Trevor Blagden, Department of Mathematics and Science, Brock University

Math Learning Disabilities

Math learning disabilities (MLDs) are categorized as a type of neurodevelopment disorder that affects between 4-6% of the population (American Psychological Association (APA), 2013; Norton, Beach, & Gabrieli, 2015). Mathematical learning disabilities are also referred to as dyscalculia or a specific learning disability (SLP) in the area of math (APA, 2013). Characteristics of this exceptionality can vary between individuals, but always lead back to difficulties within the fundamental area of the individuals' mathematical skills including poor number sense, mental math and computation (Cortiella & Horowitz, 2014). When an individual's fundamental arithmetic skills fall below the level of their peers and their own potential, seemingly without cause, the individual can then be determined to have MLD. MLDs often correspond with an impairment in the working memory and long-term retrieval of math-related concepts (Henik et al., 2011). The visuospatial component of the working memory is often the most affected part of the individuals' memory; including difficulties in their abilities to visualize and conceptualize mathematical problems (Ashkenazi, Rubinsten & Henik, 2009; Cantlon, Platt & Brannon, 2009). In addition, individuals with MLDs tend to use weak and underdeveloped strategies when solving a mathematical problem due to impairments in the long-term memory storage and retrieval (Menon, 2016). Without early intervention, MLDs often lead to difficulties in essential areas of life including employment, finances, healthcare, increased rates in physical and mental health issues, and incarceration (Price & Ansari, 2013). For a more in-depth look into the characteristics, etiology and diagnosis of MLD, please review the initial S.M.A.R.T. Math pilot report (Blagden, 2019a).

Socioemotional Impact of Math Learning Disabilities

Previous research has found that individuals with learning disabilities (LD) typically exhibit a higher comorbidity with mental health issues such as anxiety and depression (Aro et al., 2018). Gallegos, Langley, & Villegas (2012) found that when compared to their peers without LDs, children with LDs showed a higher risk of developing anxiety (22.3% vs 11.5%) as well as a higher risk of developing depression (32% vs 18%). Many individuals with learning disabilities also do not continue beyond secondary school and experience extended periods of unemployment (Aro et al., 2018). Aro et al. (2018) demonstrated that there is a greater association between antidepressant usage and unemployment in students with MLDs compared to students with reading disabilities and typically developing students, suggesting that individuals with comorbid LDs and mental health issues are dually disadvantaged in our society.

Children with MLDs have not only demonstrated poorer mathematical performance but also much higher rates of math anxiety (Kucian et al., 2018). Researchers believe that children develop negative emotions associated with mathematics from repeated mathematical failures, which is often manifested in specific math anxiety. Kucian et al. (2018) explain that individuals with MLD experience an emotional response to math-related tasks that disrupts their performance in the subject. As students' progress through school, there is a stronger correlation between poor math performance and high math anxiety. Among middle school students, Hembree (1990) found a negative correlation between math anxiety and enjoyment of math (–.75), self confidence in math (–.82), self-concept in math (–.71), motivation in math (–.64), opinion about the usefulness of math (–.37), and attitudes toward math teachers (–.46).

Thus, the sum of math anxiety and negative attitudes toward math might result in the avoidance of math-related situations and numeric contents altogether. These data are cause for concern, given that math is one of the foundations of our highly technological society, a society that offers more and better employment opportunities to those who are well trained in math. This means that math anxiety impacts negatively on the professional development, employment opportunities, and even salary prospects of students with MLD (Suárez-Pellicioni, Núñez-Peña & Colomé, 2015).

Kucian et al. (2018) shared their insight on the mechanisms in which math anxiety could hinder mathematical performance among individuals with MLD. Kucian et al. (2018) proposed two pathways in which math anxiety affects mathematical performance. First, they identified an indirect pathway that affects working memory capacity. This pathway supports the affective drop hypothesis whereby an individual's working memory is occupied by anxious thoughts and negative feelings when they must solve a math problem, which obstructs their ability to use their working memory efficiently for math (Kucian et al., 2018). Second, they noted a direct, negative effect of anxiety on mathematical performance. Many professionals believe that this is due to the individuals with MLDs avoiding mathematical problems all together due to fear of failure and being perceived as inadequate (Kucian et al., 2018). Without the motivation and confidence to practice, the gap between the achievement of students with MLDs and their typically developing peers will continue to widen.

