DYSLEXIA AND MATHS

About 20 percent of the population struggle in Mathematics. One of the reasons for this statistic is that it is an abstract subject with its own language and symbols. How can we engage a student who has difficulty in processing symbols? How can we teach Mathematics concretely?

How is Maths performance impacted by dyslexia? Currently, the most developed theory of dyslexia is the 'phonological deficit'. Because Mathematics isn't usually associated with 'words', or 'sounds', the impact of dyslexia on Maths performance (beyond difficulty in reading worded problems) is often overlooked. However, differences in the structure and organisation of the dyslexic brain can create specific challenges in Mathematics that are added to its inherent challenges. According to the International Dyslexia Association, about 50% of dyslexics experience significant difficulty with many aspects of Mathematics, in particular with learning of number bonds, number fact retrieval, number operations, understanding of place value, recall of sequences, mathematical vocabulary, solving of word problems and understanding of time and money. These difficulties should be addressed with research-based strategies and high-quality materials that utilise learning strengths, such as the Math-U-See program.

What are the inherent challenges of Mathematics? In Mathematics, large bodies of arbitrary information have to be efficiently stored mentally to allow automatic access and retrieval. It is a cumulative, building-block subject - failure to master and remember facts, concepts or procedures at one level can make it difficult to achieve at higher levels of the curriculum. Mathematics makes significant demands on working memory. Greater emphasis is put on speed of working in this subject than in any other. It requires neatness and precision. Errors in thinking are more often drawn to attention and corrected than in other subjects and so Mathematics anxiety and avoidance behaviours can develop.

The core difficulties of dyslexia include:

1. Phonological awareness – ability to recognise the sounds in words and manipulate them. The obvious impact of this in Maths is difficulty in reading word problems but research also suggests that phonological processing impacts directly on aspects of mathematics that rely on the manipulation of verbal codes (e.g. counting speed, number fact recall)

2. Naming Speed – ability to quickly name visual stimuli including letters, words, numbers, symbols or pictures. Processing speed is regarded as very important in Mathematics. In a classroom study, Steve Chinn (1995) found that dyslexic pupils took about 50% more time to complete a set of arithmetic questions than their non-dyslexic peers.

3. Orthographic Processing – ability to process (and remember) visual symbols – letters, words, numbers, and the multitude of mathematical symbols as well as musical notes.

4. Verbal memory / Short-Term Working memory – ability to hold sequences of sounds, words or numbers in memory (up to about 1 minute) while working with them. This is particularly evident in the performance of dyslexic students on tests of digit span and mental arithmetic.

It is easy to see, then, **why a dyslexic student might struggle with Mathematics**. Dr. Steve Chinn et al (2001)[1] found in a cross-cultural study of 10-13 yr old dyslexics that 70% were performing at a level more than a year below chronological age. 'More of the same' instruction is not an appropriate response to underachievement. As Dr Harry Chasty (2014)[2] said, 'If a child does not learn the way you teach, then teach him the way he learns.' Effective instruction for dyslexic students will address the weaknesses typically seen in long-term and short-term memory, working memory, sequencing skills, processing speed, phonological processing and phonological memory, reading and recording, and, in addition, lower Maths anxiety. Instruction that is explicit, systematic, sequential, multisensory and cumulative will best meet the needs of the dyslexic student (and many others!).

Math-U-See is a manipulatives based, multi-sensory, sequential, mastery-focused program, created by former Maths teacher Steve Demme in 1990 originally for home-schoolers. Distributed in Australia by Maths Australia, it comes with a free placement test, instructional manuals and DVDs, student activity books, lesson tests, monitoring sheets, an online worksheet generator and online interactive drills. The program uses three forms of manipulatives: integer blocks, algebra-decimal inserts and fraction overlays. The manipulatives can be used with any Maths program, at primary and secondary level. Research shows that **students who use structured concrete materials in Maths develop more precise and comprehensive mental representations than those who don't**, often show more motivation and on-task behaviour, have deeper understanding of Maths ideas and better apply these ideas to life situations (Harrison & Harrison,1986)[3]. Math-U-See's manipulatives allow students to literally 'build' Maths concepts.

