S.M.A.R.T. Math: A Small Group Intervention Program for Struggling Mathematicians

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What is a Math Learning Disability?

A math learning disability (MLD), also known as dyscalculia, occurs when an individual's fundamental mathematical skills fall below the level of their peers and their own potential, seemingly without cause. MLDs can lead to difficulty in areas of life that are considered essential, which include: technology, employment, finances, and healthcare. For example, people with MLDs can have difficulty measuring medicine and making logical choices (Price & Ansari, 2013). Research shows that poor fundamental arithmetic skills correlate with high unemployment rates, risk of physical and mental health issues, and increased rates of incarceration (Price & Ansari, 2013). MLDs typically present difficulties in number sense, measurement, estimation, and mental math problems. The occurrence of a mathematical learning disability, or dyscalculia, is comparable to its literacy counterpart, dyslexia, occurring in approximately 4-6% of the student population (Norton, Beach, & Gabrieli, 2015). Unlike dyslexia, there is very little research dedicated to understanding mathematical learning disabilities. Despite the similar rates of prevalence between the two learning disabilities in the school setting, there is only one publication on dyscalculia for every 14 publications on dyslexia (Price & Ansari, 2013). This lack of research leads to individuals with math disabilities receiving less support and intervention compared to individuals with reading disabilities.

The *Diagnostic and Statistical Manual of Mental Disorders* (DSM-V) has categorized mathematical learning disabilities as neurodevelopmental disorders (American Psychological Association, 2013). Qualities of this learning disability vary from person to person, but they typically include difficulties with number sense, measurement, estimation, mental math, and problem solving (Cortiella & Horowitz, 2014). To meet criteria for a mathematical learning diability diagnosis, the DSM-V articulates that individuals must (a) possess difficulties mastering number sense, number facts, calculation, or have difficulties using mathematical reasoning; (b) be notably and quantifiably below mathematical expectations for their age; (c) begin early on and persist throughout life; and (d) exclude all other causes (i.e. intellectual disabilities, poor instruction, psychosocial adversity; APA, 2013). The clinical characteristics of MLD will change depending on the age observed and must always be related to unexpected math difficulties given the normal trajectory of their peers as well as the child's adequate performance in other subjects (Shalev & Gross-Tsur, 2001).

Individuals with MLDs tend to demonstrate an impairment in both working memory and long-term memory retrieval (Henik et al., 2011). Memory aids are beneficial in learning new methods to improve memory recall among students with MLD. As previously stated, individuals with MLDs have higher rates of distractibility and inattention (Cantlon et al., 2009). With MLDs, the visuospatial component of working memory (or the visualization of the problem) is the area where the greatest struggle occurs. This makes it difficult for individuals to understand and conceptualize arithmetic problems (Ashkenazi, Rubinsten & Henik, 2009; Cantlon, Platt & Brannon, 2009). Individuals with MLD tend to have difficulty storing new strategies in their long-term working memory, leading them to use weak or underdeveloped strategies in math (Menon, 2016). For instance, a neurotypical third grader may use the "counting min" strategy wherein they start with the smaller number and then count-up adding the larger number. These individuals can start with any number in the equation and are able to add larger or smaller numbers to it. In contrast, a 3rd grader with MLD will use the "counting all" strategy where they will have to start at zero and add all of the numbers slowly (Geary et al., 1999). Students with MLD must start at zero and add the other numbers individually due to poor retrieval of information from their working memory and long-term memory storage.

Basic number processing refers to the representation and processing of numerical magnitudes and is commonly denoted as "number sense" (Price & Ansari, 2013). Many studies have confirmed that individuals with MLD suffer from a lack of automaticity in processing numerical information which is demonstrated by their struggle comparing numbers (Fazio et al., 2014; Holloway & Ansari, 2009). Number sense in mathematics can be compared to phonological awareness in reading, a skill that enables children to recognize and work with the sounds of spoken language (Vanbinst, Ansari, Ghesquière & De Smedt, 2016). Strong number sense is necessary to enhance math abilities and problem-solving skills. The part of the brain responsible for basic number processing (which is also determined to be impaired in MLDs), is known as the right intraparietal sulcus (IPS). This is a region that becomes bilaterally activated as you age, however, in MLD individuals it only activates in the right frontal region (Price et al., 2007). In contrast, in individuals with MLDs this region does not bilaterally activate, and this causes a dysfunction in arithmetic fact retrieval and general number sense abilities (Kuhn, 2015).

