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Valuing Difference and Growth: A Youcubed Perspective on Special Education

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Introduction

Nicholas Letchford grew up in Australia, a quiet boy who loved to build and solve puzzles. In Nicholas' first years of school his parents were told that he was learning disabled, that he had a very low IQ and that he was "the worst child they had seen in 20 years". 2018 was an important year for Nicholas and his family. It was the year that Nicholas' mother Lois published her book: Reversed: A Memoir[1], describing their teaching and learning journey together. It was also the year that Nicholas graduated from Oxford University with a doctorate in Applied Mathematics.

Nicholas' story of overcoming the odds that were stacked against him is inspiring but his journey – from a boy diagnosed with a learning disability to an adult with the highest academic achievement—should also remind us of the dangers of writing off any students in school, because they show signs of weakness. A few decades ago scientists believed that our brains were fixed—either at birth or by the time we were adolescents. This led to the schooling approaches that fill schools—of identifying learning disabilities, providing accommodations and working around them. Now the scientific world has new understandings, particularly regarding the incredible plasticity and adaptability of the brain[2]. Scientists have discovered that every time we learn we form, strengthen or connect brain pathways, in a process of almost constant brain change[3]. As neuroscientist Norman Doidge states, every day we wake up our brains have reorganized[4]. This knowledge of the brains' continual potential to adapt and change has led scientists and educators to take a wholly different approach to students with disabilities. Instead of working around areas of weakness, scientists now identify brain areas in need of support and strengthen them, building much needed pathways[5]. We will review some important studies later in this paper, that report upon brain interventions that set students with special education labels on entirely different journeys. One of the goals of this paper is to share evidence of these brain and learning interventions.

A second goal of this paper is to open discussion of the ways we consider difference in mathematics learning. Many students think outside of the narrow box of mathematics learning that is on offer in schools. When schools emphasize a narrow way of thinking, students who think differently turn away from the subject or worse, become labeled as having a disability. It is fairly typical for schools and homes across the US and world to offer mathematics as a subject of memorization[6]. This comes about in part because of the testing culture that is dominant in the US. Teachers know that they can teach students to memorize methods and be successful in narrow tests. The memorization approach starts early—with teachers asking students to memorize tables of multiplication facts, often from 1st grade onwards. Mathematician Francis Su describes the memorization of the 12x12 multiplication table as one of the most meaningless activities possible. Further damage is done when students are tested on their recall of math facts, under timed conditions, leading many students to develop mathematics anxiety[7]. Students who undergo such experiences learn early on that mathematics is a shallow subject needing fast recall, and for that reason they turn away from it. A previous youcubed paper[8] entitled: "Fluency without Fear" shares different ways of approaching fact fluency with students, giving students understanding and enjoyment, instead of fear.

There are many problems with the memorization approach to mathematics. One is that some students are not good memorizers. These students do not have less mathematics potential[9] and often they are students who think creatively and visually, have strong reasoning and logic, and who could contribute greatly to the discipline of mathematics. Sadly such students are not valued in memorization classrooms, and they quickly get the idea they are not "a math person" which changes their learning from that point on. For some students weak memorization of math facts, which often stems from anxiety, leads to a learning disability diagnosis and years of special education classes and low self-esteem[10]. This is something we are trying to change, through the dissemination of evidence through youcubed.org and the message that diversity in thinking is something to be valued. Even though weak memorization is often used as the indicator of a learning disability, there are many reasons that students do not memorize well, as we describe later. Also strong memorization and speedy performance of math facts and methods is not an indication of strong mathematics potential.

This paper aims to communicate scientific evidence in two main areas, that we hope will inform and support those working in special education and those working with students in need of support. First we share a growth approach to Special Education that draws from the latest scientific work in neuroplasticity. Second we report on schools and teachers taking a multi-dimensional approach to the teaching of mathematics that works to honor many different types of thinking, valuing difference and rejecting ideas of deficit. We, the authors, are not special educators and do not have the detailed knowledge of those who specialize in the field, but we hope that our knowledge of mathematics learning and of neuroscience, will help those who are doing the important work of supporting students in schools.