Math self-efficacy is the level of confidence in which a student believes they can perform the math-related task given to them (Gallegos, Langley, & Villegas, 2012). As demonstrated by the strongest negative correlation in Hembree's (1990) study, students with

high math anxiety often have very low levels of self-efficacy (Gallegos, Langley, & Villegas, 2012). Suárez-Pellicioni et al. (2015) have elucidated that improved math performance can have a positive impact on math anxiety and in turn improve math confidence and self-efficacy. The goal of the S.M.A.R.T. Math pilot project is to address these correlations by improving math performance in order to reduce math anxiety and foster math confidence among struggling mathematicians. By providing a program that offers improved academic and socioemotional outcomes for students with MLDs from an early age, the Learning Disabilities Association of Niagara Region (LDANR) hopes to combat the development of later mental health concerns for its clients.

S.M.A.R.T. Math Program

Earlier identification of MLDs leads to earlier interventions and referrals to learning disabilities centres, which can assist with the small-group and individualized components of the model that general classroom environments are not always able to provide. Research has indicated that students who have been referred to targeted community programs, much like the LDANR, show better mental health and academic self-efficacy than students with LDs who were not referred (Hossein, Seyedjavad, & Seyed., 2015). Hossein et al. (2015) demonstrated that learning disability centres and targeted programs, like S.M.A.R.T. Math, effectively improved academic performance as well as academic confidence and self-efficacy through the implementation of small-group programs and individualized support.

S.M.A.R.T Math is a small-group numeracy intervention program which facilitates the development of arithmetic skills and strategies, while also supporting math confidence and self-efficacy among students with diagnosed or suspected MLDs. Focusing on student populations in

Grades 4-6, the S.M.A.R.T Math program aims to reduce math anxiety by building math skill confidence using direct, explicit instruction and hands-on engaging activities. S.M.A.R.T. Math, located in two elementary schools in the Niagara Region, takes place twice per week over the course of 8-weeks for a total of 16 hours of intervention. When students are first introduced to the program, they undergo informal numeracy and math anxiety assessments to gage the level of their mathematical skills and how the instructors can best support each individual child. The numeracy assessment covers four areas deemed important to developing proper mathematical skills: number sense, math fact fluency, computation strategies, and problem-solving applications. Using pre-test numeracy results, engaging hands-on learning stations are planned to individualize and focus on the target needs of the group. Post-program numeracy and math anxiety assessments are administered again at the end of the programs to track and visualize student progress and the overall efficacy of the program. During the pilot session of the program, S.M.A.R.T Math was found to increase the mathematic performance of participants in each component of the program (Blagden, 2019a). This session of S.M.A.R.T. Math included a new math anxiety assessment component consisting of two scales to quantify levels of math anxiety and math self-efficacy among participants before and after the intervention.

During each hour-long session, ten students were split into small groups based on ability and rotated through three numeracy stations. Each station focused on one of the areas of need as determined by the assessment. Volunteers and instructors were trained to teach new skills following the concrete-representational-abstract strategy. The hour is split into 15-minute intervals to allow each skill to be covered and provide variety in activities to increase participant engagement. For 45 minutes, the group of students rotated through the interactive math

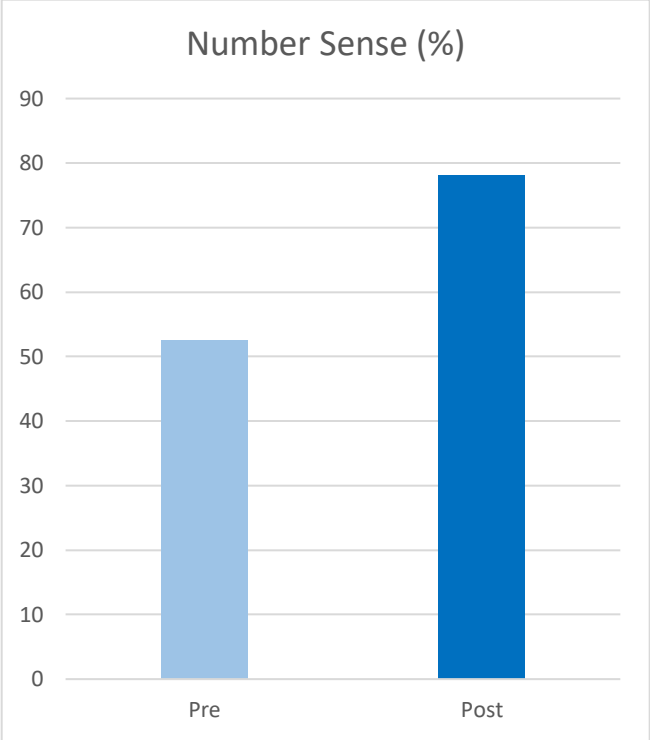
learning centers. For the last 15 minutes, the entire group was brought back together to do a group activity that targeted math anxiety. Throughout the course of the S.M.A.R.T Math program, students spent 15 minutes each week with the one-on-one instructor working on their greatest area of need as determined by the informal assessment.

