Maths and Dyslexia.
A View from the UK

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Dyslexia and dyscalculia

The International Dyslexia Association (www.interdys.org) defines dyslexia as a learning disability characterised by problems in expressive or receptive, oral or written language. Problems may emerge in reading, spelling, writing speaking or listening.

Two changes have recently occurred around the definitions of dyslexia.

First change is a return to the use of the word dyslexia. The term specific learning difficulty used to be interchangeable with dyslexia in the UK. This is no longer the case as other specific learning difficulties have been identified, for example dyspraxia, attention deficit disorder, Asperger's syndrome. These can sometimes co-occur with dyslexia.

Alongside this move back to the word dyslexia has been the second change, a tendency to use definitions of dyslexia which focus only on language difficulties, whereas ten years ago definitions would have included difficulties with mathematics or numeracy (and possibly music and social skills).

Despite this exclusion of difficulties with mathematics from the definition of dyslexia, it is still recognised as a potential consequence of dyslexia (by the International Dyslexia Association for example). It is likely that dyslexia will create difficulties in at least some aspects of mathematics, most particularly in numeracy.

Although dyslexia is a lifelong condition, the impact on potential depends enormously on educational intervention. The USA uses the word disability, whereas in the UK we use difficulty. I prefer the word difficulty as for me the implication is that the difficulty can be addressed and usually alleviated or circumvented. There are many successful dyslexics in many areas of work.

Recently there has been some increase in interest in the UK in the term dyscalculia, a specific learning difficulty in mathematics. For example, Butterworth (2002) has developed a screening test for dyscalculia. This condition may well exist as a separate learning difficulty, that is there will be individuals who have no difficulties with language, but do have difficulties

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with mathematics, but research in this field is minimal. However, for the
dyslexic, it is very likely that difficulties in maths will occur alongside
difficulties with language, although researchers may disagree on the prevalence
of this co-occurrence.

What may be very difficult to discern is where an individual's difficulties with
maths are rooted. The learning of maths is very dependent on teaching being
appropriate to the individual. We do not all learn in the same way and, as maths
is a very sequential subject in that each new idea builds on previous learning,
failure can be cumulative.

To rectify difficulties with maths it may be necessary to go back to maths
topics which were taught well before any difficulty was identified.

**How does dyslexia affect maths?**

Most people think that the rules of maths are consistent, certainly more
consistent than the rules of spelling. In fact there are many inconsistencies in
maths which are often overlooked. Many of these inconsistencies occur in
numeracy and thus the seeds of confusion and failure are sown very early. This
is one reason why attempts to deal with difficulties in maths have to go back a
long way in the individual's learning history.

Maths has more exceptions to the rules than many people think. These
inconsistencies can especially handicap the dyslexic learner in that they
challenge the security of learning

For example in fractions, which are viewed as problematic by many learners,
we write $\frac{1}{5} + \frac{3}{5} = \frac{4}{5}$ and only the 'top' numbers are added. Yet in $\frac{3}{5} \times \frac{2}{5}$
both 'top' and 'bottom' numbers are multiplied.

With angles we measure anti-clockwise. With time we work clockwise.
With time we count on from the hour until half past, then we count down to the
next hour. So 'Four thirty' is 4:30, but 'Ten to seven' has neither a ten nor a
seven (6:50).

We 'carry' in addition sums and 'decompose' in subtraction sums, yet both are
trading actions, trading ten ones for one ten and trading one ten for ten ones.
We expect absolute accuracy in answers and then expect students to abandon
this strict regime and estimate.

We write numbers as 1, 2, 3, 4, 5, 6 which are getting bigger from left to right,
then write 12, 13, 14 where the bigger digit is to the left, even though it has
been smaller in the earlier learning experience.
In whole numbers the sequence of words from left to right of the decimal point is units, tens, hundreds, thousands. For decimals, the sequence from right to left of the decimal point is tenths, hundredths, thousandths.

In early experiences of subtraction, the small is subtracted from the big. This does not remain a reliable concept.

Multiplying may be taught as a process that makes things bigger, yet multiplying by 1/2 makes things smaller. (Similar confusing things happen with division).

So just when the learner thinks everything is under control....... 

Factors affecting learning

There are a number of factors which can affect the learning of maths. (Chinn and Ashcroft, 1998, Mahon et al 1999) These may occur in isolation or may interact to create a potential learning difficulty. Each person is an individual and will have an individual combination of different levels of severity of these factors. With appropriate help most of the difficulties associated with these factors can be alleviated or circumvented.

Visual - This may be a problem with distinguishing between symbols, such as + and x or + and ÷ or the layout of work on the page of a book can cause difficulties, for example if the space between examples are too close.