Many special educators have worked for years to value students who have learning differences, and resist attempts to pull them into different classrooms, cementing ideas of deficit. We applaud this work, as well as the special educators who work with students who have been put into different schools and classes, and strive to give students the idea they can learn and achieve highly. While this paper is not giving the argument that all students have the same brain and the same potential, we will give the argument that when teaching and expectations are broadened, many more students are successful and some students even shed learning disability labels. Our aim in writing this is to provide research evidence that will help students succeed in mathematics and other subjects, past the limitations that are often placed on students who think differently.

1. Special Education and Mathematics Anxiety

Across the United States approximately 8.4% of students are diagnosed as having a special education "disability"[11]. The vast majority of those—72% are diagnosed as having mild to moderate disabilities[12]. These include learning disabilities such as dyslexia, dyscalculia, and auditory processing disorder. Inequities prevail in special education, as they do in most aspects of schooling. For example, males and students of color are more frequently classified as special education students than are females and white mainstream students. Nearly twice as many males as females are classified as students with learning disabilities.

The group most likely to be classified as "mentally retarded" or "learning disabled" are boys of color[13]. Black students with disabilities are four times more likely than their white counterparts to be educated in correctional facilities[14].

A large amount of the current research on mathematics learning disabilities (MLD) has been conducted on elementary aged students with a focus on speed and accuracy in arithmetic calculations[15]. When children have particular problems memorizing disconnected facts, they are often regarded as having a learning disability. Research indicates that 5-7% of students are diagnosed with mathematics learning disabilities[16], but there is no agreed upon assessment criterion for this diagnosis and low mathematics achievement is often used as an indicator of a disability[17]. This is troubling given that students underachieve in mathematics for many different reasons, often unrelated to cognitive differences. One of the most important and yet most neglected reasons for underachievement is math anxiety, a psychological condition that often develops in the early years and snowballs as students move through school. Ashcraft describes math anxiety, as the feeling of tension, apprehension, or fear when people work on mathematics[18]. Neuroscientists are now showing that mathematics anxiety is widespread, that it impedes the functioning of the brain[19] and it can be passed on by teachers and by parents[20]. Before deciding that a student has a "learning disability" it seems important that we consider the ways that mathematics anxiety may be affecting a student's learning and achievement.

Many children in the US, and beyond, grow up thinking that either you can do math or you can't. When they struggle, they assume they can't. From that point on any struggle is a further reminder of their perceived inadequacies. Procedural mathematics teaching and high-pressure testing combined with the prevalent ideas that only some students belong in mathematics[21], has led to the development of widespread mathematics anxiety across the world. One study found that 48% of all young adults in a work-apprentice program had math anxiety[22]; other studies have found that approximately 50% of students taking introductory mathematics courses in college suffer from math anxiety[23]. It is difficult to know the impact and extent of math anxiety across the world but even conservative estimates suggest that it is considerable and worthy of greater attention[24]. In our own work teaching mathematics as a multi-dimensional subject, valuing the different ways students think and reason, we have found that math anxiety disappears when students see that they can learn successfully and they are given the opportunity to build a new relationship with mathematics[25].

Researchers now know that when people with math anxiety encounter numbers, a fear center in the brain is activated—the same fear center that lights up when people see snakes or spiders. As the fear center of the brain becomes activated, activity in the problem-solving centers in the brain is diminished[26]. It is no wonder that so many people underachieve in mathematics—as soon as people become anxious about it, their brains are compromised.

Sian Beilock's research has revealed the ways math anxiety is passed on to young students, by teachers and parents. In one study, she and colleagues found that the amount of math anxiety expressed by parents predicted their child's math achievement in school[27]. The amount of math knowledge parents had was not important, only how anxious they were. And their math anxiety only impacted students negatively if parents helped with homework. This suggests that math anxiety is passed onto children when parents are having conversations with them about mathematics.

In another important study Beilock and her team found that the amount of math anxiety female elementary-school teachers have predicts their female—but not male—students' achievement[28]. This probably comes about because female teachers share their feelings about math through statements such as, "I was not good at math in school," and, "Let's just get through this quickly, so that we can move to reading time." Girls are probably affected by this more than boys, because they identify with their same-gender teachers. Unfortunately, while unproductive mathematics approaches and messages continue to be a part of students' education, it is difficult to know when a student has a genuine learning difference and when they are suffering from a form of anxiety that would suggest a whole different approach to remediation. Researchers agree that assessments should look for and identify math anxiety in order to help underachieving students[29].