S.M.A.R.T. Math Pilot Project Evaluation

S.M.A.R.T Math is a numeracy intervention program offered by the Learning Disabilities Association of the Niagara Region that has successfully ran its second and final pilot session. S.M.A.R.T Math is a program targeted towards students in Grades 4-6 who have or are at-risk of developing math learning disabilities. The first research project concentrated on determining the effectiveness of S.M.A.R.T Math at increasing mathematical performance. S.M.A.R.T Math was found to increase the mathematic performance of participants in each component of the program (Blagden, 2019a). Since it has been established that S.M.A.R.T. Math improved academic skills, this project aimed to examine whether S.M.A.R.T Math has also supported students with their socioemotional needs by reducing their math anxiety and fostering their math self-efficacy. In this report, the academic results were compiled from 40 participants over both the winter and spring pilot sessions. While the math anxiety data was gathered over the course of the second pilot session from a total of 20 participants. The following data compares and visually represents the academic and socioemotional impact of the S.M.A.R.T. Math program.

Number Sense

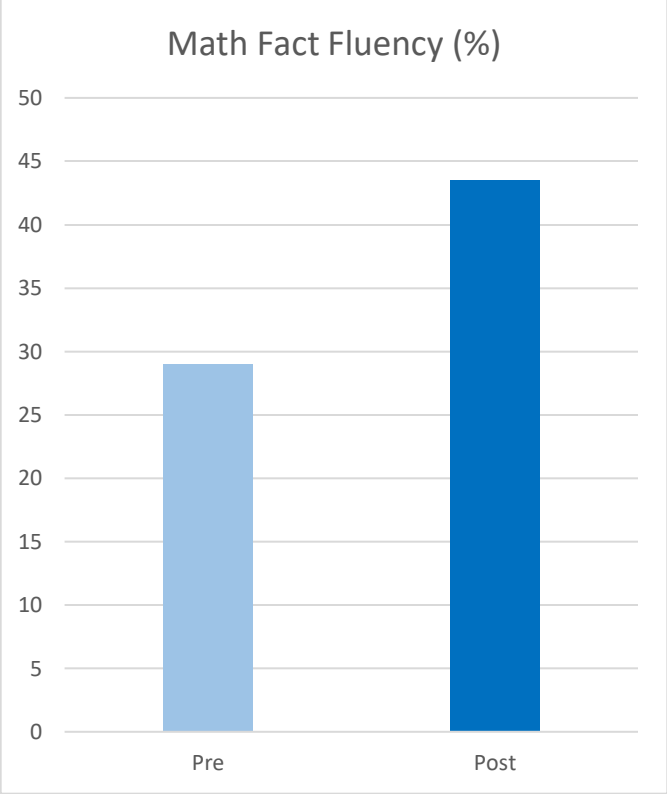
Number sense is an individual's ability to understand and work with numbers flexibly and accurately. Researchers have determined that this is an innate ability that has evolved in humans, which has allowed us to develop math for logical reasoning (Rohlan, 2018). Number sense was facilitated using a combination of direct instruction and interactive games that involved representing and identifying numbers, sequencing numbers, and understanding the magnitude of numbers. Number sense was assessed using a few different methods. First, the student was asked to represent given numbers in base ten blocks. After the student provided a representation, they were asked to continue a pattern of numbers and determine the pattern. Thirdly, they were asked to order numbers along a number line and follow this up by representing a fraction. Finally, they were asked to order fractions and determine the magnitude of rational numbers. On average, across both pilot sessions, the assessment found that there was an increase of 25% in participant number sense ability. With the null hypothesis that there would be no significant difference in number sense ability, paired sample *t*-tests were used to analyze the data. From these statistics we found that the *t*-value of 7.28571 fell well above our critical value of 1.699127, leading us to reject the null hypothesis, showing that there was a statistically