Interventions

There is not a pharmaceutical remedy for MLDs, however, intensive support has been shown to have a positive outcome on affected students. It is important that the symptoms associated with MLDs are detected early and subjected to individualized intervention, as a child's brain is much more susceptible to change than the brain of an adult (Price, Mazzocco & Ansari, 2013). A multi-tier model such as the Response to Intervention (RtI) approach used by Fuchs and Fuchs (2006) has proved to be useful. The RtI approach has 3 tiers, the first being in the classroom. Students with MLDs are often unresponsive to traditional classroom instruction, and consequently require further intervention (Fuchs & Fuchs, 2006). Tier 2 is small group instruction, and tier three is individualized intervention, where each tier becomes increasingly structured to the specific learning style of the student (Fuchs & Fuchs, 2006). Kucian et al. (2011) used a game involving the placement of a spaceship on a number line and when repeated, this helped activate the IPS region of the brain and remediate arithmetic skills of the participant. In order to lower math anxiety and achieve the greatest results, it is important that these interventions are done informally but are timed for speed. Fuchs et al. (2013) determined that timed interventions help decrease the difference in arithmetic skill in students with MLD compared to their peers. This difference occurs because the timed interventions used forced these students to learn and recall more advanced strategies. In contract, non-timed interventions allowed students to use inefficient strategies which did not enhance their recall ability.

Intervention strategies should explicitly target an area of numerical difficulty, but also use multisensory methods (Barner, et. al., 2016). This gives students with MLD other strategies to remember while reducing the stress on their working memory. Multisensory methods should also be encouraged using the concrete-representational-abstract (CRA) method. In the concrete stage, students are led through a physical exploration of the concept using concrete manipulatives, such as Base 10 blocks, counters, algebra tiles, and geoboards, to engage with the content (Agrawal & Morin, 2016). The representational stage uses visuals, such as pictures of manipulatives, virtual manipulatives, tally charts, or graphic organizers to bridge the gap between the concrete and the abstract (Agrawal & Morin, 2016). Once students have mastered a mathematical concept at the concrete and representational levels of understanding, they are ready to begin explaining a concept using numbers and symbols. The final stage of the CRA framework is where students turn their conceptual knowledge from the concrete and representational stages into procedural knowledge and fluency at the abstract stage (Agrawal & Morin, 2016).

S.M.A.R.T Math Program

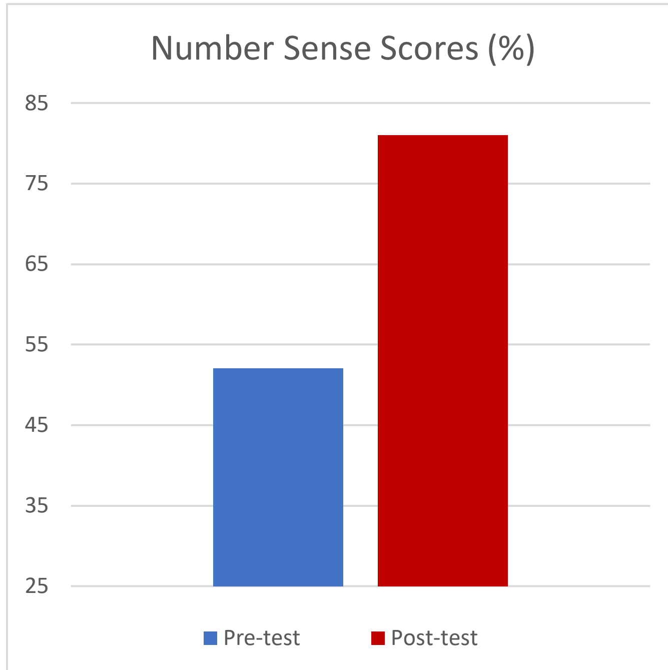
S.M.A.R.T is an intervention program which facilitates arithmetic skills and strategies in a small group setting, focusing on students in Grades 4-6. The S.M.A.R.T program, located in two elementary schools in the Niagara Region, takes place twice per week for one-hour sessions over an 8-week period. When students are first introduced to the program, they undergo an informal numeracy assessment to gage the level of their mathematical skill as well as how the instructors can best support each individual child. The assessment covers four areas deemed important to developing proper mathematical skills: number sense, math fact fluency, computation strategies, and problem-solving applications. Using the results of the informal assessments, engaging and individualized hands-on stations are set up to target the needs of the group. Post-program numeracy assessments are administered at the end of the program to track and provide a visual representation of student progress and the efficacy of the program.