The remaining two sections of the paper share evidence of different ways of supporting students who need particular help with learning. First we review the brain training interventions that are being used by neuroscientists and others, in mathematics and in reading, with highly promising results. Second we share the impact of teaching mathematics multi-dimensionally, including the ways it addresses mathematics anxiety and invites students to be mathematically successful, even when they have previously been labelled as low achieving.

2. Targeted Brain Interventions

For decades the approach of many who work in special education has been to identify students' areas of need and work around them—engaging students in learning approaches that draw from their strengths. This approach made sense for the thinking at the time. If brains were relatively set it would be unproductive to try and change them, and schools lacked the resources and knowledge to do so. But we are now in a new era, and neuroscientists have important insights into the complex working of the brain. Not only do neuroscientists have the capacity to understand brain functioning, but they can also change brain functioning through targeted interventions. In one study researchers gave a brain intervention to 24 children ranging from 7 to 12 years old who were either clinically diagnosed with dyslexia or recorded as having significant reading difficulties[30]. These children were given an intensive 8-week long reading intervention program where they participated in one-on-one training sessions for 4 hours a day, 5 days a week. Throughout the study, MRI data were collected to track the students' brain growth. The researchers found large-scale changes in brain growth for the participants. Furthermore, this brain growth was correlated with a significant improvement in reading skills. By the end of the intervention program, the average reading achievement score for the intervention group was within the range of scores for typical readers[31]. This finding shows that targeted interventions can bring about significant brain growth and change which can result in improved outcomes for students with learning differences.

A different intervention conducted by neuroscientist Teresa Luculano and her colleagues in Stanford's school of medicine, was similarly promising[32]. The researchers brought in children from two groups—one group had been diagnosed as having mathematics learning disabilities and the other consisted of regular performers. The researchers looked at the brains of the children using MRI scans taken when they were working on mathematics. They found actual brain differences—the students identified as having disabilities had more brain regions lighting up when they worked on a math problem. However, we do not want all brain areas to light up when we work on mathematics; we want a few focused areas to light up. The researchers gave one-on-one tutoring to both sets of students—those who were regular performers and those identified as having a mathematics learning disability. The tutoring, which included 8 weeks of 40-50 minute sessions per day, focused on strengthening student understanding of relationships between and within operations. At the end of the eight weeks of tutoring, not only did both sets of students have the same achievement; they also had the exact same brain areas lighting up[33].

Both of these studies show that in a short period of time with careful teaching, brains can be completely changed and rewired. Such studies are inspiring and should remind us that all students are on a growth journey. The dichotomous thinking that fills schools—with decisions that some students are "smart" or capable of high level work, or have "special needs"—make no sense if we acknowledge that all students—and teachers—are in a continual process of brain change and growth.

It is not only neuroscientists who are focused upon brain change and growth. Barbara Arrowsmith-Young is a pioneer who has been giving students cognitive training through her specialized schools in Toronto, and through the training of educators who take her approach back to their own schools[34]. Barbara is someone who was herself diagnosed with severe learning disabilities. As she was growing up, she and her family were told she was brilliant in some areas, but "retarded" in others. Fortunately for Barbara, she had an amazing memory and was able to memorize her way through school and hide what she knew was wrong.

As an adult her own learning disabilities prompted her to study child development, and eventually she came across the work of Alexander Luria, a Russian neuropsychologist who had written about stroke victims who had trouble with grammar, logic, and reading clocks. Luria worked with many people with brain injuries, produced an in-depth analysis of the functioning of various brain regions, and developed an extensive battery of neuropsychological tests. Then Barbara came across the research in neuroplasticity and realized that particular activities could produce brain growth. She began months of detailed work on the areas she knew she was weakest in. She made herself hundreds of cards with clock faces and practiced so much she was reading them faster than "regular" people. She started to see improvements in her symbolic understanding and for the first time began grasping grammar, math, and logic[35].