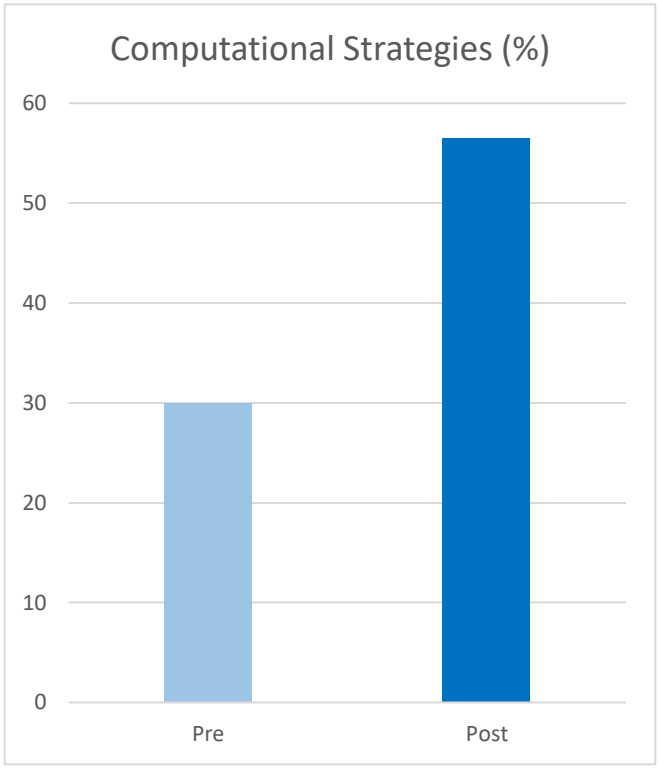
significant increase in the number sense abilities of the students enrolled in the S.M.A.R.T. Math program.

Math Fact Fluency

The ability of an individual to retrieve information from their working memory to answer calculations in an efficient manner is known as math fact fluency. Math fact fluency was reinforced across both sessions through engaging games and manipulatives, which helped encourage the students to develop new, efficient math strategies. Program instructors assessed the students using a timed assessment for the each of the four operations (addition, subtraction, multiplication and division). Each student had 5 minutes per operation to answer as many of the sixteen questions per operation as possible. With a *t*-value of 4.142857, well above the critical value of 1.699127, S.M.A.R.T. Math participants showed a statistically significant difference in pre- and post-test results with 95% confidence levels. At the end of both pilot sessions, the evaluation indicated an overall average increase of 15% in math fact fluency.