During each hour-long session, ten students are split into small groups based on ability and rotate through three numeracy stations. Each station focuses on one of the areas of need as determined by the assessment. Volunteers and instructors are 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 will rotate through the interactive learning centers. For the last 15 minutes, the entire group is brought back together to do a group activity (led by the group instructor) that targets math anxiety. Throughout the course of the S.M.A.R.T Math program, students spend 10-15 minutes each week with the one-on-one instructor working on their greatest area of need as determined by the informal assessment.

Research Project

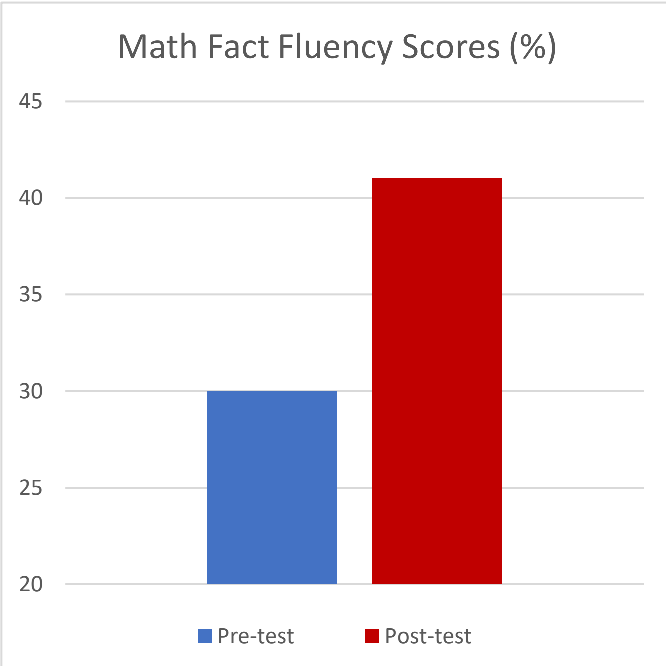
Through the creation of research toward helping children with, or at risk, of developing math learning disabilities, S.M.A.R.T hopes to target an area that is not currently a focus within the traditional education system. This program hopes to further support current theories of intervention as well as produce possible approaches to children suffering from math learning disabilities. This research project determines whether the S.M.A.R.T program is beneficial to students with MLDs and can help better their academic standing. Twenty students participated in the program during the winter of 2019 session. The following data looks at and compares the results gathered during the program sessions and provides a visual representation of participant progress in the four targeted areas.

Number Sense



Number sense refers to the student's ability to understand and work with numbers in various ways. Experts have determined that there is an intuitive number sense ability that everyone is born with (Rohlan, 2018). Number sense was facilitated using games involving identifying and representing numbers in the form of manipulatives, number lines to assist with determining the order of a sequence, and hands-on activities focusing on 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, the assessment found that there was an increase of 29% in participant number sense skills over the course of the program. Statistics were run under the null hypothesis that there would be a significant difference in number sense ability. Since our *p*-value of 0.000131 fell greatly under the critical *t*-value of 1.699127, we can accept the null hypothesis, demonstrating that there is a significant increase in the number sense ability of S.M.A.R.T participants.

