Mathematics, dyslexia, and accessibility

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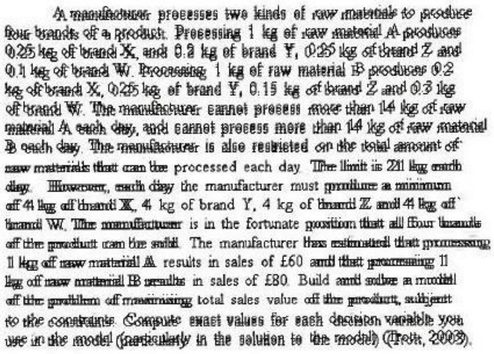
Context

This paper is based on my experiences in one-to-one mathematics support to students with additional needs, in particular dyslexia. It will build on a number of case studies, in order to explore the differences that students experience and the errors they are likely to make. The aim is to show how greater accessibility could help the dyslexic mathematician focus on developing their mathematics and demonstrate their capabilities. Three areas will be covered, namely: reading, writing and memory.

"Dyslexia is a specific learning difficulty…It is likely to be present at birth and to be lifelong in its effects. It is characterised by difficulties with phonological processing, rapid naming, working memory, processing speed and the automatic development of skills that may not match up to an individual's other cognitive abilities. It tends to be resistant to conventional teaching methods, but its effects can be mitigated by appropriately specific intervention…" (BDA, 2007)

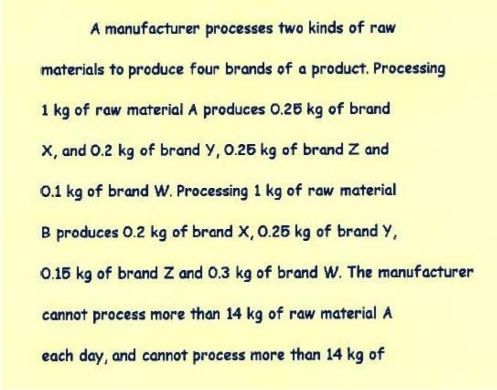
Barrier: Reading

The first area to consider is reading. The dyslexic student may have difficulty reading connecting text or have a slower reading speed. Frequently, dyslexic students are attracted to the study of mathematics because it is perceived as requiring a lower level of reading text. One very able mathematics student, Joe, with high non-verbal ability, arrived at university with a very low level of reading, which had persisted from his earliest years. He was unable to read simple text effectively. Handouts and instruction sheets given out in lecture or lab sessions were particularly difficult for this student. Support work focused on identifying and understanding key words, symbols and procedures used in a variety of mathematical contexts, such as the statement of the tasks, examination questions or lecture notes. These key words enable a clearer focus in order to prioritise responses. It was also important for his academic tutors to provide material in advance of lectures and in the more accessible sans serif fonts, such as Arial, Verdana, Comic Sans or Trebuchet. For contextual text surrounding mathematics, Verdana is arguably preferable as the symbolic elements are clearer. Documents should be well spaced with clear headings. A coloured background helps to reduce the glare that many dyslexic students encounter through visual stress: "the inability to see comfortably without distortion and discomfort" (Wilkins, 1995). Colour preferences can be individual and each student will respond to a different combination of coloured background, coloured text, spacing and fonts. It is important, therefore, to make all notes and handouts available for students to download and format as they choose. Figure 1 shows one of the visual stress affects ("whirlpool") that some students may experience and figure 2 shows the text in a more suitable format. (Beacham and Szumko, 2005)



A manufacturer processes two kinds of raw materials to produce four brands of a product. Processing 1 kg of raw material A produces 0.25 kg of brand X, and 0.2 kg of brand Y, 0.25 kg of brand Z and 0.1 kg of brand W. Processing 1 kg of raw material B produces 0.2 kg of brand X, 0.25 kg of brand Y, 0.15 kg of brand Z and 0.3 kg of brand W. The manufacturer cannot process more than 14 kg of raw material A each day, and cannot process more than 14 kg of raw material B each day. The manufacturer is also restricted on the total amount of raw materials that can be processed each day. The limit is 21 kg each day. However, each day the manufacturer must produce a minimum of 4 kg of brand X, 4 kg of brand Y, 4 kg of brand Z and 4 kg of brand W. The manufacturer is in the fortunate position that all four brands of the product can be sold. The manufacturer has estimated that processing 1 kg of raw material A results in sales of £60 and that processing 1 kg of raw material B results in sales of £80. Build and solve a model of the problem of maximising total sales value of the product, subject to the constraints. Compute exact values for each decision variable you use in the model (particularly in the solution to the model) (Trott, 2003).