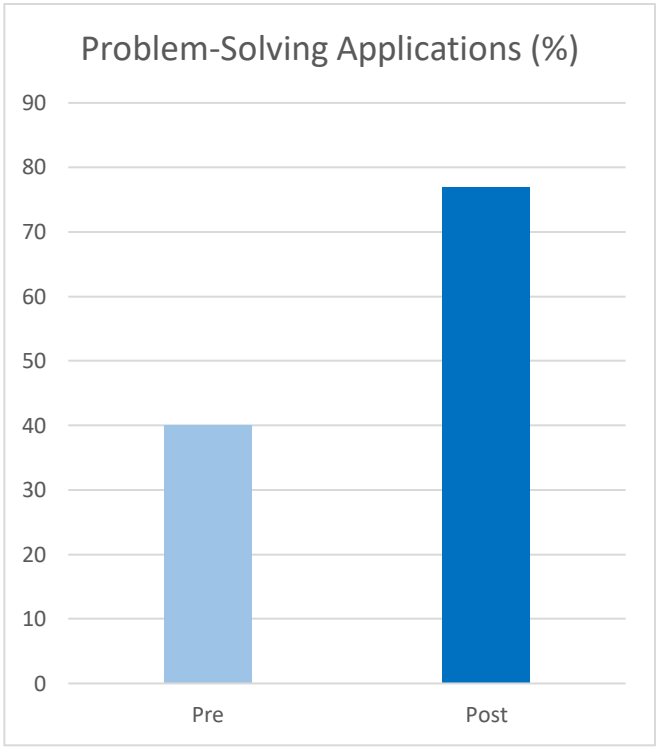
Computational Strategies



The third area of focus in the academic assessment was the ability to explain and use efficient strategies when answering a more complex math problem, also known as computational strategies. Throughout the program, participants' current strategies are reinforced and new more efficient strategies are taught during group instruction. Computational fluency was assessed by presenting the student with larger math problems that required multiple steps. The students were given materials to use whichever strategy they saw fit and were asked to explain the strategy they used to get to their answer. The statistical analysis on this section of the evaluation rejected the null hypothesis, showing that there was a statistically significant difference in the computational strategies scores from pre-test to post-test, with a *t*-value of 53 falling well above the critical value of 1.699127. The data from this evaluation found an overall increase of 27% in efficient computational strategies use that produced a correct response by the end of the S.M.A.R.T. Math program.

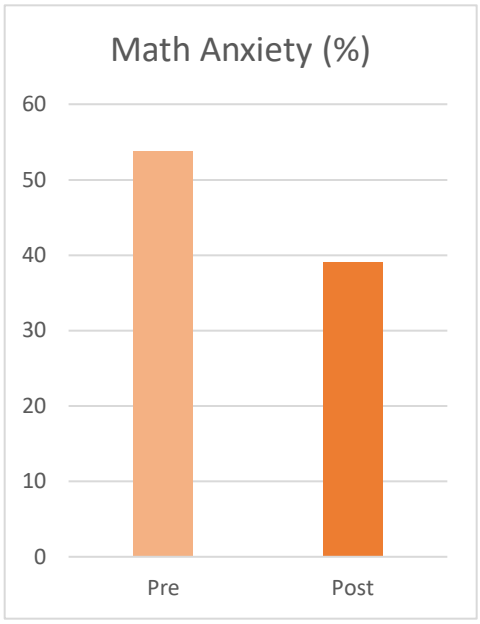
Problem-Solving Applications

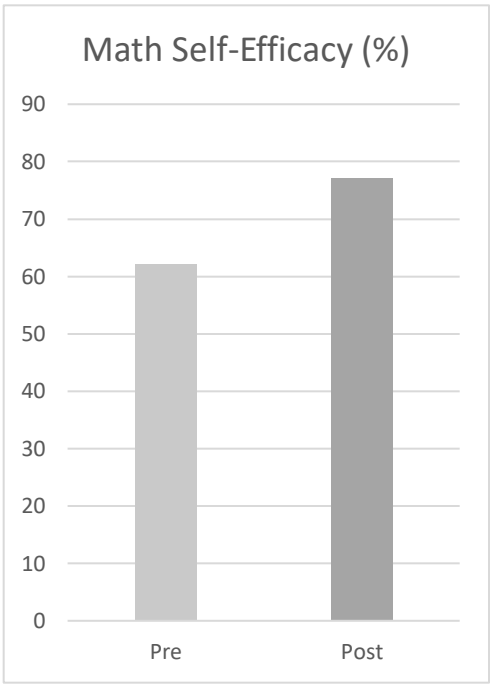
One of the most important fundamental mathematic skills is problem-solving applications, which is the ability to take new concepts and apply it to a real-life scenario. Such skills involve time-telling, money counting, and the ability to solve problems across all strands of mathematics. During the assessment, the students were asked to identify the time on an analog clock, and then set the clock to various elapsed times given a problem situation. The students were also asked to estimate the total amount of a group of coins in front of them, and then count the coins to determine the exact amount. Lastly, the students were asked to Identify 2-D shapes and 3-D figures. By the end of both pilot sessions, problem solving applications was the most improved fundamental math skill in the S.M.A.R.T. Math program. Analysis demonstrated that the *t*-value of 12.3333 once again fell above our critical value of 1.699127, telling us that there was a statistically significant improvement over the program with 95% confidence. Over the course of the S.M.A.R.T. Math program, participants increased their problem-solving and application abilities by a rate of 37% on average.



