A Review of Underlying Factors in Math Anxieties

by

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Abstract

Math anxiety (MA) has been defined as a fear of math or an emotional negative feeling towards mathematical tasks and has been argued to have a significant impact on students' mathematics learning, performance, and achievement. There are numerous studies centering on MA and the underlying factors that are theorized to contribute to it. Many studies focus on the external influences that contribute to the development of MA in students, such as parental stereotyping and math beliefs. However in addition to these findings, research also suggests that MA is rooted in genetic factors. The literature in this review will explore two dimensions: the external and internal factors that are theorized to be associated with MA. The purpose of this review is to shed light on some of the many dimensions that contribute to MA in order to develop a better understanding of the underlying factors affecting our students ridden with math anxieties.

Keywords: mathematical anxiety, cognitive abilities, mathematical development, cognitive reflection, genetic influences, working memory, math-anxious parents, teachers' math knowledge, gender stereotyping, mathematical beliefs, mathematical attitudes.

Introduction

Math anxiety (MA) has been studied and researched for years, and the topics of interest vary widely from the causes (Kazelskis, 1998), how it affects performance (Jansen, Louwerse, Straatemeier, Van der Ven, Klikenberg, & Van der Maas, 2013), to achievement (Ma & Kishor, 1997; Beilock & Maloney, 2015), and the impact it has on overall math development (Beilock & Maloney, 2015;Rossnan, 2006). MA has been described as a "feeling of tension and fear that accompanies math-related activities (Wang et al., 2014, p. 1056) or "negative emotions about math" (Ferguson, Maloney, Fugelsang, & Risko, 2015, p. 1). However, despite discrepancies across definitions, most point to the same general description, this being a fear of math. The rationale for this literature review is to explore some of the multifaceted underlying factors associated with MA and to underline the importance of viewing MA through different lenses. As a result, the aim of the paper is to develop better understanding of the scope of the research that exists in order to have a more comprehensible understanding of MA, as it presents itself in our students.

In the following literature review, I will look at research focused on the external and internal factors contributing to math anxiety. As for external factors, I will be focusing on the transmission of math attitudes and anxieties, and teacher knowledge, strategies, and beliefs. As for internal factors, I will be looking into predetermined genetic factors affecting MA, as well as cognitive factors. My goal is to arrive at a more comprehensive understanding of what is contributing to math anxiety in our students.

Personal Interest

Through my probing into the MA topic, I quickly came to realize the depth of this issue and the many facets of research expanding from this topic. I decided to focus on the issue of

underlying factors through a large sense of curiosity around MA to give me insight into my own math anxieties. I could have looked at how MA affected performance, which I came to realize was far different from achievement. In addition, many research articles looked at both, and how one correlated with the other. However, as these were very interesting, I was more drawn to finding out about the multifaceted factors of MA and to address the etiologies behind the "fear of math." I felt that a review of the roots of MA required more attention as it affects not only the self-concept of the child, but their abilities to use math in their everyday life. Personally, I definitely felt limited in my abilities in math and felt extremely anxious when it came to showing what I know. When I consider the social factors and genetic factors, I think of my childhood.

As a student, I was profiled by my parents. My mom was head secretary to the CEO of Nordair in Québec and was fortunate to be able to do math in her head and possess a deep number sense that allowed her to be the financial organizer in the family. On the other hand, there was my father, 'who was who he was', determined to show his teachers that they were wrong in their predictions about his life success. As a pilot, he came to be successful in spite of his teachers, their predictions, and his "inadequacies." My father never finished high school and possessed weak number sense and financial competencies. Genetically, I felt more like my father. My mother would lose patience quickly with me as I struggled through math problems, taking far longer than the allotted homework time at home. She could not understand what I did not understand and why I could not retain or work through problems with understanding. On the other hand, my older brother was gifted in math, and this only highlighted and intensified my own deficiencies. As a result, I began to develop a very poor self-concept as a learner in the math area, suffering poorly in any activity that was spatial, timed, or was written as a problem to

solve. Thus, my interest in this topic lies in my own curiosities in regards to the underlying factors of math anxiety and to dispel the myth of "just not being good at math."

Background

MA has the potential to impact students in a variety of ways. For example, MA can affect career choices, a persons' self-concept, and social life to name a few. Currently, there are fewer students going into the areas of science, technology, engineering, and math than our society demands for these fields to meet growth and address both economic and environmental concerns (Beilock & Maloney, 2015). Society is impacted negatively "when otherwise capable students avoid the study in mathematics, their options regarding careers are reduced, eroding the country's resource base in science and technology" (Hembree, 1990, p. 34). There is also a more personal concern regarding how MA has the potential to debilitate adults in regards to their personal lives, such as finances and a sense of direction (Wang et al., 2014). Beilock and Maloney (2015) build upon this idea by observing adults with MA struggle with everyday tasks, such as calculating tips and knowing if they received the right amount of change. These concerns point to the importance of better understanding MA (Radisic, Videnovic, & Baucal, 2014). These authors noted that although student's cognitive competencies predict confidence, it is the affective factors of MA that will predict their career and life choices.

For the purpose of this review, I will be looking at articles that focus on different areas within the external factors related to MA. First off, I will review articles that researched the transmission of anxieties and attitudes from parents to students and the potential negative effect on MA. I will be exploring how the transmission of anxiety and attitudes of math can be detrimental to the math development and MA in a child (Maloney, Ramirez, Gunderson, Levine, & Beilock, 2015). Rossnan (2006) points out that parents should help their children with math,

however he highlights that they may also cause MA if they impose their math beliefs on their child, especially if they themselves have MA.

In view of teacher transmission of MA, Finlayson (2014) concluded that there is a direct effect on the learner in terms of confidence, self-concept, and the development of MA if the teacher experiences fear, lacks self-confidence, or has a weaker understanding of the subject matter. Research speaks of the importance of providing a positive learning environment for students and how this enhances student confidence and feelings of security (Rossnan, 2006). This is supported by the research exploring the school level factors that contribute to MA and how negative experiences in math in school will continue to come up frequently in their everyday lives as adults (Radisic, Videnovic, & Baucal, 2014). Finlayson (2014) looks at the effects of teaching strategies and classroom environment as factors in MA. Causes of MA, according to this particular research, may be attributed to the teaching styles in the math classroom and the subject knowledge of the teacher.

A related sub-topic associated with external factors is the stereotypical beliefs of parents and students' self-concept. Research has investigated the correlation between parents' stereotypic beliefs about math and how these beliefs affect the child's self-perception (Tomasetto, Mirisola, Galdi, & Cadinu, 2015). The research also speaks about how these beliefs have an effect on a child's self-concept towards mathematics, demonstrating that MA is significantly related to students' beliefs of competency and ability (Ahmed, Minnaert, Kuyper, & van der Werf, 2012). Although Maloney and Beilock (2012) explore the cognitive underlying factors in MA, they also look at the environmental influences, such as how MA seems to "fall along gender lines" (p. 404) and they delve into the transmission of beliefs in math from teacher to student. Soni and Kumari (2017) also found a correlation between the belief of the parent to

the belief of the child, with the results of the research showing that parental anxieties and attitudes act as "precursors to their children's math anxiety and math attitude" (p. 331).

As a second topic of review in MA, I will look at internal factors (i.e., genetic predispositions) by exploring articles that research how anxiety and cognitive math abilities can be seen as predetermined deficits (Wang et al., 2014). This research acknowledges the involvement of both the affective and the cognitive as etiologies in MA and the interactions that exist within each genetic domain; such as, working memory and spatial abilities within the cognitive domain (Ferguson, Maloney, Fugelsang, & Risko, 2015) and genetic anxiety (Wang et al., 2014). Maloney and Beilock (2012) explore the cognitive predisposition that students may already have towards developing MA. Shi and Liu (2016) also explore how deficits in working memory and worrying-thoughts play a part in MA. Finally, Morsanyi, Busdraghi, and Primi (2014) link MA to a deficit in reflection and making good decisions. I aim to look at articles reviewing these internal factors as contributors to MA.

Presently, I am an administrator, a physical education teacher, and the Learning Support Facilitator in a French Immersion elementary school. My interest in this subject is threefold: (i) to better understand the etiologies behind MA so that I can have a better understanding of learners with MA; (ii) to gain a greater scope of knowledge in the area of MA to assist parents and students with anxieties and (iii) to support teachers who have students with MA. For these reasons, I aim to explore the articles targeting external and internal factors affecting MA.

The purpose here is to review the empirical literature on the external and internal underlying factors of MA. Specifically, as suggested in the research background, the following questions guide the review.

1. What are the external factors influencing MA in children?

(i) How do the math beliefs of parents and of the students themselves contribute to MA?

(ii) How do the math anxieties and attitudes of parents and teachers contribute to MA in children?

2. What are the internal factors that contribute to MA in children?

(i) How is math anxiety affected through cognitive genetics?

Research Pathway

This process was long and arduous. The research sites to which I mainly referred were the library in the uvic.ca website and the Web of Science website. The articles that I found first pertained to my initial topic on methods to teach struggling math learners. Through keyword searches, such as struggling math learner and math methods, I narrowed my reference list down to the suggested 25 articles.

As I read through the abstracts and conclusions in my chosen articles, and in discussion with my project supervisor, I decided to change my topic to be a more focused area of review. As I wanted to stay with the struggling learner, as my experiences lend me to know that this is an area of need, I decided to narrow it down to math anxieties in our learners. I then knew to restart my search of articles to be pertinent to this main focus of study. I returned to my web searches and repeated my search and save process. Once I had saved my articles, I read through the abstracts and this is where I then lost my direction on how to proceed further. It took me a while to realize that I am very visual and required a chart, not a list, to input my titles and categorize my sub-topics in the area of math anxiety in students.

I took my time to review the abstracts, find main quotes of reference to the sub-topic, and I copy pasted the titles into a chart. Once I read the abstract, scanned the paper, and read the conclusions, I noted down any key findings or statements that I could use later on in my

introduction. If I did not use them, they at least gave me an inside glimpse and reminder of the key findings and purpose of the articles, which hopefully will save me time in the end. I would then look at the reference section of some of the stronger articles to lead me to other articles that may be useful.

Once my chart was filled with titles and key finding or statements, I quickly went through and categorized them. In the beginning I had three categories: Social, Environmental, and Genetic. I then narrowed it to two categories, being environmental and genetic. In my last review of my categories, I changed them to external and internal influences of math anxiety.

Definitions

Mathematical anxiety (MA). "A feeling of tension and anxiety that interferes with the manipulation of numbers and the solving of mathematical problems in a wide variety of ordinary life and academic situations" (Shi & Liu, 2016, p. 1).

Cognitive abilities. General intelligence and working memory (Wang et al., 2014).

Mathematical development. "Early stages of formal acquisition of math skills" (Young, Wu, & Menon, 2012, p. 492).

Cognitive reflection. "Involves the ability to effectively monitor and correct impulsive response tendencies" (Morsanyi, Busdraghi, & Primi, 2014, p.2).

Genetic influences. The biological pathways, involving both the cognitive and the affective, that elevate risks for developing math anxiety (Wang et al., 2014).

Working memory. "A limited capacity system that integrates, computes, stores, and manipulates the information to which a person is attending" (Beilock & Maloney, 2015, p. 5).

Math-anxious parents. Parents who "may have inadequate math-helping skills or rigidly use of instructional strategies that conflict with those that teachers use in the classroom,

which could confuse children and negatively affect their math learning" (Maloney, Ramirez, Gunderson, Levine, & Beilock, 2015, p. 1481).

Teachers' math knowledge. A "teacher's facility in using mathematics knowledge for classroom teaching, including the ability to explain mathematical rules" (Maloney, Ramirez, Gunderson, Levine, & Beilock, 2015, p. 1483).

Gender Stereotyping. "Beliefs about males' and females' differential abilities" (Tomasetto, Mirisola, Galdi, & Cadinu, 2015, p. 186) whereas domains are stereotyped as either masculine or feminine.

Mathematical beliefs. An individuals' "self-perception of math ability" and task values (Passolunghi, Ferreira, & Tomasetto, 2014, p. 71).

Mathematical attitudes. How one perceives and feels towards the value of learning math (Papanastasiou, 2000).

Literature Review

The reason for this study is to explore and review the literature surrounding the reasons for math anxiety (MA). MA can generally be described as the "state of discomfort caused by performing mathematical tasks" (Devine, Fawcett, Szucs, & Dowker, 2012). Attitude can be described as "a mental concept that depicts favorable or unfavorable feelings toward an object" (Papanastasiou, 2000, p. 28). Beliefs can be defined as the perception of abilities in math (Passolunghi, Ferreira, & Tomasetto, 2014). In our classrooms, we are finding that many students are exhibiting anxious behaviors, negative attitudes, and poor self-concepts surrounding the content area of mathematics. MA can present itself through absenteeism during testing situations in math, through mental blocks with the verbalization of "I am not good at math", and work avoidance, to name a few. As an educator in an elementary setting, as well as the Learning Support Facilitator, I have had many discussions surrounding MA. As MA seems to be prominent in our schools, as well as amongst the parents who feed into the anxiety due to their own anxieties, I aim to review the studies that may explain the underlying factors, both external and internal, of MA.