Direction - At the beginning of this section I highlighted the tendency for learners to look for consistency (and thus patterns, rules and connections) in what they learn. There are more inconsistencies in direction in maths than many people realise, for example the teen numbers, thirteen, fourteen, fifteen (13, 14, 15) and so on are inconsistent with other two digit numbers such as thirty six, forty six, fifty six (36, 46, 56, where the digits are written in the same order as the words). Any inconsistency can affect an insecure learner and many maths learners are insecure.

We do subtraction and addition sums right to left

123
+456
<-----

but do division left to right

8

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Organising Work on Paper - The setting out of a sum such as

\[
\begin{array}{c}
123 \\
+456 \\
579
\end{array}
\]

makes organisational demands. If the sum is not set out properly then errors are likely to happen.

**Short Term Memory** - Most dyslexics have poorer short term memories than their non-dyslexic peers. The consequences of this are that they may lose track in the middle of doing a multistep mental arithmetic problem or fail to absorb a sequence of instructions. For example, in adding 234 + 93 mentally, the learner may attempt to add mentally using a written method, so starting with the units, there is 4 + 3 = 7, then the tens, 3 + 9 = 12, carry on the 1 to end as 2 + 1 = 3, then reverse these numbers (7, 2, 3) to give 327.

**Long Term Memory** - There seem to be gaps in a dyslexics long term memory. For example it is unlikely that dyslexics can retain by rote learning basic number facts especially times table facts (Pritchard et al, 1989 and Chinn 1994) or it may be that they cannot remember the sequence of steps needed to complete a long division sum, especially if the process has no meaning or logic to support memory. Krutetskii (1976) talks of a 'mathematics memory' (which suggests that this factor, like many of the others, is not exclusive to dyslexics).

**Language** - Maths has its own vocabulary, for example algebra is exclusively a maths word. But maths also shares words with other activities, so 'take away' relates to food as well as subtraction. In numeracy there is a range of words used to imply the same maths operation, so we could use add, more, and, plus to mean add. But we can also use more to mean subtract as in 'Mark has three more pens than James. Mark has ten pens, how many pens does James have?' Maths word questions often use a peculiarly mathematical form of the English language. It is not enough just to be able to read the words, you have to know the meaning that is pertinent to maths. Thus it is not surprising that people list word problems as one of the most difficult areas of maths, even if they are not dyslexic.

A child may be doing well in maths until he meets word problems. A similar situation may occur when children are required to document their work.

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**Speed of Working** - One of the strange things about maths is the requirement to do it quickly. This requirement tends to increase anxiety and thus decrease accuracy. Dyslexics tend to be slower in maths with many factors contributing to this, such as slow recall of basic facts. In a classroom study (Chinn 1995) I found that dyslexic pupils took about 50% more time to complete a set of arithmetic questions than their non-dyslexic peers, but there was a hidden factor operating which may make this an underestimate.

This is a good example of an area where simple awareness and adjustment by the teacher can reduce pressure and help learning.

**Sequencing** - Maths requires sequencing abilities. These might be the ability to count on, or back, in eights or sixes or they might be the complex sequence of the steps in the long division procedure. This difficulty can link with language problems in questions such as 'Take 17 away from 36' which presents the numbers in the reverse sequence for computation to '26 minus 16' which presents the numbers in the order in which the subtraction is computed.

The sequence of negative numbers can be confusing as in negative co-ordinates (-3, -6). This example can also illustrate the disproportionate effect of what might be considered to be a minor increase in difficulty. Going from coordinates which are positive to coordinates which are negative can create a surprisingly high anxiety level or comprehension problem for some learners.

**Anxiety** - Maths can create anxiety in most learners (and some teachers). For example, fractions often do this. It is a characteristic of dyslexics (and probably other learners, too) that if they pre-judge a question as too hard to solve then they avoid failure by not begin to try to solve the question. This is the hidden factor referred to above. The dyslexic pupils showed a much higher proportion of 'no attempts' in the arithmetic test, that is they decided they were unable to get the question correct, so they avoided failure by not attempting the question. Learning requires the learner to take a risk and get involved in the learning process. Fear of failure can stop the learner taking the risk necessary for learning. Here it is the ethos of the classroom that can help or hinder.

Anxiety can also have a detrimental effect on working memory (Ashcraft, 1998)

**Conceptual Ability** - There seems to be just an ordinary spread of conceptual ability in maths for dyslexics and they can achieve at or above this potential with appropriate teaching and motivation. Unfortunately the speed of working and the other factors covered here can mean that they do not get the experience and practice necessary to develop skills and concepts. Another important factor is the problem that an early misunderstanding and initial incorrect practise of an
idea may create a dominant memory. It is important to make sure that each new idea is practised correctly.