Math Anxiety

In the spring session of the program, math anxiety was quantified and analyzed using pre- and post-test scales, focusing on math anxiety and math self-efficacy. Math anxiety comprises of the negative feelings that students encounter when they imagine math-related tasks. The math anxiety scales had the assessors read some situations regarding math-related tasks aloud such as “You are asked to share the answer to a math problem with your class.” or “You are in math class and your teacher is about to teach something new.”. The assessors then asked the children to rate how nervous that scenario would make them on a 5-point visual emotion scale from not nervous at all to very nervous. Math self-efficacy scales were implemented to gauge the level of confidence that students had when they were given a statement about themselves in terms of math. For example, students were asked to rate how much they agree with statements like "I believe I can do well on math tests” and “I am not afraid to make a mistake in math class” on 5-point graphic scale from strongly disagree to strongly agree. Throughout the program these areas

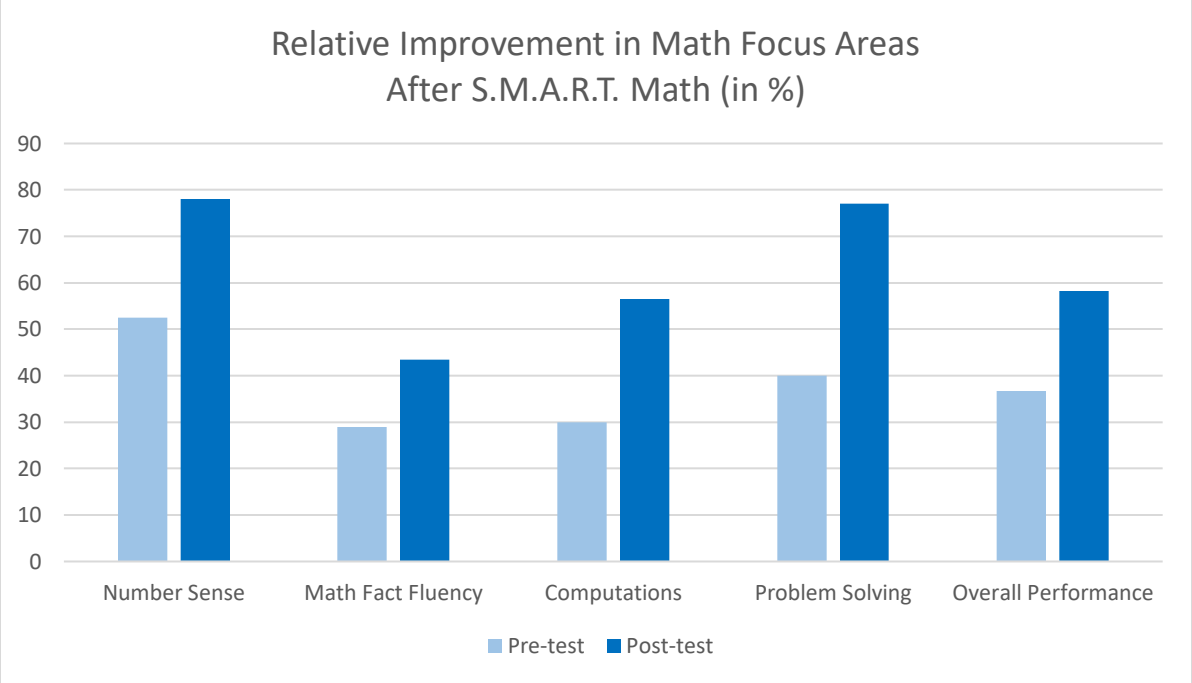




were facilitated through positive reinforcement and learning when the students made a mistake, and by making the students feel comfortable when engaging in new math activities in the program. Through the math anxiety scales, we found a 15% decrease in math anxiety. The *t*-value of 3.42955 fell above our critical t-value of 1.699127 for a 95% confidence level. Consistently, the self-efficacy portion of the assessments found a 17% statistically significant increase in math confidence among participants after completing the program.