Due to their difficulty in processing sounds and symbols, **dyslexic students often have a preference for visual-spatial and experiential learning** so use of manipulatives can 'teach them the way they learn'. Math-U-See's Integer Blocks are individually segmented for each number (2, 3, 4 and so on) as raised squares so the

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[1] Chinn, S.J. et al (2001) 'Classroom studies into cognitive style in mathematics for pupils with dyslexia in special education in the Netherlands, Ireland and the UK' in *British Journal of Special Education*, Vol 28, No.2.pp 80-85

[2] Chasty, H. (2014) 'A new approach to developing illiteracy worldwide' – a paper on the Dyslexia International website https://www.dyslexia-international.org/books-and-articles/?doing_wp_cron=1556957972.6838340759277343750000

[3] Harrison, M., & Harrison, B. (1986). Developing numeration concepts and skills. *Arithmetic Teacher,33*, 1-21.

unit factor can be seen and felt. It is widely known that colour enhances attention and memory, especially in predominantly right-brain thinkers, so colour should be used systematically with manipulatives. In Math-U-See, each integer block piece is assigned a particular colour, to aid visualisation and recall. The program's systematic use of colour and rectangular shapes as a model helps students to 'see' number structure, number relationships and place value, and to 'see' links between each concept. (Research shows that the brain retains pictures of rectangles more easily than pictures of other shapes).

The dyslexic student who struggles with Maths typically needs to use concrete materials for longer, and more frequently, than non-dyslexic peers, so making the best choice of manipulatives is vital. Some schools use wooden MAB blocks when teaching Maths. The students work with units, tens, hundreds and thousands but are not helped to visualise, for example, 6 or 8. No use of colour is made to aid understanding and recall of number combinations or place value. The blocks are solid, whereas the Math-U-See blocks are hollow on one side. The hollow (or 'owe') side shows the inverse of addition, which is subtraction. The student with weak working memory can see how much has been 'taken away' while he calculates. Later, the hollow side will illustrate the concept of a negative number in operations with directed numbers.

Dyslexic students often struggle to achieve automaticity in recall of addition / subtraction facts and thus tend to rely on finger counting. They need help to see numbers as patterns that can be re-arranged – partitioned or decomposed. They can work out a number fact they can't remember by visualising and reasoning, rather than counting. The Math-U-See Integer Blocks help students to use reasoning to work out number facts, to understand concepts such as commutativity. Strategies such as use of doubles and near doubles, the compensation strategy and bridging ten are easy to visualise with repeated use of Integer Blocks.

Research shows that **dyslexics have a much lower immediate recall of Maths facts than their peers**. They typically find learning the 121 facts of the multiplication tables a highly frustrating task, due to sequencing and verbal memory problems. Reliance on rote-learning causes anxiety, as there is no possibility of obtaining the correct answer when a fact is forgotten. The most effective way to teach dyslexic children times-table facts is to teach them strategies based on the patterns and inter-relationships of numbers. Strategies give them a route to the answer if rote memory fails them. Using the area model, manipulatives are used in the Math-U-See program to build and give meaning to the multiplication facts, to help students 'see' turn-around facts and to reason from key facts. Building with the area model helps them to understand the inverse nature of multiplication and division.

Doing long division without a calculator is ranked as the second highest factor in maths anxiety in a study by Dr Steve Chinn[4]. 40% of dyslexics did not attempt a long

[4] Chinn, S.J. Mathematics Anxiety in Secondary Students in England *Dyslexia* 15(1):61-8 · February 2009

division problem, as compared to 6% of non-dyslexic. Building algorithms with the area model helps students to 'see' the steps in procedures they struggle to remember such as those involved in long multiplication and division.