Now Barbara runs schools and programs that give cognitive training to students diagnosed with learning disabilities[36]. During visits to her schools in Toronto we met many children and adults who were attending the programs. Many of them spoke in similar terms—talking about a "fog lifting" after they started on her cognitive tasks. Researchers studying the Arrowsmith program have now found that it causes improvements in brain connectivity, and network reorganization[37].

Barbara not only offers cognitive training for students who go to Toronto and enroll in the school; she has now developed a program that educators can be trained in and take back to their schools. Some students stay in the program for a few months, some for a few years, and now a remote program is being developed for students to work in different locations. A free webinar will be shared on youcubed.org to help those who would like to learn more about and possibly become trained in the Arrowsmith approach[38]. The Arrowsmith program and the research that is now emerging from it, holds promise. For subject teachers in schools, similarly exciting results come about when expectations and content are opened up, as examples in mathematics show.

3. Teaching Mathematics through Multiplicity

We recently ran a Youcubed summer mathematics camp for students at Stanford. Eighty-four students attended, from a range of achievement levels, and all shared with interviewers that they did not believe they were a "math person". We worked to change those ideas and teach mathematics in an open and multi-dimensional way. After eighteen lessons the students improved their achievement on standardized tests by the equivalent of 2.7 years[39]. When district leaders visited the camp and saw students identified as having learning disabilities, who were low achieving in their district, solve complex problems and share their solutions with the whole class, they became teary and said it was impossible to know who was in special education and who was not in the classes.

When mathematics is taught as a narrow subject, with one way to be successful—follow and reproduce the teacher's methods—only a small number of students are successful. When mathematics is opened and teachers work to recognize and value all the ways of being mathematical including making conjectures, problem solving, communicating, reasoning, drawing, modelling, making connections, and using multiple representations—many more students are successful. A more open mathematics approach has been shown by multiple research studies to bring about more equitable and higher achievement[40]. The teaching of mathematics as a set of methods to follow, encourages students to regard mathematics as a subject of memorization. Without the opportunity to explore mathematical ideas, develop understanding, and see important mathematical connections, students resort to memorizing methods and procedures. The limitations and the pervasiveness of this approach in the US was shown by a study of student learning conducted with 13 million students worldwide[41].

PISA testing is a form of international testing in mathematics and science given to 15-year-olds worldwide. In 2012 the Organization for Economic Co-Operation and Development (OECD) focused on mathematics in particular and collected evidence of students' approaches to learning. This showed something interesting. Analysts divided students into one of three learning styles: students either approached mathematics learning by memorizing, by relating material to previously known material, or by self-monitoring—connecting new ideas to those they had learned. Analysts found that students who took a memorization approach to mathematics were the lowest achieving students in every country and any country that had high numbers of memorizers (such as the US) was low performing[42]. The US was in the top third of countries across the world with high proportions of students taking a memorization approach.

A research study that sheds light on the limitations of a memorization approach and the ways young students become low achievers in mathematics was conducted by two professors in the UK, Eddie Gray and David Tall[43]. They conducted a study with a group of 7 to 13 year old students who were identified by their teachers as low, average, or high achieving. The students were asked to work out addition problems like 7+19 and were presented with a visual representation. The researchers categorized the strategies that students used to complete these questions as using "known facts", "counting all", "counting up", and "derived facts". The "derived facts" approach, which could also be described as "number sense" meant that students were using numbers flexibly to solve problems. For example, when faced with a problem such as 7+19 a student with number sense might add 6 and 20, whereas a student using a counting strategy would count the numbers one by one. Gray and Tall found that the strategies used by above average students and below average students varied greatly:

Above Average Student Strategies	Below Average Student Strategies
30% known facts 9% counting on 0% counting all 61% derived facts	6% known facts 72% counting on 22% counting all 0% derived facts

The researchers noted something important—the difference between the low and high achieving students was not that the high achievers knew more, but that they were engaging with numbers flexibly and the low achievers were not. The researchers also pointed out that low achievers are often learning a more difficult mathematics, and they illustrated this with the strategy they used to subtract 13 from 16. Whereas the students with number sense subtracted 3 from 6 and 10 from 10, the students without number sense counted down, from 16 to 13. This requires a great deal of cognitive focus and is more difficult than the number sense approach. Unfortunately, as the researchers note, when students are identified as low achieving, they are often pulled out of class and given more "drill and practice" which cements their memorization approach to mathematics. Students pulled into special education classes are often taught mathematics procedurally and encouraged to memorize methods. This is unfortunate as the students most need a different and more conceptual approach to mathematics, so that they develop number sense, and a comfort with numbers and number relationships[44].