Figure 1 “whirlpool” affect



A manufacturer processes two kinds of raw materials to produce four brands of a product. Processing 1 kg of raw material A produces 0.25 kg of brand X, and 0.2 kg of brand Y, 0.25 kg of brand Z and 0.1 kg of brand W. Processing 1 kg of raw material B produces 0.2 kg of brand X, 0.25 kg of brand Y, 0.15 kg of brand Z and 0.3 kg of brand W. The manufacturer cannot process more than 14 kg of raw material A each day, and cannot process more than 14 kg of

Figure 2: a clearer representation of the text

Another dyslexic mathematics student, Kate, had excellent numerical skill and a vivid visual memory; however, these strengths were offset by her weaker reading speed and accuracy, which only scored in the first percentile of the population. She also frequently lost her place when reading and had poor working memory. Support for Kate focused on the dissection and simplification of the more worded problems into a more manageable form. This included the use of bullet points to split text into smaller chunks, highlighting key information in two colours that distinguished the given information from the required instruction, e.g. to obtain a differential equation. It should be noted, at this point, that Kate had no difficulty at all with a page of mathematics almost devoid of connecting text, such as a solution to a differential equation. Another particular issue for Kate was the use of mathematics course text books. Henderson (1998) notes that in mathematical texts, tables, graphs and diagrams often intersperse text and each of these can have its own labels and subtext. Examples are often worked out in the middle of information or text on how to complete the calculation, so that if you have trouble reading the connecting text you may ignore both the text and the example. This irregularity is particularly an issue for dyslexic students. Kate found this to be the case for one book in particular that formed a core text. The Interspersion of text and mathematics was high and many of the figures were out of order so that, for example, half way down a page it referred to a figure that was on the following page, or even a couple of pages further on. Kate would turn to the required figure, study it, but rarely returned to the point of the text. This meant that the sense was lost and the work without meaning.

Recommendations:

An essential requirement has to be the accessibility of text to students with dyslexia. Whenever possible the use of text books such as above should be avoided. Notes and worksheets should be made available beforehand and sans serif fonts used at all times. It is also useful for dyslexic students who find it difficult to read and interpret the feedback given on assignments, to have an MP3 recording of this feedback.

Barrier: Writing

A second area that sometimes poses issues for the dyslexic is that of writing. Andrew was a physics student who excelled in non-verbal elements, had good number skills and sound reading comprehension. He was very articulate and a good physics student. However, he struggled to process at speed and had a poor working memory. His writing speed was assessed as being in the 5^{th} percentile for the population. Andrew was holistic in his approach to tasks, working in a non-sequential way that arose from his intuitive feel for a situation. He was, above all, insightful. However, invariably this led to non-standard solutions and poor documentation of his method. His dyslexia also meant that he was inaccurate and made frequent errors. One example occurred during an exercise involving a series of row operations on a 4 by 4 matrix. His poor written presentation meant that the rows and columns were far from aligned so that the entries became confused and, having started with a 4 by 4, ended with a non-aligned 4 by 3. The use of centimetre squared paper was helpful in this instance. A second example occurred when Andrew was undertaking integration by parts of *cosh h cos h* with respect to h. The similarity of the two functions when written down caused errors in his writing and presentation of the solution. However, he was very clear about the nature of the problem and its solution. Andrew miscopied *cos h* as *cosh h* as well as the converse. Throughout, Andrew's written submissions did not have a logical order, flow or cohesion and there were frequent copying errors that occurred when transferring between media, pages or lines. Frustratingly, Andrew had an insight into the problems that enabled him to "see" the potential for solution.

Recommendations:

Accessibility for dyslexic students should, therefore, include the willingness to accept less well documented solutions or facilitating the students to talk through their ideas and solutions. There should also be a willingness to accept sketches that are poorly defined (in the case of a dyspraxic student) and give a choice of diagram or description. It is frequently considered inappropriate to comment on spelling in essays and written work that comes from a dyslexic student; this would appear to be equivalent to the copying errors in mathematics. Fundamentally, it is about addressing the student's understanding of the mathematics.