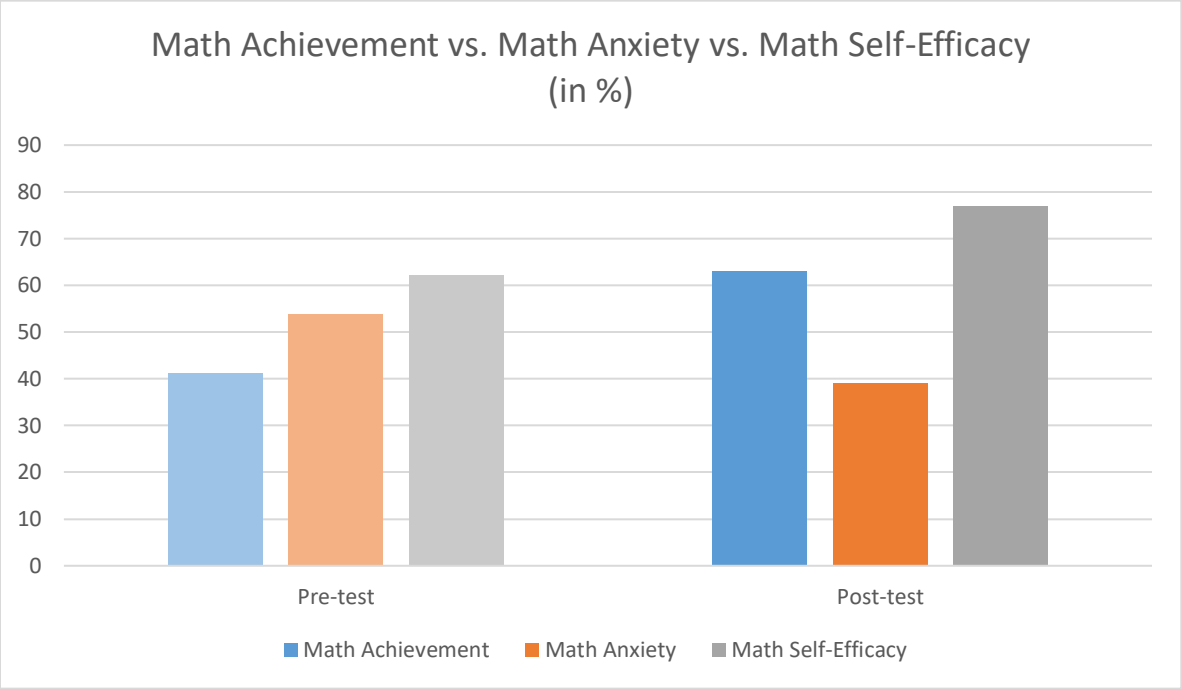
Discussion

Overall, the S.M.A.R.T Math has fostered increases in participants' fundamental mathematical skills in all areas of focus, including number sense (25%), math fact fluency (15%), computational strategies (27%) and problem-solving abilities (39%). The overall pre-test average score for math performance was 16.6 and the post-test average score was 26.2. A paired samples *t*-test concluded that the results were statistically significant [t (31) = -13.41, p < .001] such that participants improved their overall math performance by 21.5% on average.



Thus, participants in the S.M.A.R.T. Math program significantly improved in each individual component and in their overall math performance over the course of the 8-week intervention program.

Research literature suggests a relationship between self-efficacy, math anxiety and math performance. In the current project, we wanted to explore the roles of math anxiety and math self-efficacy in the academic success of participants in the S.M.A.R.T. Math program.



By graphing the pre- and post-test data for math anxiety, self-efficacy and math achievement at S.M.A.R.T., we can visualize the inverse relationship between math anxiety, math self-efficacy and math achievement. Such that, after participants engaged in the S.M.A.R.T. Math program, their math performance increased by 21.72 points and self-efficacy increased by 14.9 points while their math anxiety was reduced by 14.72 points. As such, any intervention aimed at improving math achievement must also take into account the socioemotional aspects of

learning math. Findings from our evaluation of S.M.A.R.T. Math support previous findings that math anxiety impedes math performance, and has negative impacts on math self-efficacy. In turn, participating in math intervention programs, like S.M.A.R.T. Math, increased academic performance and improved socioemotional outcomes among middle school students with MLDs.

Conclusion

In conclusion this research shows that S.M.A.R.T Math is a beneficial program for increasing mathematical skills and confidence among students with diagnosed or suspected MLDs. It also shows the program produces positive math anxiety results, meaning that over the course of the program math anxiety is decreased. This research holds important practical and theoretical implications. Professionals working with students should be aware of comorbid emotional and behavioural disorders that often affects students with LDs. If a student is avoiding a specific academic activity that it could be indicative of a possible specific LD or anxiety disorder (Gallegos, Langley, & Villegas, 2012). Programs and community agencies specializing in learning disabilities should consider both academic skill development and socio-emotional wellbeing when developing intervention programs (Aro et al., 2018). Researchers should work towards further looking into the association between social-emotional difficulties and academic success to develop better interventions to support students with learning differences.

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