External factors that can contribute to MA include social and environmental factors that could act as contributors to the anxiety. In terms of social factors, I will be reviewing literature on the beliefs of parents and the self-concept of students. In terms of environmental factors, I will be looking at parental math anxieties, and how this affects the attitudes and anxieties of the children. Another environmental factor is be the effect of the teachers' confidence, knowledge, and comfort level with the subject, including if the teacher also has anxieties and attitudes that may be passed onto the students.

Likewise, internal factors of math anxiety (MA) would include any genetic cognitive contributors to MA. I will be exploring the cognitive factors of working memory and spatial ability.

External Factors Influencing Math Anxiety

Beliefs of Students and Parents

The first question explored is "How do the math beliefs of parents and of the students themselves contribute to MA?" To be successful in an area, one needs to believe they have the capacity. A belief can be described as perceived information about a subject, such as believing if one can do math or doesn't have the abilities to do math (Papanastasiou, 2000). There are many factors that affect the self-concept of the child, and so I felt it important to look at the belief systems of the adult role models in the lives of the students. Student's own belief systems are influenced by the beliefs of their parents, and also those of their teachers (Parsons, Adler, & Kaczala, 1982).

Beliefs of Students

Student self-concept. Research has shown that a child's self-concept has the largest effect on MA (Ahmed, Minnaert, Kuyper, & Greetje van der Werf, 2012; Bartley & Ingram, 2017; Jameson, 2014). In saying that, a child's self-concept is heavily influenced by verbal assertions (Bartley & Ingram, 2017; Jain & Downson, 2009). When a child is continually praised, they internalize this information and will move forward with a stronger concept of self and self-efficacy to make solid decisions. In contrast, if a child is told numerous times that they will fail or that they do not have the ability, this child will also avoid math experiences due to MA (Jameson, 2014). This poor self-concept also has large repercussions on a child's self-efficacy.

Self-efficacy is the amount of confidence that one has in their ability to complete tasks (Jain & Dowson, 2009). Self-efficacy is related to MA. In one study, it speaks of the "Deficit Theory" whereas "anxiety emerges a result of poor mathematics performance in the past" (Devine, Fawcett, Szucs, & Dowker, 2012). If a child has experienced difficulties in being successful on math tasks and tests, this in turn has contributed largely to their self-efficacy beliefs in math. In this study, self-efficacy has shown to be a high predictor of MA (Devine, Fawcett, Szucs, & Dowker, 2012).

Self-concept of males and females. There is also the factor of how females view success as opposed to males. Males may attribute their rate of success and failure in math to their effort, whereas females tend to relate it to their ability, being critical of their math performance (Frenzel, Pekrun, & Goetz, 2017; Jain & Dowson, 2009). Females tend to experience more of a negative emotional response to failure than their opposing counterparts, therefore enhancing their belief that they are less mathematically skilled (Frenzel, Pekrun, & Goetz, 2017; Hill et al., 2016).

Beliefs of Parents

Parental math beliefs. There is research that shows that a child's belief in their own math abilities is heavily influenced by the parents' interpretations of marks and by the value that the parents place on math (Soni & Kumari, 2014). Parenting practices contribute to anxious behaviors; if a parent does not value math and see its usefulness, this is the same message conveyed to their children (Soni & Kumari, 2014). The process of observing behaviors is one way of learning about social norms, and children tend to imitate and act out what they see modelled (Parsons, Adler, & Kaczala, 2017). Parents, who themselves possess a low self-concept in math and who perceive low math efficacy in their child, pass on these beliefs to their children

(Parsons, Adler, & Kaczala, 2017). This in turn, affects a child's self-concept in math, which we have already discussed as being the main contributor to MA (Bartley & Ingram, 2017; Jameson, 2014; Ahmed, Minnaert, Kuyper, & Greetje van der Werf, 2012).

Parental gender beliefs. In terms of gender ability beliefs, parents again play a role in the development of math anxiety (MA) in their children. According to research, parents are the major environmental factor influencing children's beliefs about their abilities (Tomassetto, Marisola, Galdi, & Cadinu, 2015). In determining how gender beliefs play a part in the gender MA, parents generally tend to believe that their sons are more competent than their daughters in terms of math ability (Tomassetto, Marisola, Galdi, & Cadinu, 2015). Results shared in many studies reveal that girls MA is higher than that of boys MA (Devine, Fawcett, Szucs, & Dowker, 2012; Frenzel, Pekrun, & Goetz, 2017; Hill et al., 2016). These biased views result in affecting their own child's self-perception of math ability. Mother's perceptions of math ability seem to have more of an influence than that of the father's beliefs about ability (Tomassetto, Marisola, Galdi, & Cadinu, 2015; Steele, 2003). The sex-role socialization hypothesis (Devine, Fawcett, Szucs, & Dowker, 2012) argues that math is typically a male oriented domain and that women may therefore be socialized to deem themselves incompetent in math abilities.

Attitudes of Parents and Teachers

The second question addressed in this literature review is "How do the math anxieties and attitudes of parents and teachers contribute to MA in children?" This question raises the issue of how adult role models can affect and influence the attitude and anxiety of children in their care. We will look at the two primary adult role models, parents and teachers. As parents carry attitudes and anxieties toward math, we are called to look at how these are passed on to the children or students, thus affecting their own attitudes and anxieties. One of the main reasons for

parents affecting their children is that they are the first teachers and carry the most influence in terms of academic achievement (Maloney, Ramirez, Gunderson, Levine, & Beilock, 2015). From this, it is not that far a jump to recognize that teachers are also highly influential in terms of behavior and attitudes towards math. For example, Beilock, Gunderson, Ramirez, and Levine, (2010) note that students are likely to be influenced of teachers of same gender. On that thought, it is important to review the studies particularly of female teachers on their same gender students, seeing that girls exhibit higher MA than boys (Devine, Fawcett, Szucs, & Dowker, 2012; Frenzel, Pekrun, & Goetz, 2007). Therefore, we will be looking at how both the transmission of attitudes and anxieties of both role models, parents and teachers, play into the attitudes and anxieties of students.

Parental Attitudes and Anxieties in Math

Math attitude. It has been shown that parents with MA negatively affect their child's math attitude, and alternatively that parents with a negative math attitude also influence a child's MA (Soni & Kumari, 2015). Similarly other research echoed the transmission of MA from parent to child, also mentioning that parental attitude about a child's abilities has more power than a child's own past performance in math (Parsons, Adler, & Kaczala, 2017). Additionally, according to a study using a path analyses to rate the transmission of parental MA to their child, a parent's MA can act as a predictor of MA and math attitude in their child, further influencing their math achievement (Soni & Kumari, 2015). The parents' own feelings about math transmits negative messages to their child, thus affecting the child's own attitudes and creating anxieties. Parents with higher MA have a tendency to share their negative outlook towards math, also presenting low engagement and belief in being successful in math. The transmission of this

perception and fear of math can then affect the motivation of their own child in math, and as a result, less learning elevates the potential for MA (Maloney et al., 2015).

Homework help. Students struggling in math and showing signs of stress often turn first to their parents for support and assistance (Maloney et al., 2015). This pattern of requests for support in the area of math homework may affect the anxiety of the child if the parents themselves indicate signs of MA. According to research, parents who have MA can influence their child and transmit their own anxieties, fear, and attitudes if they are working directly with their child (Maloney et al., 2015). One of the reasons why parents with MA are discouraged from working with their child at home on math, is due to the findings that parents who have MA possess weaker math skills and abilities to instruct adequately the material to their child (Maloney et al., 2015). These same parents do not then possess a deep understanding and use "old ways" of teaching, and as a result, the assistance is not only not helpful, but the child's perception of the parent's emotional response acts as a trigger for MA (Bartley & Ingram, 2017).

Observational learning. According to research, one way in which children learn behaviors and attitudes is through observational learning. Children imitate and adopt the attitudes and behaviors of their parents (Maloney et al., 2015). As a child sits down to work on homework with a parent, the perception of the parental emotional attitude toward the subject matter contributes greatly to the attitude and behavior of the child. Another study supports this concept of observational learning, whereas they find that "parental modelling of mathematical affect can contribute to the development of children's mathematics self-efficacy when children observe and assimilate their perception of their parents demonstrated behaviors relating to mathematics"(Bartley & Ingram, 2017, p. 5). According to these studies (Bartley & Ingram,

2017; Maloney et al., 2015), if a parent felt unsuccessful and experienced negative situations in school math, this may contribute to MA.

Teacher Attitudes and Anxieties in Math

Teacher attitude. Likewise, MA is also caused in part by the feelings and attitudes that a teacher may have towards math (Bekdemir, 2010; Finlayson, 2014). Much like the transmission of anxiety from parent to child, teachers who experience MA also pass on their attitudes and feelings of fear of math to their students (Fiore, 1999).

Teachers with high MA and what they transmit to students. According to Tobias & Weissbrod, students' negative experiences in math class are largely due to how the matter is presented, the attitude of the teacher towards math, and the teacher MA being transmitted to their students (as cited in Fiore, 1999). Finlayson (2014) also shares in her research that students often develop MA as a result of having teachers who have poor self-efficacy beliefs in their own math abilities. According to Stuart, MA does not originate from the subject itself, but on how it is presented (as cited in Finlayson, 2014). All of these findings point to the importance of placing a teacher with high self-efficacy beliefs in math in front of our students.

Anxiety transmitted by same gender role model. Children are more attuned to model the behaviors and attitudes of same gender teachers than those of the opposite sex (Beilock, Gunderson, Ramirez, & Levine, 2010). Although girls seem to perform generally as well as boys, they are more prone to experience less enjoyment and confidence, and higher MA (Devine, Fawcett, Szucs, & Dowker, 2012; Frenzel & Pekrun, 2007; Steele, 2003). Female teachers in particular, affect the attitudes of math in same gender students. There appears to be negative consequences for girls in terms of attitude and anxiety in math when a female teacher exhibits MA. It seems that if the female teacher acts nervous and uncomfortable when teaching math, this

stress is transmitted in particular to the female students (Beilock, Gunderson, Ramirez, & Levine, 2010).

Contributing teaching practices and environment to anxiety. Research has also shown that a positive and encouraging environment is needed in order to instill confidence in students in their learning, therefore teachers need to be confident and not in fear of the subject matter (Rossnan, 2006). As teachers communicate how they feel towards a subject to their students, students can develop anxiety if the teacher is not fully prepared to teach math (Dossel, 2016), and possesses a negative attitude towards the subject; math anxious teachers tend to teach more traditionally and do not teach along the best practices guideline, focusing more on skills than on the comprehension behind the math skill (Chernoff & Stone, 2014; Downson & Jain, 2009; Rossnan, 2006). According to research, if teachers fail to implement certain measures, this may contribute to math anxiety in their students. Measures to decrease anxiety in students would include: a positive attitude towards math, a display of enjoyment in the subject, authentic tasks meaningful to their everyday life, lessons that are differentiated to the students interest, goals that are manageable and realistic, and activities that would allow for high success (Rossnan, 2006). In order for a teacher to be able to produce such a learning environment, they would need to be able to feel comfortable and confident in the subject matter. The teacher would need to "engage in careful and reflective practice that ensures a more humanistic approach suited to each learner" (Chernoff & Stone, 2014, p.30) and use teaching methods that encourage competencies such as creativity and problem solving for deeper understanding (Bekdemir, 2010).

Discussion of External Factors

Through a comparison reading of the studies on the external factors of MA, there are a number of parallel and opposing thoughts. One finding that has resonated quite loudly is the

importance of the formative beginning years of a student to regulate MA and increase math self-concept. The learning conditions that we create through negative experiences, such as "hostile teachers, and teachers who themselves have mathematical anxiety" (Harari, Vukovic, & Bailey, 2013, p. 539) set the students up to develop MA. However, this is not enough to completely trigger MA as it is developed through an interplay of factors that are then internalized and believed by the student (Harari, Vukovic, & Bailey, 2013). There appear, however, to be two trains of thought of when MA develops, as early as grade one (Maloney & Beilock, 2012) or later on in their scholar years, where they have had time to internalize negative experiences and form math beliefs and self-concepts that play into it (Harari, Vukovic, & Bailey, 2013; Parsons, Adler, & Kaczala, 1982). This might be especially relevant when it comes to gender ability beliefs (Hill, Mammarella, Devine, Caviola, Passolunghi, & Szucs, 2016). However, both views point to the importance of creating a positive learning environment, rich in differentiation and in teaching to the level of the child (Metje, Frank, & Croft, 2007).