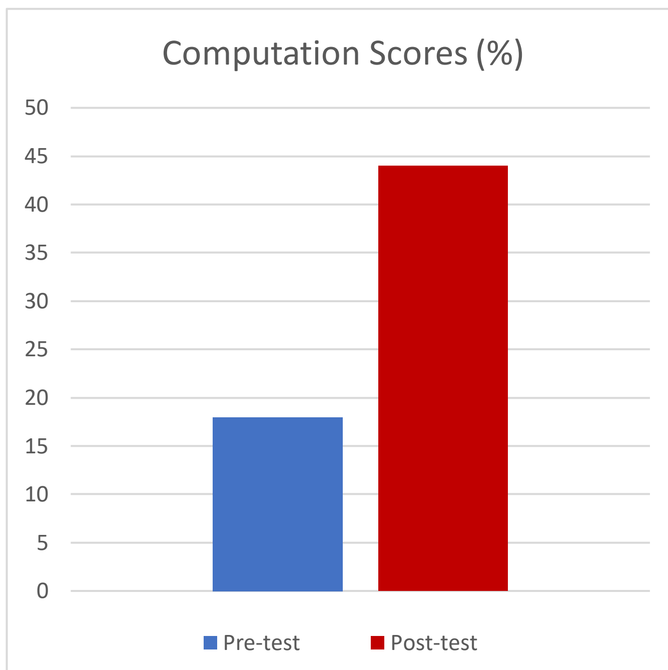
Math Fact Fluency



Math fact fluency refers to the ability of an individual to retrieve information from the working memory to answer calculations in a timely manner. Math fact fluency was reinforced throughout the program using hands-on games and manipulatives. These resources encouraged the students to develope better strategies to answer simple calculations in an efficient manner. The students were assessed using a timed assessment for each operation (addition, subtraction, multiplication, and division). Students were given 5 minutes per operation to answer as many of the questions as possible. The assessments showed that over the course of the program, math fact fluency improved by 11%, under the null hypothesis that there would be a significant difference in math fact fluency. Our *p*-value (0.080543) fell below our critical value (1.699127), indicating that there was a significant difference between pre- and post-test results.

Computation Strategies

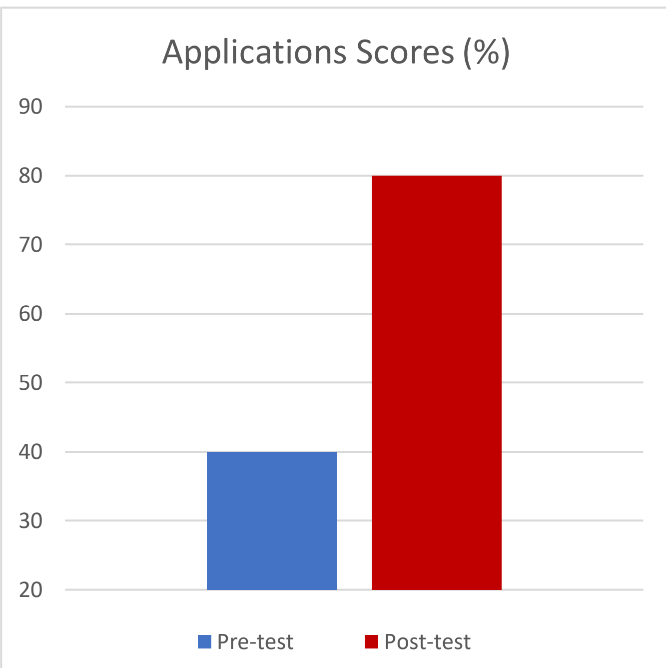
Computation strategies the student's ability to explain and use proper mathematical strategies when given a larger problem. For example, one student may use manipulatives to answer a question, whereas another student may break the larger problem down into smaller, simpler calculations. During the S.M.A.R.T Math Program, the current strategies were reinforced, and new, more efficient strategies were taught through group instruction. These areas were assessed by presenting the student with larger problems that required multiple steps. The students were given materials to use whichever strategy they saw fit and were then asked to explain the strategy they used to get to their answer.



The pre- and post-test assessments determined that there was a 26% increase in computation strategies by the end of the program. Under the null hypothesis that there would be a significant difference between pre- and post-test results, our P-value of 0.004983 fell below the critical value of 1.699127, telling us that there was a significant difference between the timepoints.

