), 224.

Ashcraft, M. H., & Moore, A. M. (2009). Mathematics anxiety and the affective drop in performance. *Journal of Psychoeducational Assessment*, 27(3), 197-205.

Ashcraft, M. H., Krause, J. A., & Hopko, D. R. (2007). Is math anxiety a mathematical learning disability?

Bai, H. (2011). Cross-validating a bidimensional mathematics anxiety scale. *Assessment*, 18(1), 115-122.

Bai, H., Wang, L., Pan, W., & Frey, M. (2009). Measuring mathematics anxiety: Psychometric analysis of a bidimensional affective scale. *Journal of Instructional Psychology*, 36(3).

Baloğlu, M. (2010). An investigation of the validity and reliability of the adapted mathematics anxiety rating scale-short version (MARS-SV) among Turkish students. *European Journal of Psychology of Education*, 25(4), 507-518.

Beilock, S. L. (2008). Math performance in stressful situations. *Current Directions in Psychological Science*, 17(5), 339-343.

Beilock, S. L., & Willingham, D. T. (2014). Math Anxiety: Can Teachers Help Students Reduce It? Ask the Cognitive Scientist. *American educator*, 38(2), 28.

Berlin, I. (1953). *The hedgehog and the fox: An essay on Tolstoy's view of history* at https://www.blogs.hss.ed.ac.uk/crag/files/2016/06/the_hedgehog_and_the_fox-berlin.pdf (last accessed 27.7.18)

Betz, N. E. (1978). Prevalence, distribution, and correlates of math anxiety in college students. *Journal of counseling psychology*, 25(5), 441.

Boaler, J. (2013). Ability and mathematics: The mindset revolution that is reshaping education. *Forum* (Vol. 55, No. 1, pp. 143-152).

Boaler, J., Selling, S. K., & Sun, K. (2013). Where Are the Foxes in Mathematics Education? in K. R. Leatham (ed) *Vital directions for mathematics education research*. New York: Springer. 189-199

Boaler, J. (2015). *The elephant in the classroom: Helping children learn and love maths*. Souvenir Press.

Boaler, J. (2016). *Mathematical mindsets: Unleashing students' potential through creative math, inspiring messages and innovative teaching*. John Wiley & Sons.

Booth, A., Sutton, A., & Papaioannou, D. (2016). *Systematic approaches to a successful literature review*. 2nd Ed, Sage.

Bryman, A. (2008). *Social research methods*. 3rd Ed, Oxford university press.

Buckley, S. (2013). *Deconstructing maths anxiety: Helping students to develop a positive attitude towards learning maths* at https://research.acer.edu.au/cgi/viewcontent.cgi?article=1016&context=learning_processes (last accessed 27.8.18)

Carey, E., Hill, F., Devine, A., & Szücs, D. (2016). The chicken or the egg? The direction of the relationship between mathematics anxiety and mathematics performance. *Frontiers in Psychology*, 6, 1987.

Carey, E., Hill, F., Devine, A., & Szűcs, D. (2017). The modified Abbreviated Math Anxiety Scale: A valid and reliable instrument for use with children. *Frontiers in psychology*, 8, 11.

Cassady, J. C., & Johnson, R. E. (2002). Cognitive test anxiety and academic performance. *Contemporary educational psychology*, 27(2), 270-295.

Chinn, S. (2012). Beliefs, anxiety, and avoiding failure in mathematics. *Child Development Research*, 2012.

Dew, K. H., Galassi, J. P., & Galassi, M. D. (1984). Math anxiety: Relation with situational test anxiety, performance, physiological arousal, and math avoidance behavior. *Journal of Counseling Psychology*, 31(4), 580.

Dossel, S. (1993). Maths Anxiety. *Australian mathematics teacher*, 49(1), 4-8.

Dowker, A., Sarkar, A., & Looi, C. Y. (2016). Mathematics anxiety: what have we learned in 60 years? *Frontiers in psychology*, 7, 508.

Dreger, R. M., & Aiken Jr, L. R. (1957). The identification of number anxiety in a college population. *Journal of Educational Psychology*, 48(6), 344.

Dweck, C. S. (1999). *Self Theories: Their Role in Motivation, Personality and Development*. Philadelphia: Psychology Press

Ernest, P. (1997). The epistemological basis of qualitative research in mathematics education: A postmodern perspective. *Journal for Research in Mathematics Education*. Monograph no. 9, 22-177.

Finlayson, M. (2014). Addressing math anxiety in the classroom. *Improving Schools*, 17(1), 99-115.

Foley, A. E., Herts, J. B., Borgonovi, F., Guerriero, S., Levine, S. C., & Beilock, S. L. (2017). The math anxiety-performance link: A global phenomenon. *Current Directions in Psychological Science*, 26(1), 52-58.

Ganann, R., Ciliska, D., & Thomas, H. (2010). Expediting systematic reviews: methods and implications of rapid reviews. *Implementation Science*, 5(1), 56.