Internal Factors Influencing Math Anxiety

The third question reviewed is "How is math anxiety affected through cognitive genetics?**"** Underlying internal factors of MA would include any predisposed genetic cognitive contributors to MA associated with affecting "the building blocks of mathematics" (Maloney & Beilock, 2012, p. 404), such as working memory, cognitive reflection, and spatial ability (Ashcraft & Krause, 2007; Beilock & Maloney, 2015; Morsanyi, Busdraghi, & Primi, 2014; Shi & Liu, 2016). These are factors that are not influenced socially or environmentally. According to the research of Wang et al.(2014), genetic factors are responsible for more than 40% of MA (Wang et al., 2014). It was concluded in this study that this percentage included genetic risks of

anxiety and math cognition. In this section, I will look primarily at the effects of cognitive skills on MA, namely working memory, cognitive reflection, and spatial ability.

Working memory. Anxiety seems to have an effect on cognitive factors, such as working memory. Working memory can be defined as "a limited resource cognitive system used to actively maintain information in the face of ongoing processing and/or distraction" (Shi & Liu, 2016, p. 2). Worrisome thoughts, or behaviors exhibited in students with MA, tend to interfere with the resources of working memory when faced with a arithmetic or math related problem (Ashcraft & Krause, 2007; Shi & Liu, 2016). The worries tie up "valuable thinking and reasoning resources" (Beilock & Maloney, 2015) that are required to accomplish math tasks. As the complexity of math problems and arithmetic grows, so does the demand on the working memory (WM); as problems become more complex, more steps are required, more numbers need to be manipulated. A student with MA is then being asked to do two things at once, worry and process information (Beilock & Maloney, 2015, Moran, 2016). The worries disrupt the process and drain the resources required for WM to work (Ashcraft & Krause, 2007; Shi & Liu, 2016).

Cognitive reflection. There also tends to be a link between cognitive reflection and working memory, whereas MA, as it burns through the WM resources, the ability to reflect is compromised (Morsanyi, Busdraghi, & Primi, 2014). Therefore, the ability to make good decisions in problem solving is compromised. The empirical research by Young, Wu, & Menon (2012) found, through neuroscientific data, that students with high MA show higher activity in their brain region that is associated with negative emotions (the amygdala) and less activation in the area of their brain that is responsible for WM (as cited in Beilock & Maloney, 2015). In sum,

students who have lower math abilities also have compromised WM resources, and thus are more vulnerable to MA (Ashcraft & Krause, 2007).

Spatial ability. According to the research of Ferguson, Maloney, Fugelsang, & Risko (2015), there is a correlation between spatial ability and MA. Although spatial ability is not directly dealing with numbers, there is a relationship between rudimentary math and spatial skills at a very early age in math development, for example in the use of the number line. According to research, students who display a weak sense of the spatial-numerical association are predicted to struggle more in math, and are more susceptible to MA (Beilock & Maloney, 2015; Ferguson, Maloney, Fugelsang, & Risko, 2015). Students with MA also seem to exhibit a poorer sense of direction (Ferguson, Maloney, Fugelsang, & Risko, 2015). Therefore, there is a strong connection between MA and a sense of direction, as well as MA and spatial abilities (Beilock & Maloney, 2015; Ferguson, Maloney, Fugelsang, & Risko, 2015) demonstrating that MA begins in part at the very beginning of the "building blocks of complex math" (Beilock & Maloney, 2015, p.7).

Discussion of Internal Factors

As we look at the students in our class, we need to account for the various internal starting points of our students. As pointed out by Beilock and Maloney (2015), students with MA struggle on math tasks that put demands on number and spatial sense "which suggests that math anxiety is related, at least in part, to problems in the basic building blocks of complex math" (p. 7). As we look at how to decrease MA in our students, we need to also look at how students process information and the gaps in their learning that will cause MA down the line. As detailed in the research noted above, there are large connections between a student's spatial processing, counting, short term memory, ability for cognitive reflection, and the development of MA.

Therefore, if a student begins their math formation with struggles in the basic math skills, this will affect the math learning and MA in their future (Beilock and Maloney, 2015).

Discussion

The purpose of this review was to find major contributing factors to math anxiety (MA). There seems to be a vicious cycle of which we need to be aware, where there is not only one but many contributing factors that cause MA (Jameson, 2014; Wang et al., 2014). The genetic influences of MA and cognitive factors affect math performance, as well as the environmental factors of teacher and parent attitudes and beliefs, which in turn affect the self-efficacy math beliefs of the child. This spiraling cycle influences the child's self-concept towards math, as either being good or not good in math, and in all math-related life activities.

In light of these findings, a number of recommendations come into focus to decrease MA in our teachers, parents, and students. First, teachers need to be aware of what they request of parents when they ask for parent math support. As suggested by Maloney, Ramirez, Gunderson, Levine, and Beilock (2015), we need to put into place interventions focused on decreasing parental MA and increasing positive attitudes and beliefs. We need to provide parents with the tools and skills to best encourage their child at home. Home math support would then be more effective, which would in turn increase math performance and decrease MA.

Second, we need to ensure that our teachers are confident, and possess a high self-efficacy and understanding of mathematics (Finlayson, 2014; Fiore, 1999). Teachers who exhibit high MA tend to teach conservatively and traditionally, as they are not able to take risks and extend their teaching. To decrease MA in our students, we need to instill strong knowledge base and confidence in our teachers so they are able to teach problem-solving and deepen

comprehension instead of focusing solely on skills (Chernoff & Stone, 2014; Jain & Downson, 2009; Rossnan, 2006).

Third, we are charged with ensuring the best education for all students, and to differentiate as needed for students to be successful. In the area of MA, we need to pay close attention to our students who have difficulty with attention and who are struggling with the basic building blocks of math as they are the ones most prone to MA (Beilock & Maloney, 2015). In light of the findings on cognitive factors, especially in terms of WM both verbal and visual, this makes us aware of those students who tend to worry (highly anxious), as well are easily distracted (attention deficit) as they are likely to have issues with their WM as it requires an ability to "control attention and thought" (Shi & Liu, 2016, p. 2). We need to be proactive in recognizing this early and in providing supports and resources for students and parents.

Being aware of the contributing factors of MA, we are then called to take action in order to help our students be successful in managing their anxieties and increasing their learning in math. In the end, we have the responsibility of providing positive learning experiences to increase math self-concept and develop confidence in our students as learners.

Project Rationale

Due to the rising math anxieties (MA) exhibited in our math classrooms on a daily basis, this project was designed to bring about an awareness of the existence of MA and its contributors. We address frequently and assess even more frequently, ability through performance of our students in our math classes. Students who struggle are differentiated through product expectation, work load, chunked assignments, more allotted time, graph paper, but we always seem to be on the receiving end. This project aims to open the minds of educators to look at the beginning and not the receiving end of MA; what are the underlying factors of MA and how can

we support our students with MA?

Extending the Research

The findings in the research report many contextual factors, both internal and external, that have large effects on MA. To focus on only one would be at our students' disadvantage; in order to decrease MA and increase math self-concept of all stakeholders in education, we need to see the larger picture and explore the various contributing factors of MA. The goal is to bring awareness and resources of this topic to all involved: parents, teachers, and students.

The final project, after reading and reviewing the research that answered these questions, aims at supporting our students and children through the education and support of teachers and parents. Again, with the same goal of addressing various beginning factors (parents and teachers) and not the end results (students) of math anxiety. The product of the project is through the mode of power-point presentation aimed at teachers and parents, including a handout of brief supports for each.

First, I would define and bring awareness to the existence of math anxiety in our classrooms, and this would lead to describing certain internal and external factors that contribute to this anxiety. By identifying the external first, I am addressing factors that are caused by the social environment of the child, and which we have more control, to either be a positive or negative influence in MA. Beginning with the concept of child, the idea is to bring the focus to the detrimental or empowering factor of belief in one's own abilities, and to start with the child. From there we look outside of the child to their parents and teachers, to see how their beliefs, attitudes, anxieties, behaviors affect the self-concept and anxiety of the child.

For parents, I address issues surrounding homework help and the effects on a child of observational learning. This brings in the observations of a parents anxiety, attitude towards

math, beliefs in math abilities of their child, and how they display this to their child. If a parent already has math anxiety, or a poor attitude and specific gender beliefs about abilities, it is emphasized not to help their child with homework at home, as this would only aggravate the child's own MA. Figure 1 displays a humoristic view on observational learning, whereas a child . imitates and adopts the attitudes and behaviors of their parents through what they see and hear (Maloney et al., 2015)

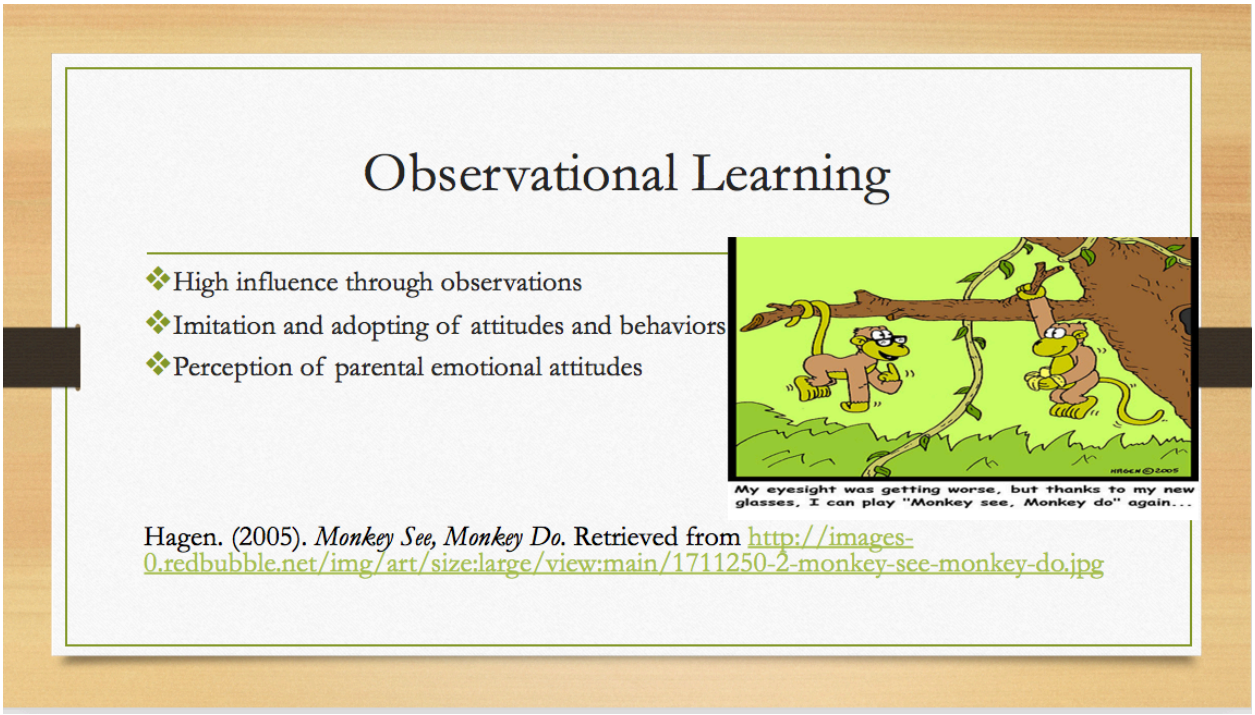

Figure 1

In turn, it is discussed that teachers also not transmit their personal beliefs and anxieties of math to their students. As listed in figure 2, teachers are provided with the basics of providing a nurturing and positive learning environment, and what is required to support students with MA. Through observational learning, children tend to mimic attitudes, beliefs, and behaviors towards mathematics. I discuss the studies that deal with the importance of establishing a positive self-concept in the child, and to make math fun and engaging, with realistic goals for success. Also

emphasized is the realization that the teacher also must possess a strong confidence and knowledge base of the mathematics, in order to be able to teach it in depth for understanding to the students.