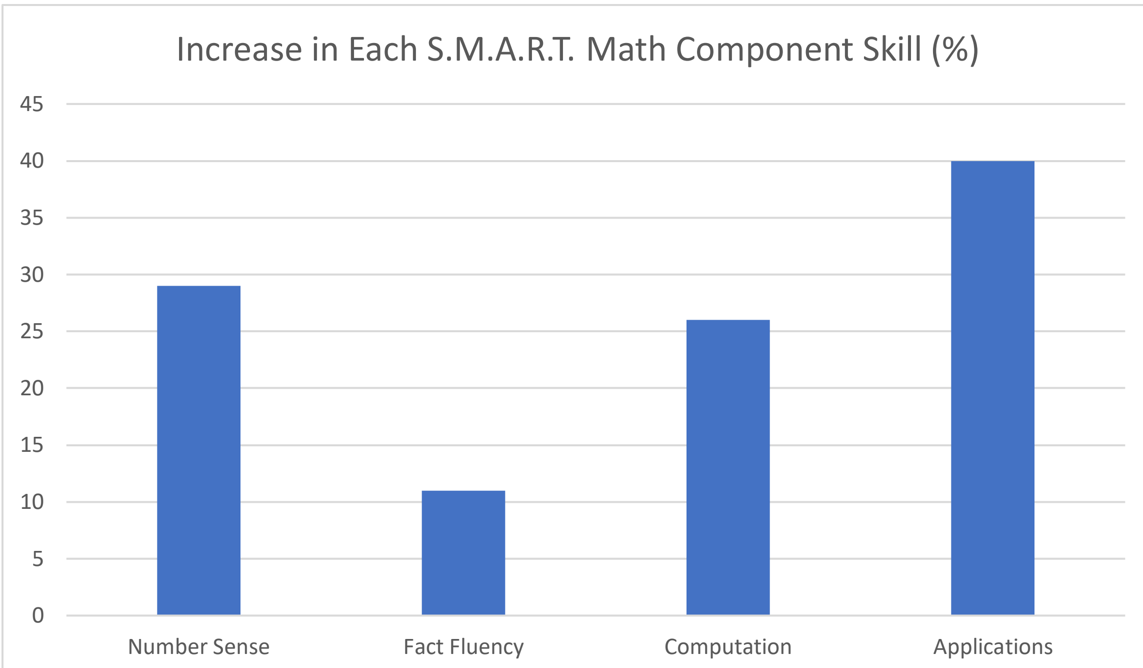
Applications

Applications is one of the most important areas of focus in this research. Applications refers to the ability to take the mathematical skills that have been learned and use them in a real-life setting. These skills involve time-telling, money counting, and problem-solving across the strands of mathematics (geometry, measurement, etc.). In the S.M.A.R.T program, applications were facilitated using engaging activities that were focused around real-world problem-solving. 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. At the end of the program, there was a 40% increase in application scores, which is the greatest increase shown in the program. Under the null hypothesis that there would be a significant difference between the pre- and post-test scores, the *p*-value was much less than the critical value. These results indicate that, out of every area focused on in the program, the area of applications saw the most significant improvement for majority of participants.



Conclusion

Overall, participants in the SM.A.R.T. math program showed a significant increase in ability in all areas of focus. The results of this research indicate that the S.M.A.R.T. program is beneficial in helping children, with or at the risk of developing math learning disabilities, remediate their arithmetic skills to close the gap between them and their peers.



Number sense showed an 29% increase on average from the beginning to the end of the program. Additionally, there was an increase in the area of math fact fluency of 11% on average. Number sense and math fact fluency are the two areas where the participants began with the most background knowledge (on average). Computation strategies had an increase of 26%, making it the lowest scoring section of the pre-test, indicating the 26% here is more significant than the previous percentages. Applications was the most improved area of the program, boasting a 40% increase in participant ability. The improvement in applications is highly significant since this is the area where the students bring together all their mathematics knowledge and apply it to real-world situations. These findings correlate with the start of bilaterally activating the IPS region of the brain, which was found previously stunted in individuals with MLDs (Price et al., 2007). Interventions, such as S.M.A.R.T Math, could provide students with MLD higher chances of employment, increased mental and physical health, and lower rates of incarceration in the future (Price & Ansari, 2013). This study suggests that programs like S.M.A.R.T, which follow effective instructional methods for MLD students, help to remediate arithmetic discrepancies in individuals with math learning disabilities, thus providing them with better quality of life.

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