Geist, E. (2010). The Anti-Anxiety Curriculum: Combating Math Anxiety in the Classroom. *Journal of Instructional Psychology*, 37(1).

Gough, M. F. (1954). Why failures in mathematics? Mathemaphobia: Causes and treatments. *The Clearing House: A Journal of Educational Strategies, Issues and Ideas*, 28(5), 290-294.

Greenwood, J. (1984). Soundoff: My Anxieties about Math Anxiety. *Mathematics teacher*, 77(9), 662-63.

Hammersley, M. (2001). On 'systematic' reviews of research literatures: a 'narrative' response to Evans & Benefield. *British educational research journal*, 27(5), 543-554.

Hammersley, M. (2002). Systematic or unsystematic: Is that the question? Some reflections on the science, art, and politics of reviewing research evidence. *Public Health Evidence Steering Group of the Health Development Agency*.

Hembree, R. (1988). Correlates, causes, effects, and treatment of test anxiety. *Review of educational research*, 58(1), 47-77.

Hembree, R. (1990). The nature, effects, and relief of mathematics anxiety. *Journal for research in mathematics education*, 33-46.

Ho, H. Z., Senturk, D., Lam, A. G., Zimmer, J. M., Hong, S., Okamoto, Y., ... & Wang, C. P. (2000). The affective and cognitive dimensions of math anxiety: A cross-national study. *Journal for research in mathematics education*, 362-379.

Hopko, D. R., Mahadevan, R., Bare, R. L., & Hunt, M. K. (2003). The abbreviated math anxiety scale (AMAS) construction, validity, and reliability. *Assessment*, 10(2), 178-182.

Jackson, C. D., & Leffingwell, R. J. (1999). The role of instructors in creating math anxiety in students from kindergarten through college. *The Mathematics Teacher*, 92(7), 583-586.

Jansen, B. R., Louwerse, J., Straatemeier, M., Van der Ven, S. H., Klinkenberg, S., & Van der Maas, H. L. (2013). The influence of experiencing success in math on math anxiety, perceived math competence, and math performance. *Learning and Individual Differences*, 24, 190-197.

Kazelskis, R. (1998). Some dimensions of mathematics anxiety: A factor analysis across instruments. *Educational and Psychological Measurement*, 58(4), 623-633.

Kazelskis, R., Reeves, C., Kersh, M. E., Bailey, G., Cole, K., Larmon, M., ... & Holliday, D. C. (2000). Mathematics anxiety and test anxiety: Separate constructs? *The Journal of Experimental Education*, 68(2), 137-146.

Kilpatrick, J. (2013). 'Needed: Critical foxes' in K. R. Leatham (ed) *Vital directions for mathematics education research*. New York: Springer. 173-187

Leatham, K. R. (ed). (2013). *Vital Directions for Mathematics Education Research*. Springer Science & Business Media.

Levitt, E. E., & Hutton, L. H. (1984). A psychometric assessment of the Mathematics Anxiety Rating Scale 3. *Applied Psychology*, 33(2), 233-242.

Lichtman, M. (2013). *Qualitative research in education*: Third Edition. Thousand Oaks: Sage Publications.

Liebert, R. M., & Morris, L. W. (1967). Cognitive and emotional components of test anxiety: A distinction and some initial data. *Psychological reports*, 20(3), 975-978.

Lyons, I. M., & Beilock, S. L. (2011). Mathematics anxiety: separating the math from the anxiety. *Cerebral cortex*, 22(9), 2102-2110.

Ma, X. (1999). A meta-analysis of the relationship between anxiety toward mathematics and achievement in mathematics. *Journal for research in mathematics education*, 520-540.

Ma, X., & Xu, J. (2004). The causal ordering of mathematics anxiety and mathematics achievement: a longitudinal panel analysis. *Journal of Adolescence*, 27(2), 165-179.

Maloney, E. A., & Beilock, S. L. (2012). Math anxiety: Who has it, why it develops, and how to guard against it. *Trends in cognitive sciences*, 16(8), 404-406.

Maloney, E. A., Ramirez, G., Gunderson, E. A., Levine, S. C., & Beilock, S. L. (2015). Intergenerational effects of parents' math anxiety on children's math achievement and anxiety. *Psychological Science*, 26(9), 1480-1488.

Martinez, J.G.R (1987). Preventing math anxiety: A prescription. *Academic therapy*, 23(2), 117-125.

Metje, N., Frank, H. L., & Croft, P. (2007). Can't do maths—understanding students' maths anxiety. *Teaching Mathematics and its Applications: An International Journal of the IMA*, 26(2), 79-88.

Newstead, K. (1998). Aspects of children's mathematics anxiety. *Educational Studies in mathematics*, 36(1), 53-71.

Núñez-Peña, M. I., Guilera, G., & Suárez-Pellicioni, M. (2014). The single-item math anxiety scale: An alternative way of measuring mathematical anxiety. *Journal of Psychoeducational Assessment*, 32(4), 306-317.