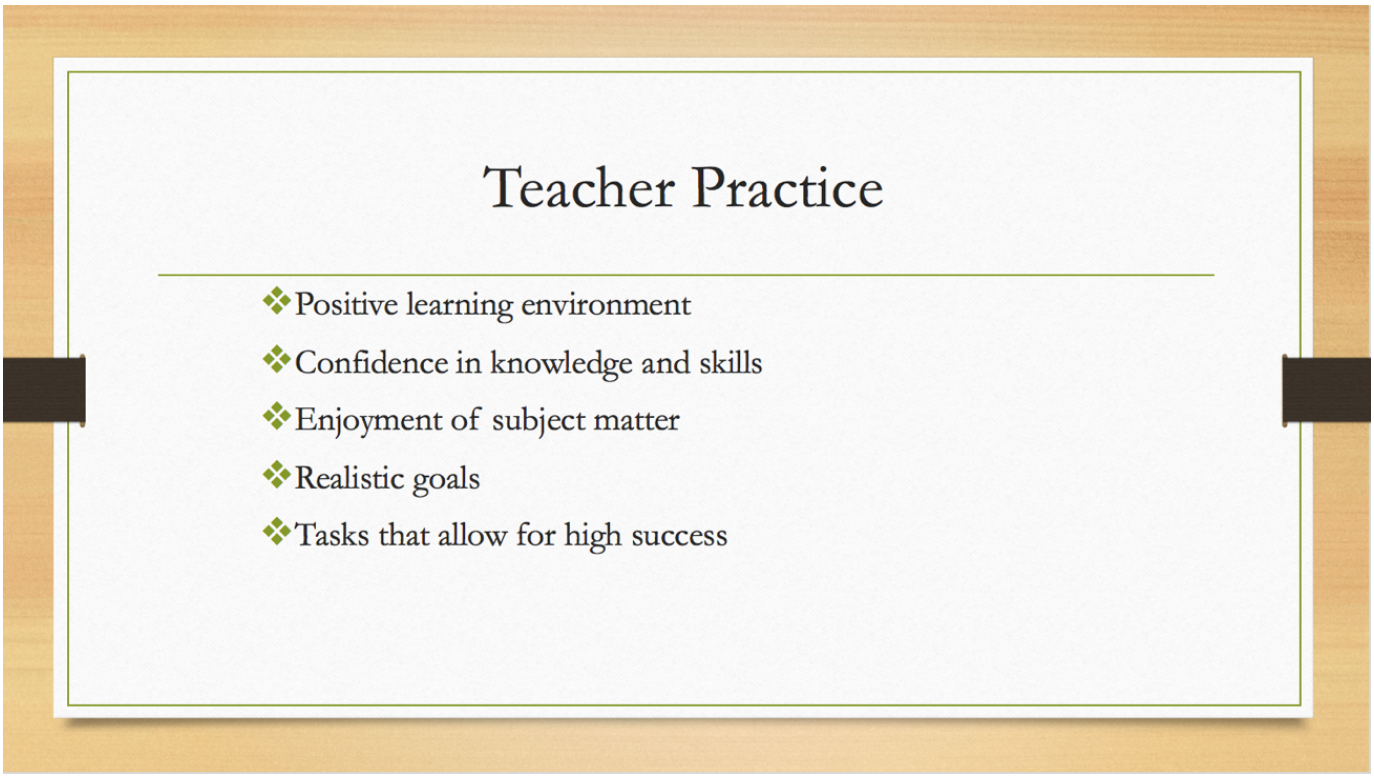

Figure 2

The second topic of interest is that of internal factors. I present to parents and teachers how anxiety is affected by internal factors such as working memory, cognitive reflection, and spatial abilities. Anxiety tends to affect the working memory (WM) by exhausting the brain of the resources required to manipulate information due to the worrisome thoughts and anxieties. As shown in figure 3, anxiety interferes with fluid cognition, which then directly affects memory, attention, processing speed, reasoning, and vocabulary.

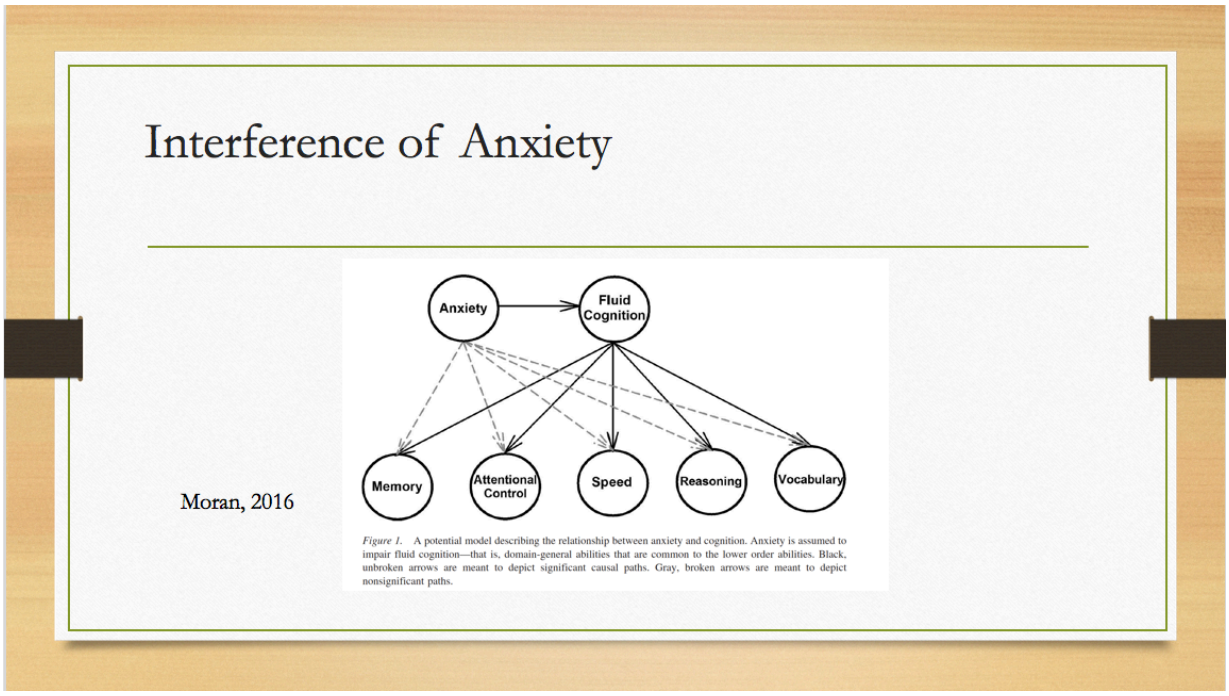

Figure 3

I would like to build awareness in teachers and parents to assist in decreasing MA through offering strategies and providing resources. The goal would be to build comprehension and a positive attitude in math through making resources available to parents, such as activities to help parents interact with their child in math in positive ways (practice online tasks, math games, apps for learning, practice sheets in form of game, etc.), and tips and examples on how to help at home.

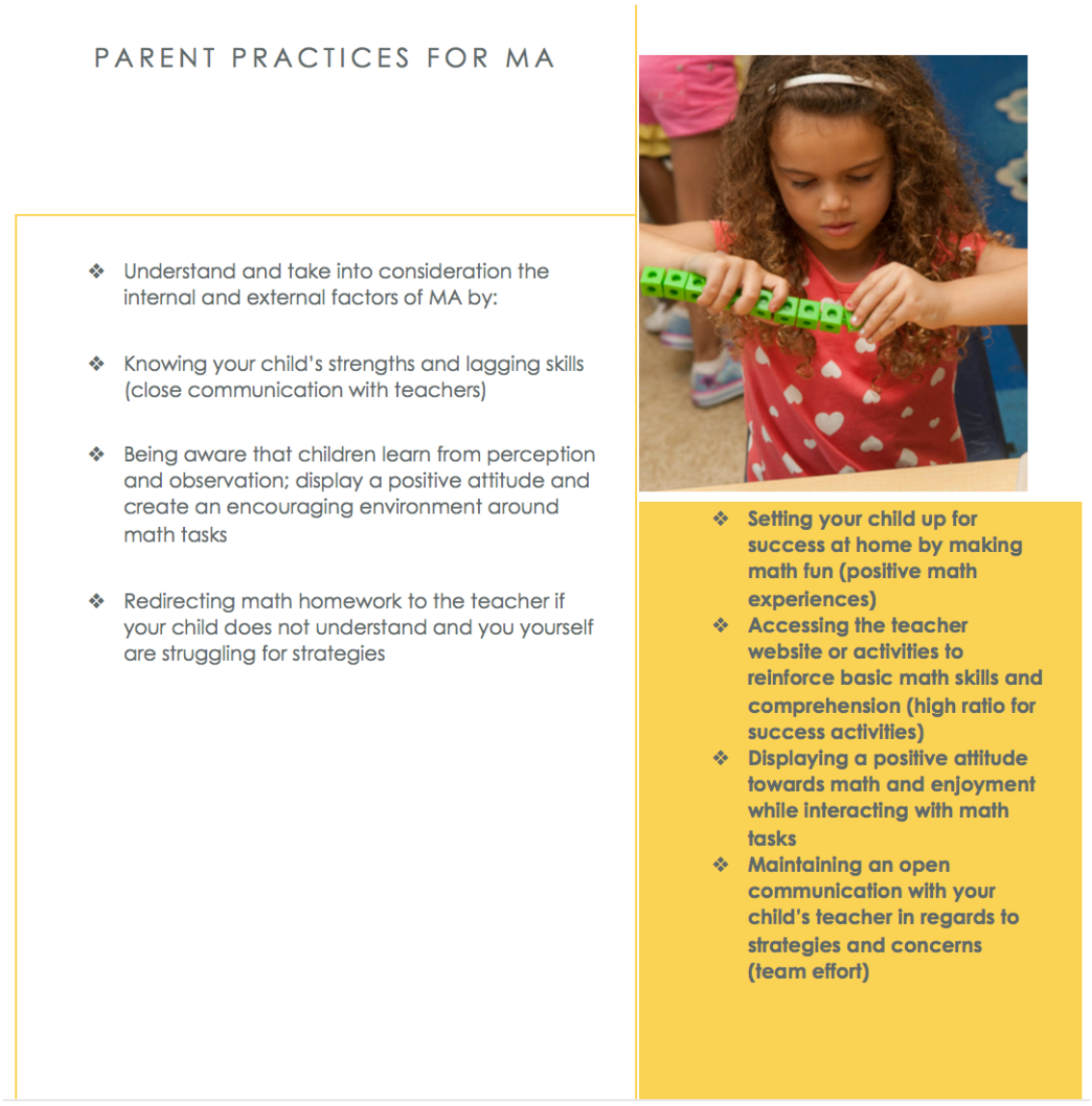

Figure 4

For the teachers, the topics of awareness would be the importance of knowing the basic abilities and struggles/strengths of their students to properly differentiate. The focus would be on assessing formatively and frequently their basic building blocks and paying close attention to those who may have attention difficulties and anxieties. The next step would be to resource the teachers with activities that would assist in decreasing the MA in students, such as journaling prior to math tasks and tests.

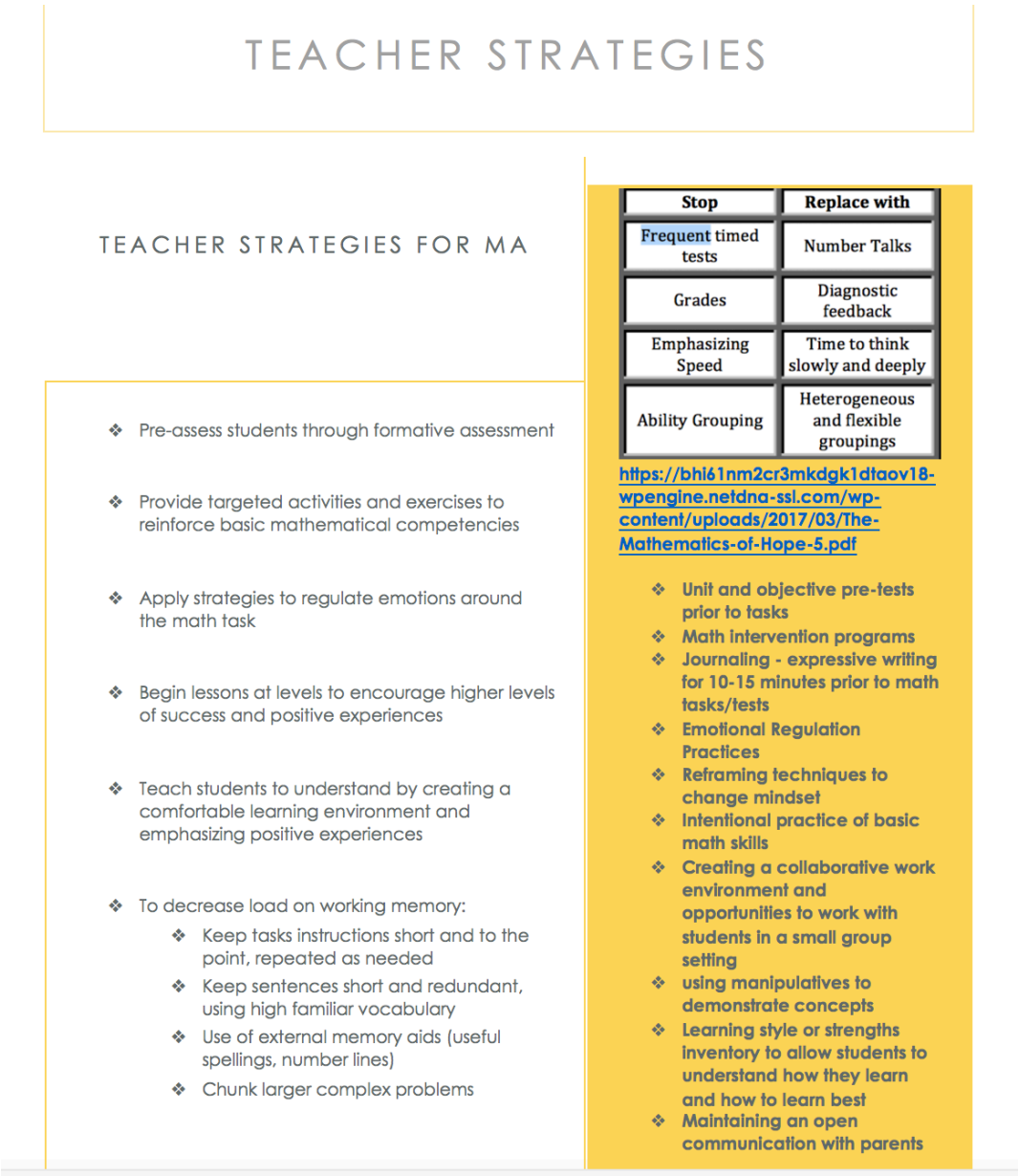

Figure 5

In conclusion, the findings on the topic of math anxiety have been extremely helpful in directing my project. I aim to provide teachers with professional development sessions and resources to bring the underlying factors to life. I would follow up with teachers to discuss their in-class successes, their communication with parents, and to support them in any encountered obstacles in their commitment to build students' math self-concept and decrease their MA.