The relative importance of factors which create difficulties in maths for pupils in Ireland, The Netherlands and England.

Reading accuracy, comprehension, knowledge of x and divide facts, add and subtract facts, maths age lag, sequential ability, transposals, number reversals, organisation of work on paper, speed of working.

The diagram shows that the same profile of difficulties in all three countries.

**Thinking Style** - A number of researchers over the years have identified two thinking styles. Although they have a good selection of labels, basically one style is formulaic and sequential and the other is intuitive and holistic. In work done with American colleagues, we call the two styles 'inchworm' and 'grasshopper'. Most learners will lie somewhere on a continuum between the two extremes of style and indeed this blend is likely to be the most successful style as success in maths tends to require flexibility in thinking. Our most recent research (Chinn et al 2001) makes some interesting observations on the interaction of curriculum and thinking style.

Knowing a learner's thinking style can be one of the most significant pieces in the jigsaw of understanding the learner. Each style requires sub-skills, but this does not infer that the learner elects to use the style more appropriate to his own sub-skills.
Both the learner and the teacher need to be aware of these potential barriers to progress so that they can be pre-empted and/or addressed.

**The Structure of Numeracy**

The basic rules of algebra are experienced very early in learning numeracy. For example knowing that $7 \times 8$ is equal to $8 \times 7$ introduces $ab = ba$. Knowing that $7 \times 6$ is $5 \times 6$ plus $2 \times 6$ introduces $a(b + c) = ab + ac$.

Knowing that $7 \times 6$ can be broken down into $5 \times 6$ plus $2 \times 6$ leads to $13 \times 6$ as $10 \times 6$ plus $3 \times 6$ which leads to $23 \times 13$ as $23 \times 10$ plus $23 \times 3$ which leads to working out $(x + a)(y + b)$.

If the basics are not secure then any development of these basics will not be secure. Learners need to associate new information with known facts. For dyslexics working from what they know to what they do not know is crucial to success. The teacher needs to know what the learner brings to the lesson. For example, if dyslexics only know $1x$, $2x$, $5x$ and $10x$ facts, the teacher could use these numbers in early examples of new topics so that they can focus on the topic rather than struggle with unknown number facts.
The charts show that cognitive style for non-dyslexics is affected by curriculum. At the time of this study, the Irish maths curriculum was very restrictive in the methods taught to solve problems. The Dutch 'Realistic Maths' programme encourages flexibility in problem solving methods. Our hypothesis for explaining the apparent dominance of inchworm (formulaic) style in the inchworm sample was that they will not take the risk of using intuitive methods. They will use the formula even though it is not necessarily their best option because it is, to them, the 'safe' option. Children will often avoid risk taking in maths, particularly those with learning, difficulties. (Chinn et al)

**Learning maths**

In a short article it would be an impossible task to explain how to teach all the varied topics which make up mathematics (which in itself can explain why failure in maths may not be total). However, there are some basic principles which should help.

Learners learn maths in different ways. Some cope well with abstract symbols. Others require a visual model, which may be as simple as a number line or a more sophisticated model such as base ten blocks, which can then evolve into an area model for many basic areas of maths, from long multiplication to multiplying fractions to quadratic equations. Some learners and teachers perceive such materials as 'babyish' or not age appropriate. This should not be so. Base ten materials are a sophisticated learning/teaching tool if used properly. There is a tremendous opportunity to use the multisensory capacity of the computer to present maths topics visually, orally, symbolically simultaneously. Dyslexics often need the support of images and inter-relationships to strengthen their memories. A simple example of this is relating unknown facts to known facts such as $8 + 7$ which can be derived from $8 + 8$ less 1 or $4 \times 7$ which can be derived from $2 \times 7 \times 2$.

Some learners are highly intuitive in the way they learn and do maths (grasshoppers). For example, if asked to find three consecutive numbers which add up to 33 they will divide 33 by 3 and arrive at 11, then quickly complete the trio with 10 and 12. Other learners are formulaic and step by step in their style (inchworms). They would approach the 33 question algebraically, possibly by deriving the equation $x(x + 1)(x + 2) = 33$, which solves to $x = 10$. Learners need to draw on both these learning styles. A over-dependence on one style is likely to be a disadvantage. Dyslexics will often opt for the style which they perceive as safest, the formulaic style, even though it may not be the best way for them to solve the problem.
All learners, but especially dyslexics, will do better in maths if they understand the value and inter-relationships numbers and the procedures used to manipulate numbers. Relying on pure recall of facts and procedures is unsafe for those with memory deficits. A classic example is the decomposition procedure used in the UK for subtraction. A recent study in the USA identified this as a common and frequent error for dyslexics. If this procedure has to be performed purely as a rote exercise it is likely to fail. The understanding requires many previous concepts and skills to be secure. These include clear and organised presentation of the sum on paper, a good understanding of place value and an ability to 'see' numbers in other ways (for example to see 72 as 60 and 12).