In different studies in which researchers report an approach to mathematics that values the different forms of thinking that learners offer, teachers find that students diagnosed as having learning disabilities contribute a great deal, communicating sophisticated thinking strategies[45]. A number of different studies have shown that when students are given the freedom to think in ways that make sense to them, learning disabilities are no longer a barrier to mathematical achievement[46]. Many teachers do not know how to teach multi-dimensionally, which is why youcubed offers professional development, online courses and a range of other resources to help teachers know and teach mathematics differently (see youcubed.org). These courses are designed to help teachers of mathematics and special educators.

Dylan Lynn was diagnosed as having dyscalculia, a particular brain condition that makes learning mathematics hard. But Dylan refused to accept that she could not learn mathematics and pursued and achieved a degree in statistics at the University of California, Berkeley. Many people told Dylan to change her focus from mathematics, instead of this she worked out her own system of tackling mathematics problems, engaging with them in more multi-dimensional ways. Dylan now collaborates with Katherine Lewis, a professor at the University of Washington, in communicating her approach to mathematics, to help others achieve their goals, even when those who have been assessed as having a learning disability[47].

In Conclusion

This paper has shared some ideas and research that are focused on brain growth and difference. It has taken a necessarily selective approach, with the aim of sharing some new initiatives and research that are not well known. When students like Dylan Lynn and Nicholas Letchford move from labels of special education to high mathematics achievement many factors are at work, including educators or parents who believe in the students. The students also displayed a growth mindset approach to their lives and their learning. A large body of research has now shown that when students develop a growth mindset, and believe that they can achieve, they go on to higher achievement[48] and their brains function more effectively[49]. But it is hard for students to develop a growth mindset if they are learning in school systems that communicate the opposite idea – that only some students can be successful.

An important shift that needs to be made in the school system and in homes concerns the way in which students and teachers react when students struggle. Neuroscience and educational research shows that times of struggle are some of the most productive times for brains, and they should be celebrated[50]. If students face struggle and think that it is a time of challenge and brain growth, rather than assuming they are failures and not "math people" (or substitute any other subject), their learning pathways will change. This takes different messages from teachers and parents, especially around times of struggle[51].

This paper is not giving the argument that all students have the same potential or that some students do not have learning differences that need special attention, but we are claiming that many students develop the incorrect idea that they cannot be successful when mathematics is taught in a narrow and closed way, because of the narrowness of the approach. All students benefit from a multi-dimensional mathematics approach that values different ways of seeing and working, that is true to the discipline of mathematics[52], and that focuses upon the big ideas of mathematics and the connections that link them[53]. A connected, meaningful and multi-dimensional mathematics experience should be a right for all students.

To conclude this paper we ask a question, that was first asked by Ray McDermott: How would learning change for students if we did not have labels in our school system?[54] Unfortunately any label—even one that brings with it funding and helpful accommodations—has a fixed idea about it. This film shows Stanford students reflecting on labels of giftedness and smartness, and the ways these labels changed them, in some unexpected ways[55]. When students arrive at schools with brain and learning differences that need special attention and help, it is important to provide accommodations, but when labels are attached to such accommodations, they start to define children, in unproductive ways. We work with schools now that have special educators who help students without labels, and always refer to learning differences, rather than learning disabilities. This may seem like a small linguistic shift but it is one that changes students' perceptions and pathways. All learners are different and that is something to be celebrated. Teaching would be a very un-rewarding job if we asked learners questions and they all gave the same answer and thought in the same way. I (JB) was very struck by the recommendations that came to me as a parent for my own child with dyslexia and auditory processing difficulties. All of the recommendations for the teaching she should receive and that would really help her – to see content and ideas in different ways, to engage with multiple media and methods, to avoid disconnected facts, or find ways to connect them—seemed like good teaching for all students. Perhaps we should not even call it "special education". Maybe there is a better name: good education.

This article contains extracts from Jo's new book: Limitless Mind: Learn, Lead & Live without Barriers. (Harper Collins:2019).

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