PROJECT: UNDERSTANDING FACTORS OF MATH ANXIETY

I. DEFINITION AND RATIONALE OF MATH ANXIETY (MA)

II. EXPLANATION OF EXTERNAL AND INTERNAL FACTORS OF MA

III. IDENTIFICATION OF THE UNDERLYING EXTERNAL FACTORS OF MA
- A. Self-concept of student
- B. Parental math beliefs
- C. Transmission of parental and teacher math attitudes and anxieties
    1. Parents
        - a. Attitude and anxiety
        - b. Homework help
        - c. Observational learning
    2. Teachers
        - a. Attitude and anxiety
        - b. Practice

IIII. IDENTIFICATION OF THE UNDERLYING INTERNAL FACTORS OF MA
- A. Working memory
- B. Cognitive reflection
- C. Spatial ability

IV. SUMMARY FOR TEACHERS
- A. Strategies for teachers
- B. Teacher practices to help students with MA

V. SUMMARY FOR PARENTS
- A. Parent practices to help children with MA

VI. DECREASING MATH ANXIETY SUMMARY

VII. REFERENCES

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Appendix A

TEACHER STRATEGIES

TEACHER STRATEGIES FOR MA

- Pre-assess students through formative assessment
- Provide targeted activities and exercises to reinforce basic mathematical competencies
- Apply strategies to regulate emotions around the math task
- Begin lessons at levels to encourage higher levels of success and positive experiences
- Teach students to understand by creating a comfortable learning environment and emphasizing positive experiences
- To decrease load on working memory:
  - Keep tasks instructions short and to the point, repeated as needed
  - Keep sentences short and redundant, using high familiar vocabulary
  - Use of external memory aids (useful spellings, number lines)
  - Chunk larger complex problems

Stop	Replace with
Frequent timed tests	Number Talks
Grades	Diagnostic feedback
Emphasizing Speed	Time to think slowly and deeply
Ability Grouping	Heterogeneous and flexible groupings

https://bhi61nm2cr3mkdgk1dtaov18-wpengine.netdna-ssl.com/wp-content/uploads/2017/03/The-Mathematics-of-Hope-5.pdf

- **Unit and objective pre-tests prior to tasks**
- **Math intervention programs**
- **Journaling - expressive writing for 10-15 minutes prior to math tasks/tests**
- **Emotional Regulation Practices**
- **Reframing techniques to change mindset**
- **Intentional practice of basic math skills**
- **Creating a collaborative work environment and opportunities to work with students in a small group setting**
- **using manipulatives to demonstrate concepts**
- **Learning style or strengths inventory to allow students to understand how they learn and how to learn best**
- **Maintaining an open communication with parents**

Resources:

Youcubed Website
https://www.youcubed.org/

How Students Should be taught math
https://bhi61nm2cr3mkdgk1dtaov18-wpengine.netdna-ssl.com/wp-content/uploads/2017/09/How-Students-Should-be-Taught-Mathematics.pdf

Number Sense
https://www.youcubed.org/resources/what-is-number-sense/

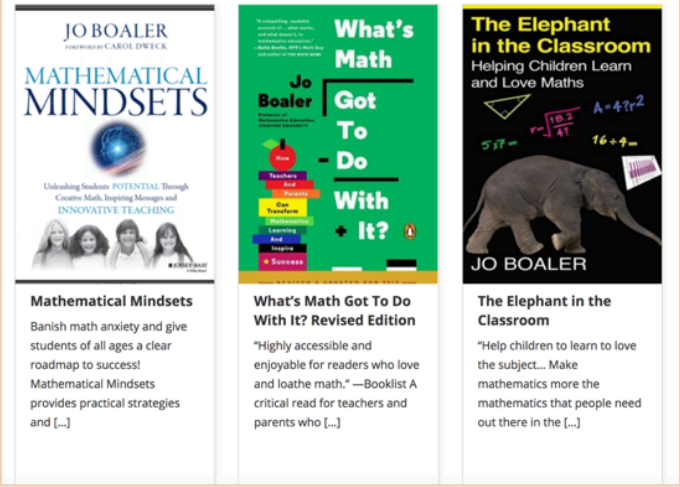
Games to build math skills
https://www.youcubed.org/resource/apps-games/

Every day math
http://everydaymath.uchicago.edu/teachers/

Self-Regulation
https://self-reg.ca/parent-resources/

Teaching math videos
https://www.youcubed.org/resource/teaching-videos/

Books for number sense and mindset



https://www.youcubed.org/resource/books/

Together we can help children be successful in math.

APPENDIX B

PARENT STRATEGIES

PARENT PRACTICES FOR MA

- Understand and take into consideration the internal and external factors of MA by:
- Knowing your child's strengths and lagging skills (close communication with teachers)
- Being aware that children learn from perception and observation; display a positive attitude and create an encouraging environment around math tasks
- Redirecting math homework to the teacher if your child does not understand and you yourself are struggling for strategies

- **Setting your child up for success at home by making math fun (positive math experiences)**
- **Accessing the teacher website or activities to reinforce basic math skills and comprehension (high ratio for success activities)**
- **Displaying a positive attitude towards math and enjoyment while interacting with math tasks**
- **Maintaining an open communication with your child's teacher in regards to strategies and concerns (team effort)**

Resources:

https://www.youcubed.org/resource/parent-resources/

Ways to support your child in math
https://www.youcubed.org/resources/6-ways-support-childs-mathematical-development/

Engaging math tasks to do at home – make it fun!
https://www.youcubed.org/tasks/

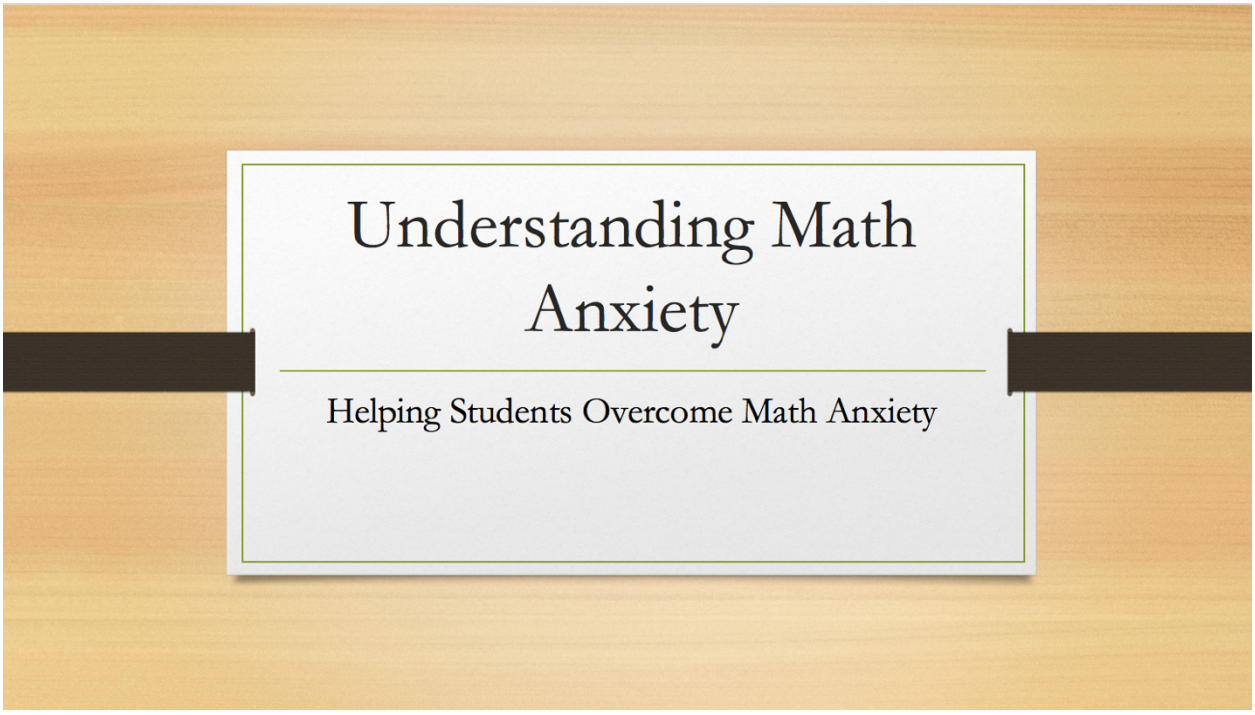
https://www.weareteachers.com/best-of-teacher-helpline-9-math-websites-kids-will-love/

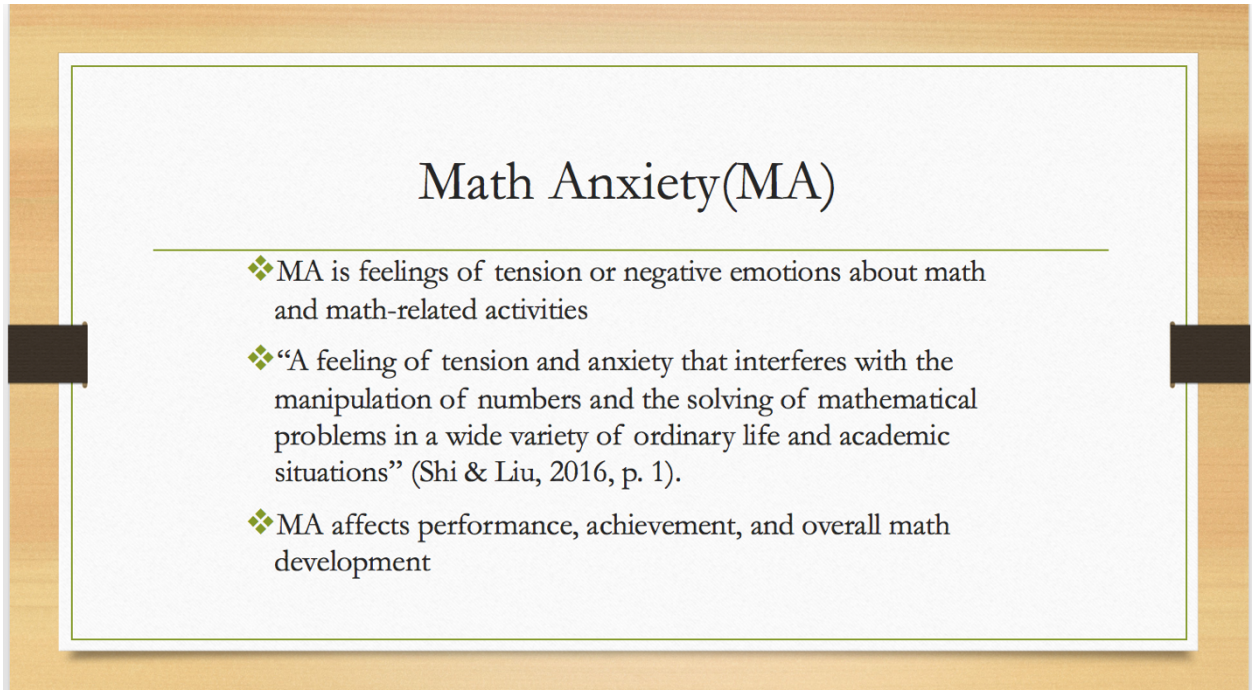
Every day math at home
http://everydaymath.uchicago.edu/parents/

5 Ways to build your child's numeracy skills
http://www.nlnw.nsw.edu.au/pdfs/docs09/numfly09.pdf

Together we can help children be successful in math.