Decimal numbers are often hard for students with sequencing difficulties to understand, as one hundredth is smaller than one tenth yet 100 is bigger than 10. Math-U-See makes clever use of decimal inserts that click into the back of the integer blocks to develop understanding of decimal numbers. The green 'one' is magnified to take the form of a 'one' equivalent in size to the hundred square. A smooth blue insert goes into the back of a ten-stick to represent tenths and a red cube represents one of the hundred cubes needed to fill the 'one' square. The continuity of colour helps the dyslexic student to see the relationship between part and whole numbers.

Algebra is perhaps one of the most difficult Maths topics for dyslexic students, as letter symbols are mixed in with number symbols and index notation requires the student to pay attention to the position in space of a digit. To some dyslexic students, a 'b' will look like a 6, a 'g' like a 9. In Math-U-See, the inserts are used to replicate algebra tiles. Students can use the smooth red square to represent 'x squared', a smooth blue stick to represent 'x', a smooth grey stick to represent 'negative x' and integer blocks to represent integers in 'building' algebraic expressions and equations. They can physically make substitutions and factorise equations.

Fractions work is hard for dyslexic students**,** firstly because many fractions are hard to visualise. Students rarely see fractions other than halves and quarters in daily life, except when food is cut up. Identification of equivalent fractions and the simplification of fractions requires automaticity of recall of multiplication and division facts. Most people with neuro-typical brains find it impossible to visualise multiplication or division of fractions. They operate immediately with symbols. The Math-U-See fraction overlays are unique and make visualisation of operations with fractions remarkably easy. They also help the student to physically turn fractions into decimals.

While the Math-U-See manipulatives can be used with any Maths program, they are central to Math-U-See's K-12 curriculum. **The curriculum materials will be a valuable resource for those seeking a student-paced, mastery-based program with regular cumulative review**, for example, home schoolers and teachers of students at educational risk or learning difficulty. The U.S. Institute of Education Sciences transcribed a guide providing eight specific recommendations to help educators and school administrators to use Response To Intervention to identify students who need assistance in mathematics and to address the needs of these students through focused interventions. Math-U-See follows those recommended practices. To see how these RTI practices are used, download https://www.mathcanada.ca/pdfs/researchbased_thumb.pdf

The Math-U-See program is not categorised by the student's grades or year level, but by carefully sequenced skill and concept mastery. The content in each

workbook has been aligned to the Australian National Curriculum (ACARA) and makes teaching Maths simple and enjoyable, providing easy to follow step-by-step procedures for introducing, reviewing, practising, and mastering concepts. Teaching is explicit and systematic, with the same language and manipulatives used throughout the program, creating a strong foundation for the student. The videos are particularly helpful for dyslexic students who have memory deficits, allowing the student to watch demonstrations as often as needed to master a concept or skill. The time needed for lesson preparation is minimal so the instructor can focus on student understanding and skill.

The combination of difficulties dyslexic students experience often works to compound a belief that he/she can't do Mathematics. Dr Steve Chinn's 1995 analysis of error patterns in mathematical answers showed that dyslexics are more likely to make no attempt than non-dyslexic peers. **They would rather not attempt a question than risk getting it wrong.**

Use of manipulatives, such as blocks, inserts and overlays, can help teachers to begin to teach students the way they learn. It makes Mathematics less threatening for students who struggle to process symbols and understand abstract concepts. It also makes Maths something students experience and enjoy rather than memorise. The opportunity to use visual-spatial strengths and literally 'build' concepts can not only deepen understanding of Maths concepts but also reduce the Maths anxiety that prevents optimal performance.

"Every student can learn, just not on the same day, or in the same way."

(*George Evans)*

Recommended Reading

Chinn, S.J. and Ashcroft, J.R. Mathematics for Dyslexics: A Teaching Handbook, Whurr Publishers, 1993

Clayton, P. How to Develop Numeracy in Children With Dyslexia, LDA, 2004

Kay, J and Yeo, D. Dyslexia and Maths, David Fulton Publishers, 2003

Miles, T.R. and Miles, E. (Eds) Dyslexia and Mathematics, Routledge, 2003