This means that addressing a problem in maths may well require the learner to go back to re-learn early concepts and skills. It will mean inter-relating facts and procedures, working from what the learners knows to what she or he can know, working with what the learner brings to the situation, skills, learning style, attitude and anxiety, limited access to number facts, memory and so on.

And good teaching is continuously diagnostic.

Calculators

The appropriate use of calculators can be very helpful. As with all equipment there can be disadvantages and cautions.

The calculator can be used to perform sums which would take a long time on paper, for example 522 ÷ 11.72 (a recent currency conversion I needed to do), but I do like to see this use combined with some capable estimations (I knew that 522 ÷ 11.72 was something near to 45 and certainly between 40 and 50). Calculators are also a source of information previously supplied by log tables and slide rules. They can also compute complex statistical data and present data graphically.

For dyslexics there needs to be some care over correct keys and correct order of keys, which again can be checked by pre-estimations. So if we ask for '5.3 divided into 607' we key in the numbers in reverse order 607 ÷ 5.3, looking for an answer just over 100.

Again if the keys are used correctly and in the correct order, the calculator can be used to illustrate or develop patterns. As ever, avoiding the pressure of artificial time limits can reduce the occurrence of incorrect entries.

The useful, and simple question "Is the answer going to be bigger or smaller?" often guides the learner to the correct procedure.
Software for maths

This, like so many aspects of ICT is an area where new material is being developed almost daily. So rather than just reviewing existing programmes I shall suggest some criteria to use when selecting software.

Ideally software should be able to offer the dyslexic learner an effective learning input. Voice output, graphics, symbols and text can all be combined to give a multisensory experience to the learner and, where appropriate, a diagnostic component can be incorporated as well. Although some programmes are near to this, most are not.

Existing programmes seem to fall into four groups

* Games which offer practice. The biggest problem with these is that the appearance and design can be somewhat age specific to the level of maths in a similar way that books with a reading level suitable for 'poor' readers are often far too young in content. Some have a built in progressive maths structure which enables the user to target the level of maths required. Sometimes the games can be frustrating in that they slow up the maths or take an eternity to complete and reach the 'goal'.

* Programmes that 'do' maths, for example plot graphs. These can be particularly helpful if presentation skills are not good and if speed of producing such work is slow. They can also be used to illustrate and demonstrate concepts. Often these are part of a package such as Excel or Word

* Some programmes are just books on screen making little use of the potential of the computer to do so much more than just show print. However, for a dyslexic learner these programmes may be easier to track through than a book.

* Software that teaches maths. These can vary from the very clear and responsive to the 'say it slower and louder' style of remediation.

Using ICT for practise

Computers are said to improve concentration and increase attention span. Software can be designed to be entertaining and visually stimulating and introduce maths tangentially. Software often provides rewards which can also increase time on task.

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Using ICT for independent working and learning

Software can allow the learner to work independently. Obviously the success of this depends on the design of the programme. For example, it is important that the learner can move easily around the programme. It is good if there is clear voice output and that the programme uses good images. Many dyslexics find screen design overdone. There seems to be a tendency among some designers to throw everything from their design collection onto the screen. Getting the balance right is difficult as learners are very individual. Also, a design feature which can be an appealing first experience can be very irritating if it cannot be by-passed on later attempts.

One of my key observations of dyslexic learners and indeed all learners is based on this individuality. Learning styles and thinking styles are not the same for all pupils. It is hard to design a text book to cater for different learning styles and often teaching does not address this issue. Again the computer has the potential to address this need. Information can be presented in both multisensory and cognitively sensitive ways. Software could be designed to give the learner an individualised pathway through the learning process., even if this were as simple as a choice of using or not using voice output or graphics.

Evaluation questions for software

* Does it offer what you want, practice, learning (remediation) or production?

* Is it just a book on screen?

* Is the design cluttered?

* Is there mathematical structure?

* Is it just 'drill and kill'?

* Does it irritate?

* Does it have voice output?

* How does it motivate, success and/or entertainment?

* Is it age specific in design?

* Does it address more than one way of learning?

* Is it good value for money?
* Can the learner use it independently?
* Does it have a record keeping system?
* Can the programme be individualised?
* Does it include assessment and/or diagnostic features?

Resources

What to do when you can’t learn the times tables (1997) Chinn. Available as a book or a CD-ROM from Egon Publishers, Baldock, UK


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