APPENDIX C


Understanding Math Anxiety
Helping Students Overcome Math Anxiety

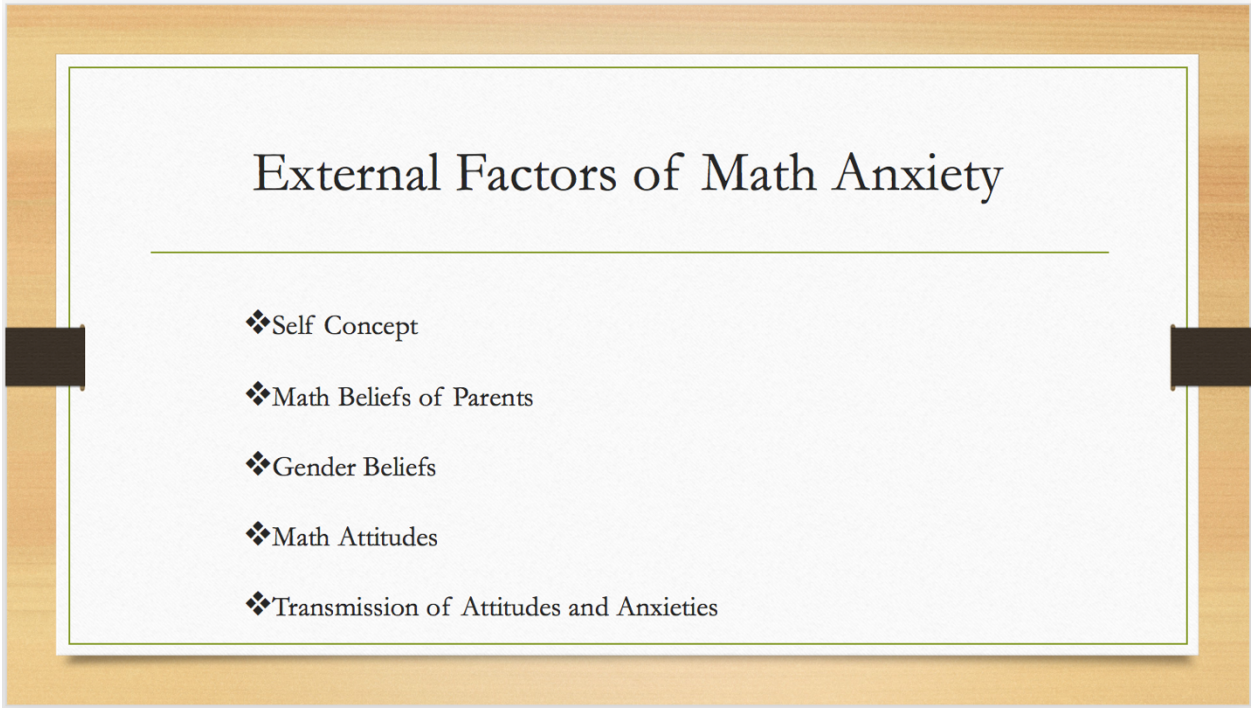

Math Anxiety(MA)
MA is feelings of tension or negative emotions about math and math-related activities
"A feeling of tension and anxiety that interferes with the manipulation of numbers and the solving of mathematical problems in a wide variety of ordinary life and academic situations" (Shi & Liu, 2016, p. 1).
MA affects performance, achievement, and overall math development

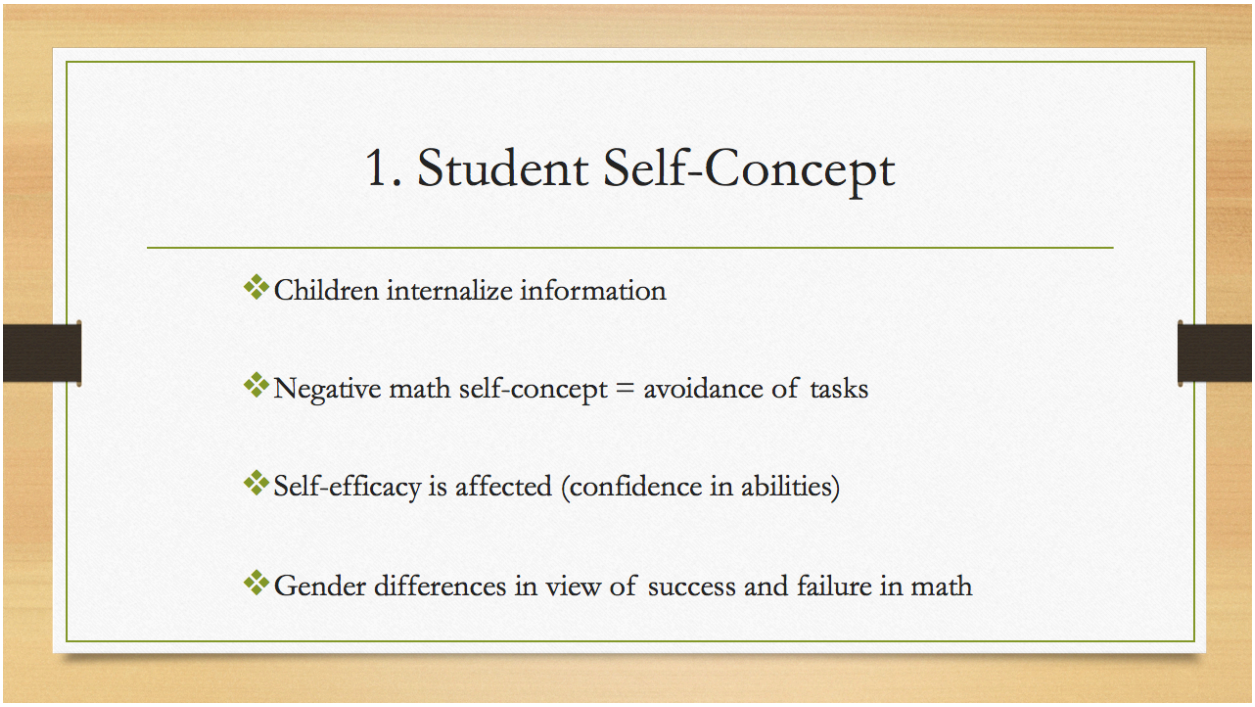
Rational for Research

- MA is detrimental to the mathematical development of the child
- MA has a direct effect on the learner in terms of confidence and self-concept
- MA affects career choices with less students entering STEM (Science, Technology, Engineering, Math) faculties
- MA affects factors in personal lives, such as finances and sense of direction

Internal and External Factors

- External factors contributing to MA include social and environmental factors (ie: self-concept of students, beliefs of parents, and parental and teacher math anxieties and attitudes)
- Internal factors of MA would include any genetic cognitive contributors to MA (ie: cognitive factors of working memory, spatial ability, cognitive reflection)


External Factors of Math Anxiety
Self Concept
Math Beliefs of Parents
Gender Beliefs
Math Attitudes
Transmission of Attitudes and Anxieties


1. Student Self-Concept
Children internalize information
Negative math self-concept = avoidance of tasks
Self-efficacy is affected (confidence in abilities)
Gender differences in view of success and failure in math

2. Parental Math Beliefs

- Major environmental influential factor
- Imitation of parental practices of behaviors
- Gender academic ability beliefs and MA

3. Transmission of Anxieties and Attitudes Parents

- Negative math attitudes influence MA
- Parental attitude has more influence than a student's performance

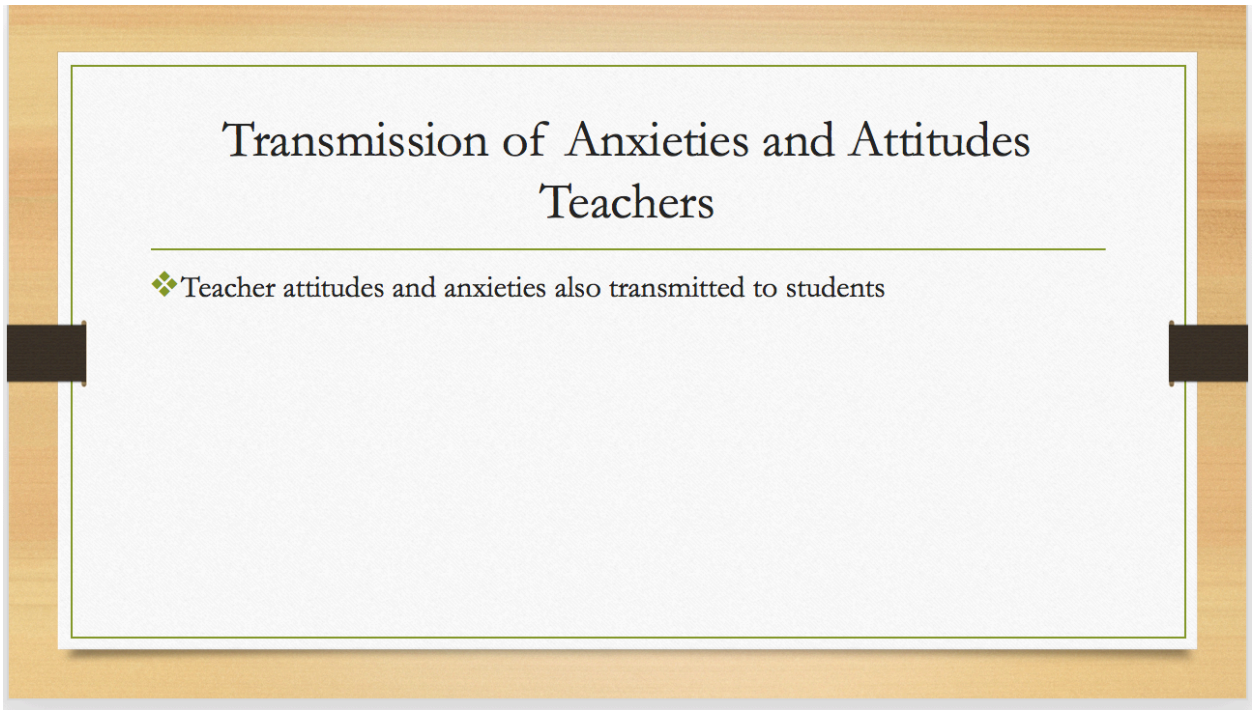
Parental Anxiety and Homework Help

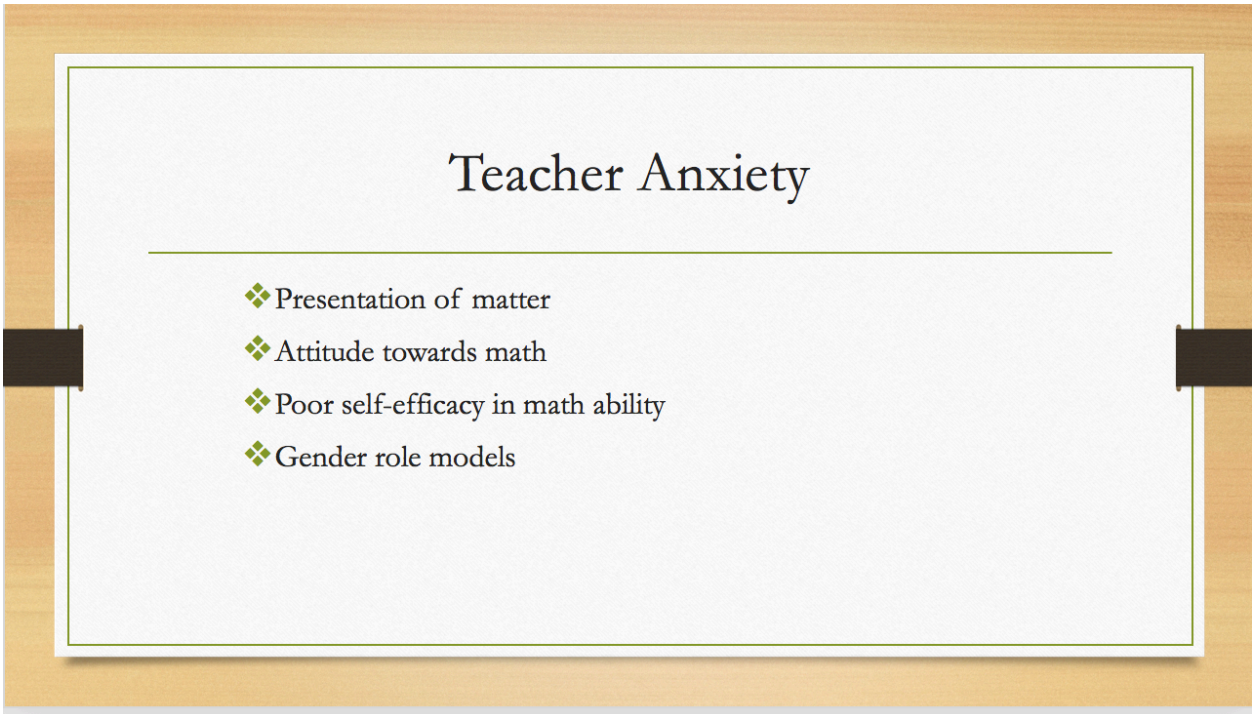
- Parental anxiety and fear of math is transmitted to child through trying to help with homework
- Parents with MA generally possess weaker math skills and abilities
- Easily frustrated and tend to return to traditional methods

Observational Learning

- High influence through observations
- Imitation and adopting of attitudes and behaviors
- Perception of parental emotional attitudes

Hagen. (2005). *Monkey See, Monkey Do.* Retrieved from http://images-0.redbubble.net/img/art/size:large/view:main/1711250-2-monkey-see-monkey-do.jpg


Transmission of Anxieties and Attitudes Teachers
Teacher attitudes and anxieties also transmitted to students