OECD (2015). *Improving Schools in Scotland: An OECD Perspective* at http://www.oecd.org/education/school/Improving-Schools-in-Scotland-An-OECD-Perspective.pdf (last accessed 26.8.18).

OECD (2017). *Education at a glance 2017* at https://doi.org/10.1787/eag-2017-en (last accessed 27.8.18).

O'Leary, K., Fitzpatrick, C. L., & Hallett, D. (2017). Math Anxiety Is Related to Some, but Not All, Experiences with Math. *Frontiers in psychology*, 8, 2067.

Plake, B. S., & Parker, C. S. (1982). The development and validation of a revised version of the Mathematics Anxiety Rating Scale. *Educational and Psychological Measurement*, 42(2), 551-557.

Richardson, F. C., & Suinn, R. M. (1972). The mathematics anxiety rating scale: psychometric data. *Journal of counseling Psychology*, 19(6), 551.

Richardson, F. C., & Suinn, R. M. (1973). A comparison of traditional systematic desensitization, accelerated massed desensitization, and anxiety management training in the treatment of mathematics anxiety. *Behavior Therapy*, 4(2), 212-218.

Rounds, J. B., & Hendel, D. D. (1980). Measurement and dimensionality of mathematics anxiety. *Journal of Counseling Psychology*, 27(2), 138.

Schonell, F. J. (1942). *Diagnosis of individual difficulties in arithmetic*. Oliver and Boyd.

Scottish Government (SG) (2016). *Transforming Scotland into a Maths Positive Nation. The Final Report of the Making Maths Count Group* at http://www.gov.scot/Resource/0050/00505348.pdf (last accessed 26.8.18).

Stuart, V. B. (2000). Math curse or math anxiety? *Teaching children mathematics*, 6(5), 330.

Suárez-Pellicioni, M., Núñez-Peña, M. I., & Colomé, À. (2016). Math anxiety: A review of its cognitive consequences, psychophysiological correlates, and brain bases. *Cognitive, Affective, & Behavioral Neuroscience*, 16(1), 3-22.

Suinn, R. M., & Edwards, R. (1982). The measurement of mathematics anxiety: The mathematics anxiety rating scale for adolescents—MARS-A. *Journal of Clinical Psychology*, 38(3), 576-580.

Suinn, R. M., Taylor, S., & Edwards, R. W. (1988). Suinn mathematics anxiety rating scale for elementary school students (MARS-E): Psychometric and normative data. *Educational and Psychological Measurement*, 48(4), 979-986.

Suinn, R. M., & Winston, E. H. (2003). The mathematics anxiety rating scale, a brief version: psychometric data. *Psychological reports*, *92*(1), 167-173.

Taylor, J. A. (1953). A personality scale of manifest anxiety. *The Journal of abnormal and social psychology*, 48(2), 285.

Tobias, S. (1985). Test anxiety: Interference, defective skills, and cognitive capacity. *Educational Psychologist*, 20(3), 135-142.

Torgerson, C., Hall, J. and Light, K., (2012). 'Systematic reviews' in J. Arthur, M. Waring, R. Coe, L. V. Hedges (Eds) *Research Methods and Methodologies in Education*. London: Sage, 217-230.

Wang, Z., Lukowski, S. L., Hart, S. A., Lyons, I. M., Thompson, L. A., Kovas, Y., Mazzocco, M. M. M., Plomin R., & Petrill, S. A. (2015). Is math anxiety always bad for math learning? The role of math motivation. *Psychological science*, 26(12), 1863-1876.

Waring, M., (2012). 'Finding your theoretical position' in J. Arthur, M. Waring, R. Coe, L. V. Hedges (eds) *Research Methods and Methodologies in Education*. London: Sage, 15-19.

Wigfield, A., & Meece, J. L. (1988). Math anxiety in elementary and secondary school students. *Journal of educational Psychology*, 80(2), 210.

Wood, E. F. (1988). Math anxiety and elementary teachers: What does research tell us? *For the learning of mathematics*, 8(1), 8-13.

8. APPENDIX 1:

Maths Anxiety Scale (MAS) (Betz, 1978)

Respond to the following questions using the scale from 1 – 4.
1 (almost never); 2 (sometimes); 3 (often); and 4 (almost always).

1. It wouldn't bother me at all to take more math courses.

1 2 3 4

2. I have usually been at ease during math tests.

1 2 3 4

3. I have usually been at ease in math courses.

1 2 3 4

4. I usually don't worry about my ability to solve math problems.

1 2 3 4

5. I almost never get uptight while taking math tests.

1 2 3 4

6. I get really uptight during math tests.

1 2 3 4

7. I get a sinking feeling when I think of trying hard math problems.

1 2 3 4

8. My mind goes blank and I am unable to think clearly when working mathematics.

1 2 3 4

9. Mathematics makes me feel uncomfortable and nervous.

1 2 3 4

10. Mathematics makes me feel uneasy and confused.

1 2 3 4