Teacher Anxiety
Presentation of matter
Attitude towards math
Poor self-efficacy in math ability
Gender role models

Teacher Practice

- Positive learning environment
- Confidence in knowledge and skills
- Enjoyment of subject matter
- Realistic goals
- Tasks that allow for high success

Interference of Anxiety

Moran, 2016

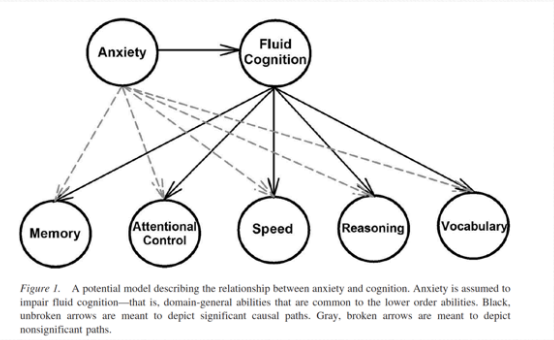
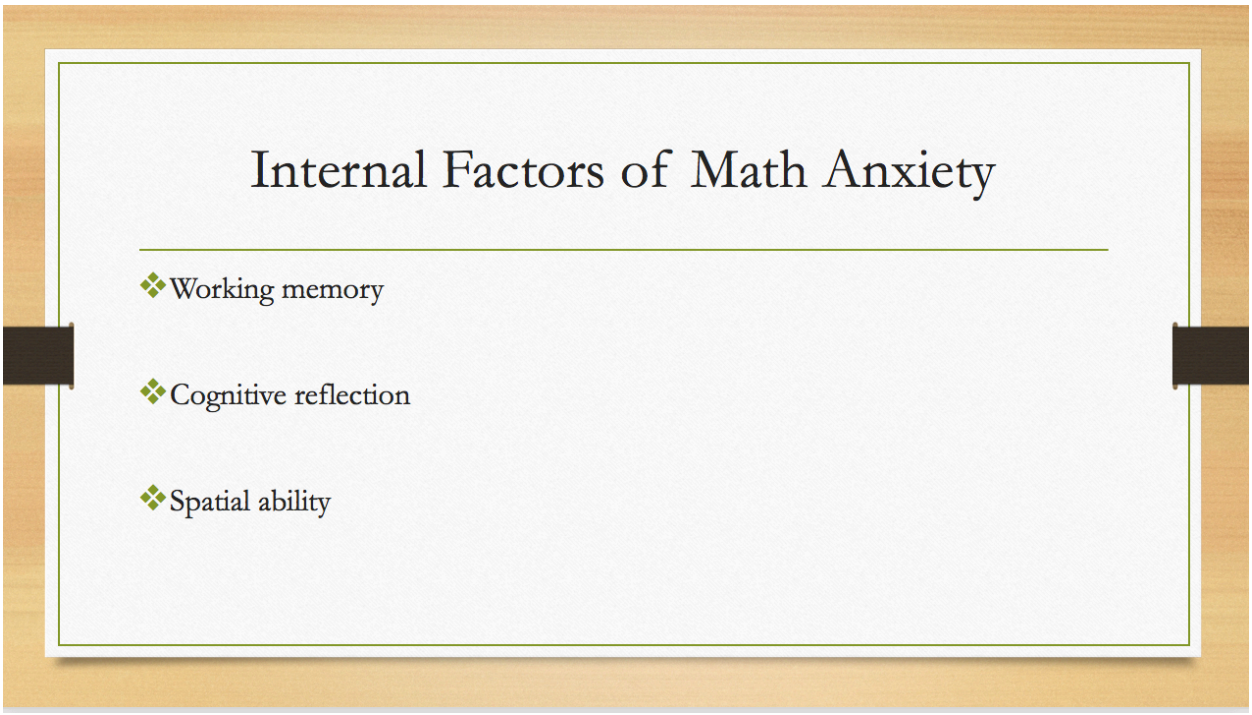
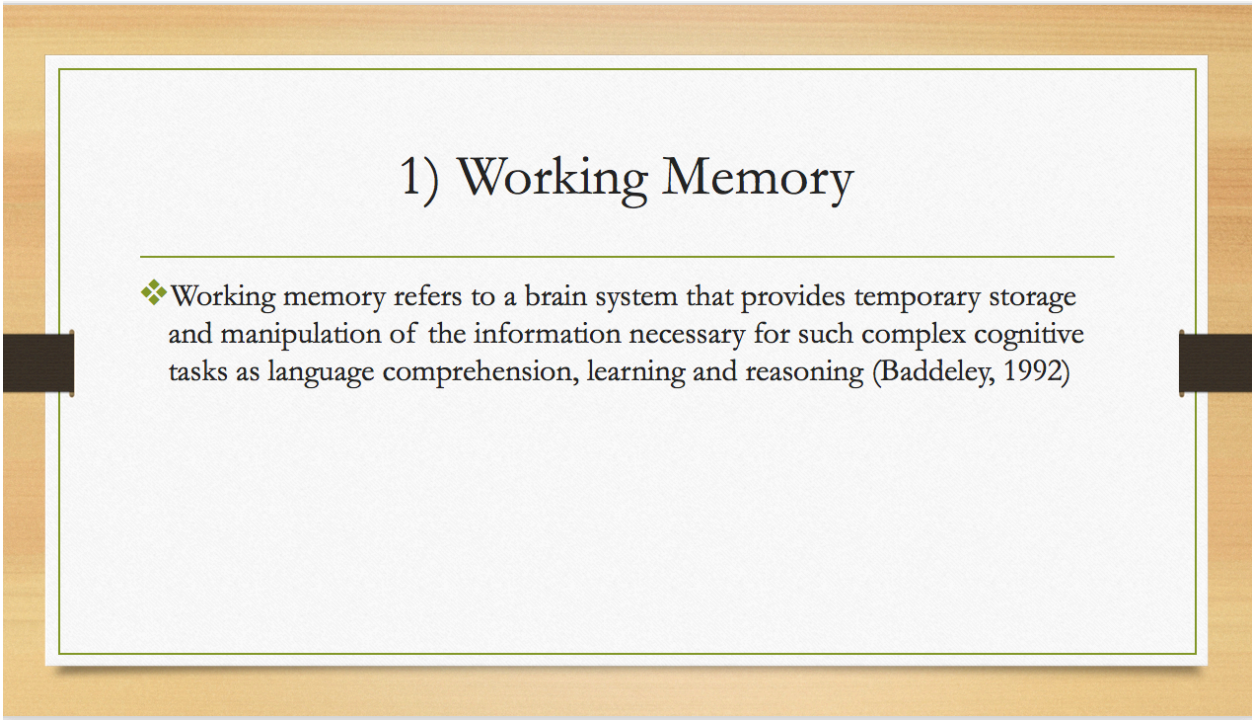


Figure 1. A potential model describing the relationship between anxiety and cognition. Anxiety is assumed to impair fluid cognition—that is, domain-general abilities that are common to the lower order abilities. Black, unbroken arrows are meant to depict significant causal paths. Gray, broken arrows are meant to depict nonsignificant paths.


Internal Factors of Math Anxiety
Working memory
Cognitive reflection
Spatial ability


1) Working Memory
Working memory refers to a brain system that provides temporary storage and manipulation of the information necessary for such complex cognitive tasks as language comprehension, learning and reasoning (Baddeley, 1992)

Working Memory

- Worrisome thoughts interfere with the resources needed for working memory (Ashcraft & Krause, 2007; Moran, 2016; Shi & Liu, 2016).
- Anxiety is higher in attentional demanding tasks (Moran, 2016).
- "Anxious arousal is assumed to interfere with the maintenance of spatial information" (Moran, 2016, p.3).

2) Anxiety on Cognitive Reflection

- Cognitive reflection is compromised due to MA (Morsanyi, Busdraghi, & Primi, 2014)
- More Activation in the brain in the amygdala (negative emotions), and less in the area needed for WM (Beilock & Maloney, 2015)

The Interrelationship between Anxiety and Working Memory

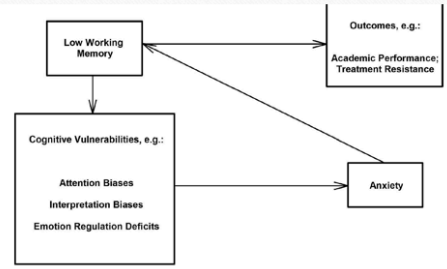
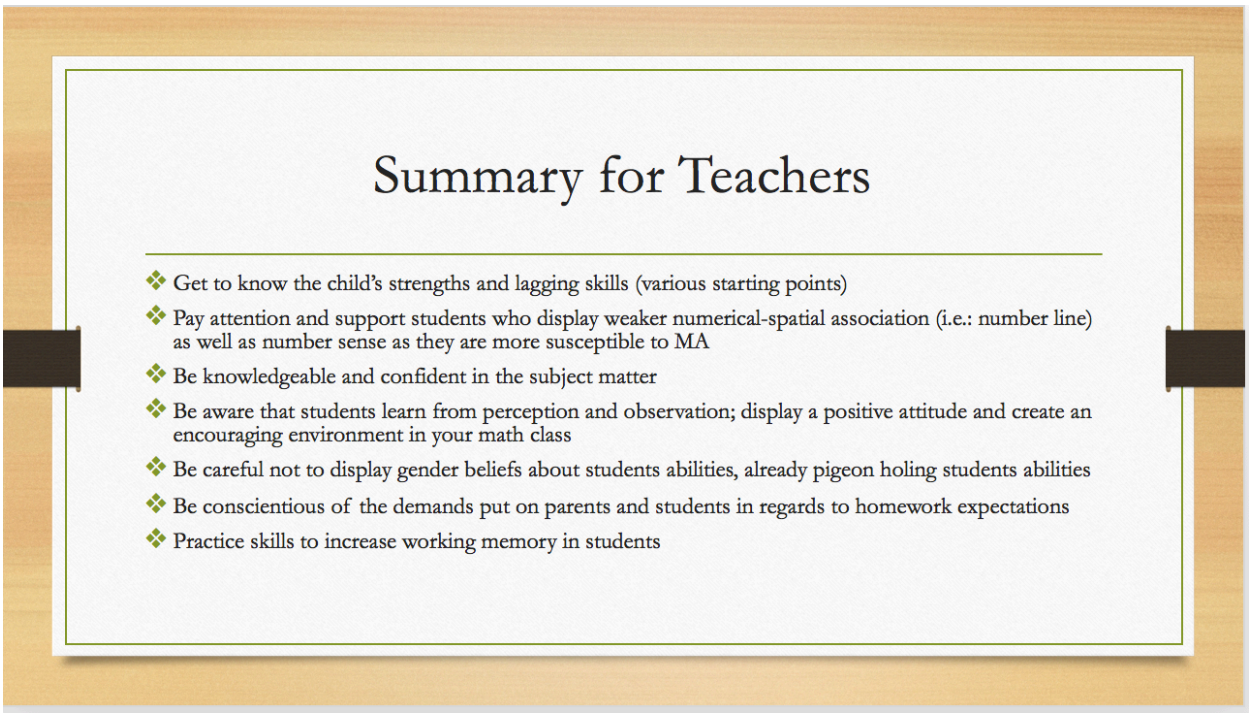


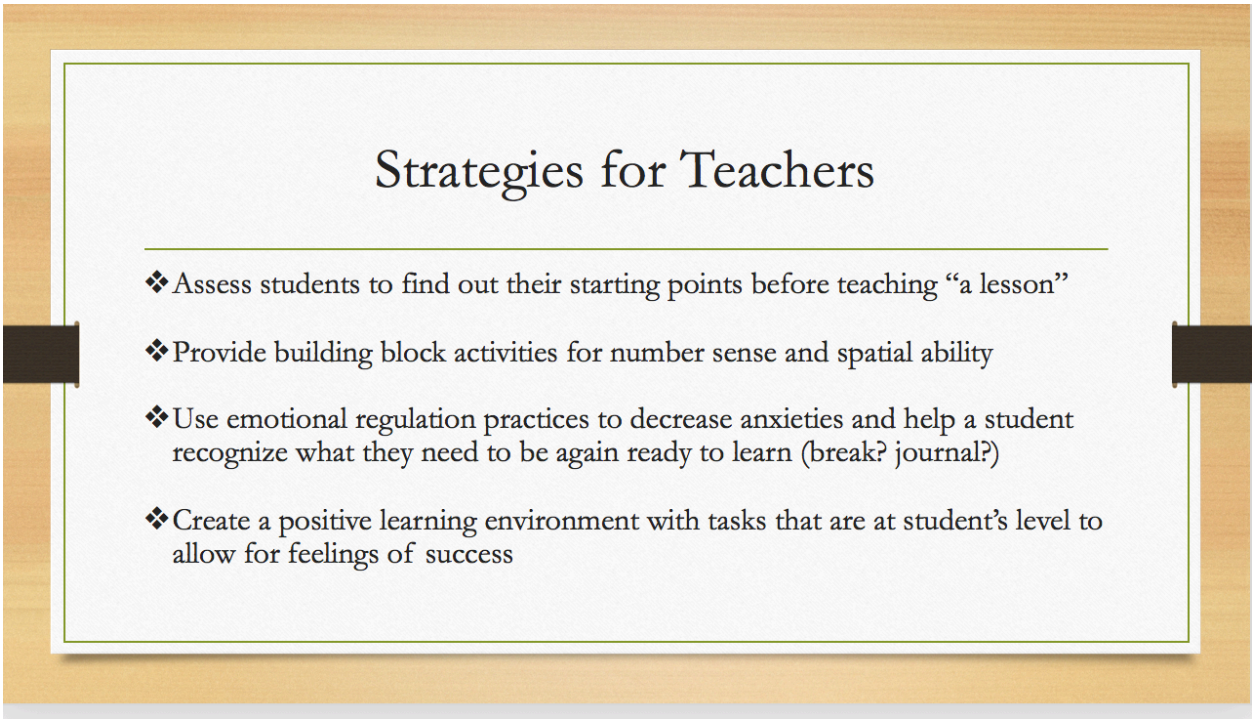
Figure 3. A potential model describing the interrelationships between anxiety, WMC, cognitive vulnerability, and outcome variables (e.g., academic performance, treatment resistance, etc.). In this model, anxiety and WMC are cyclically related such that low WMC predisposes one to cognitive vulnerabilities and anxiety. Anxiety then interferes with WM. Single-headed arrows depict causal pathways.

Moran, 2016

3) Spatial Ability

- Early detection of lagging math skills in spatial-numerical association (i.e.: number line) (Beilock & Maloney, 2015; Ferguson, Maloney, Fugelsang, & Risko, 2015)
- Prediction of demonstrating struggles in learning the basics building blocks in math and higher risk of MA (Beilock & Maloney, 2015; Ferguson, Maloney, Fugelsang, & Risko, 2015)
- Poor sense of direction (Ferguson, Maloney, Fugelsang, & Risko, 2015)


Summary for Teachers
Get to know the child's strengths and lagging skills (various starting points)
Pay attention and support students who display weaker numerical-spatial association (i.e.: number line) as well as number sense as they are more susceptible to MA
Be knowledgeable and confident in the subject matter
Be aware that students learn from perception and observation; display a positive attitude and create an encouraging environment in your math class
Be careful not to display gender beliefs about students abilities, already pigeon holing students abilities
Be conscientious of the demands put on parents and students in regards to homework expectations
Practice skills to increase working memory in students


Strategies for Teachers
Assess students to find out their starting points before teaching "a lesson"
Provide building block activities for number sense and spatial ability
Use emotional regulation practices to decrease anxieties and help a student recognize what they need to be again ready to learn (break? journal?)
Create a positive learning environment with tasks that are at student's level to allow for feelings of success

Teacher Practices to Help Students with MA

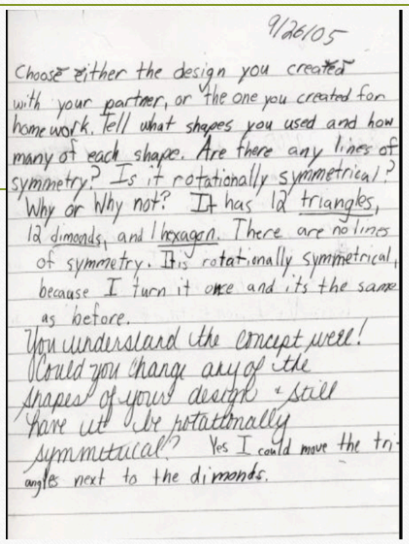
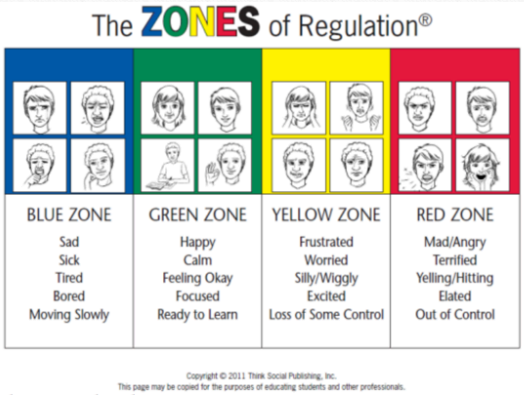


Figure 10. This entry (above) demonstrates a student answering a question I posed to him through our dialogue.

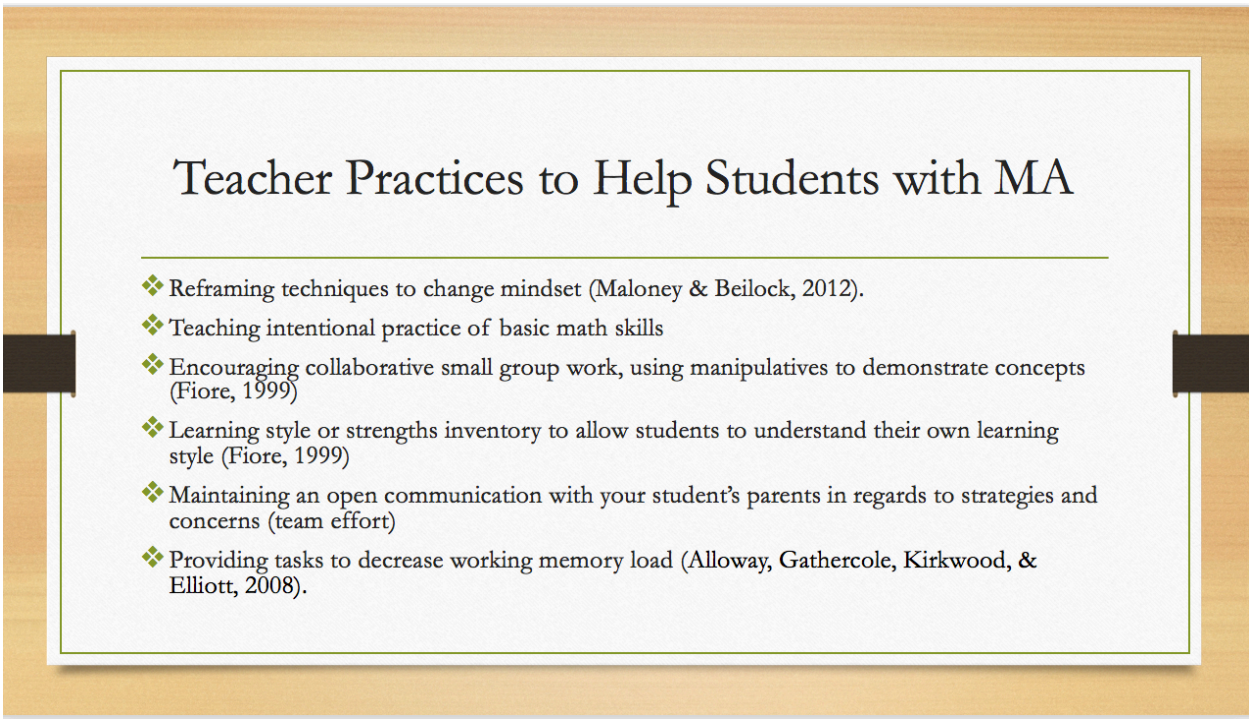
http://home.moravian.edu/public/educ/eddept/med/2007/Thesis/banko.pdf

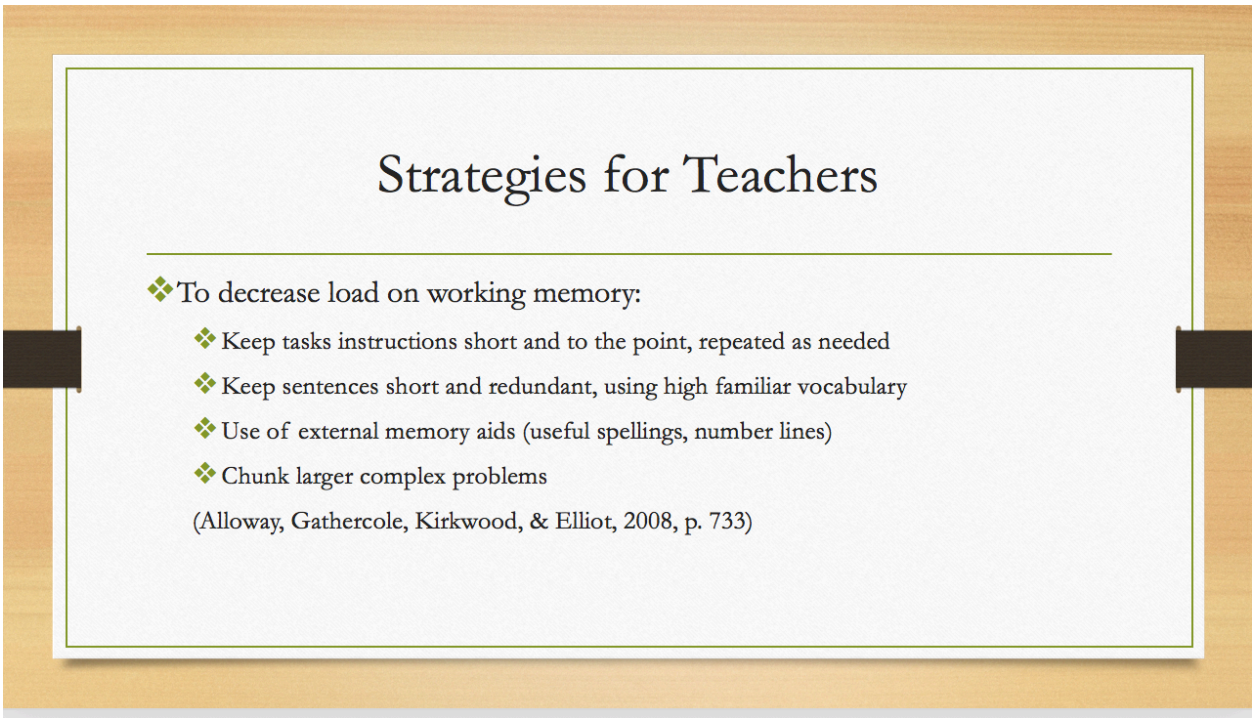
Teacher Practices to Help Students with MA

- ZONES



http://www.zonesofregulation.com/learn-more-about-the-zones.html


Teacher Practices to Help Students with MA
Reframing techniques to change mindset (Maloney & Beilock, 2012).
Teaching intentional practice of basic math skills
Encouraging collaborative small group work, using manipulatives to demonstrate concepts (Fiore, 1999)
Learning style or strengths inventory to allow students to understand their own learning style (Fiore, 1999)
Maintaining an open communication with your student's parents in regards to strategies and concerns (team effort)
Providing tasks to decrease working memory load (Alloway, Gathercole, Kirkwood, & Elliott, 2008).


Strategies for Teachers
To decrease load on working memory:
Keep tasks instructions short and to the point, repeated as needed
Keep sentences short and redundant, using high familiar vocabulary
Use of external memory aids (useful spellings, number lines)
Chunk larger complex problems
(Alloway, Gathercole, Kirkwood, & Elliot, 2008, p. 733)

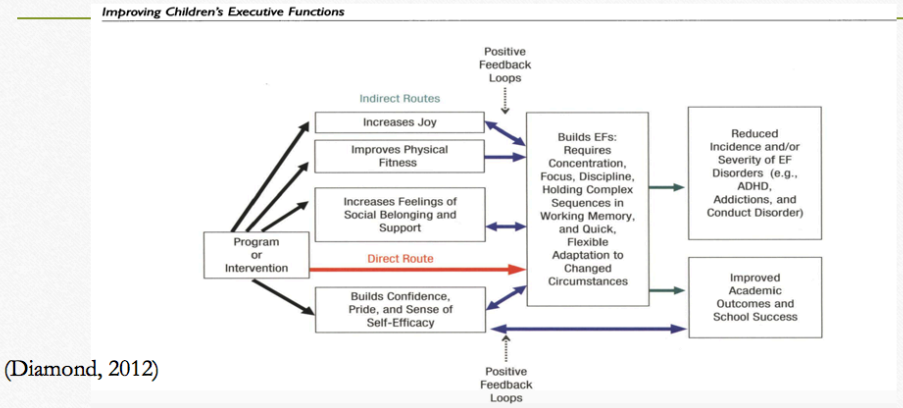
Summary for Parents

- Understand and take into consideration the internal and external factors of MA by:
- Know your child's strengths and lagging skills (close communication with teachers)
- Be aware that children learn from perception and observation; display a positive attitude and create an encouraging environment around math tasks
- Redirect math homework to the teacher if your child does not understand and you yourself are struggling for strategies

Parent Practices to Help Children with MA

- Set your child up for success at home by making math fun (positive math experiences)
- Access the teachers website or activities to reinforce basic math skills and comprehension (high ratio for success activities)
- Display a positive attitude towards math and enjoyment while interacting with math tasks
- Maintain an open communication with your child's teacher in regards to strategies and concerns (team effort)

Decreasing MA - summary



(Diamond, 2012)

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