Barrier: Memory

The third and final area for consideration in this paper is that of memory. Andrew had a poor working memory. It was important for him to draw on his visualisation skills in order to see situations. Indeed, Benoit Mandelbrot, the famous mathematician, had similar strengths: "(Mandelbrot) was not a good student; it was said that he never learned the alphabet (he could never use a telephone directory, for example), nor his multiplication tables past five. Despite his poor performance at school, he found that he had a quite extraordinary ability to "visualise" mathematical questions and solve problems with leaps of geometric intuition rather than the "proper" established techniques of strict logical analysis. After the war he passed the entrance exams for the École Polytechnique, achieving the highest grade in Algebra by "translating the questions mentally into pictures" (The Telegraph, 2010).

Notation also contributes to the load on memory as students have to remember a wide range of standard notations throughout their studies. Michael Faraday (1851) wrote: “Mathematical formulae, more than anything else, require quickness and surety in receiving and retaining the true value of the symbols, and when one has to look back at every moment to the beginning of a paper, to see what H or A or B mean, there is no making way. Still, though I cannot hold the whole train of reasoning in my mind at once, I am able fully to appreciate the value of the results...”

Issues of memory not only encompass remembering the symbolic notation needed, but also linking symbol, word and process. For example, in integration the integration sign, the word “integration” and the process itself have to all be linked together. Students also need to frequently hold all aspects of a problem and various partial solutions in mind. An example of this is a partial differentiation problem. This type of question is most usually answered in a linear format, one partial derivative following another, and bringing these together later. For a dyslexic student, some of the earlier partial derivatives are forgotten and overlooked so that the final solution becomes intangible. By using a branching diagram, it is possible to create a situation whereby several partial derivatives can be kept at the same horizontal eye level. This eye-level is also an issue in scrolling because screen-sized information can be referred to, but if scrolling is necessary, then information from the top of the page will be easily forgotten as the scrolling moves down the page. See figure 3

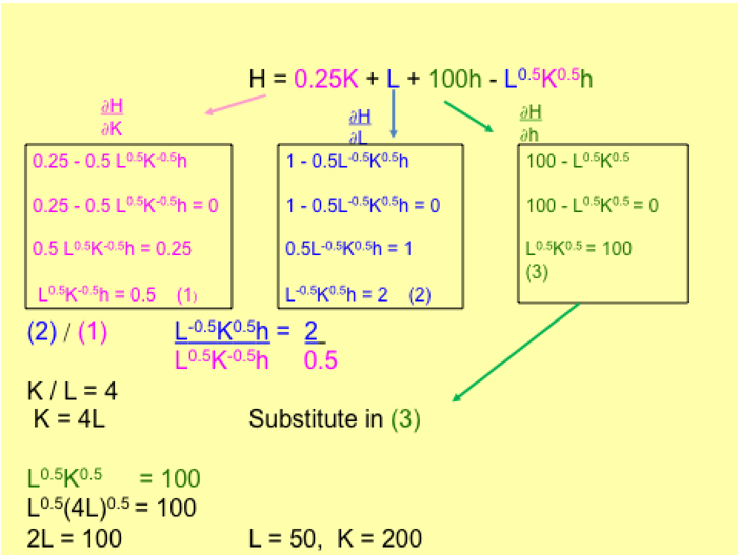


Figure 3: a “tree diagram” to show three partial derivatives horizontally

“Many students have significant difficulties thinking and reasoning about mathematical concepts” (Alcock et al. 2002). Often this follows from a definition or theorem. These definitions and theorems feature in many examination papers, often requiring students to state a particular definition or theorem, before going on to reason a proof. When statements of definitions or theorems (without proof) are assessed, it is a test of rote recall. One mathematics module contained 16 definitions and 42 theorems and the end of module examination devoted 24% of the marks to the recall of definitions and theorems, excluding the proof. While it is accepted that certain definitions and theorems are of prime importance, their rote learning appears to place at a disadvantage those students who find such learning difficult, but who fully comprehend the mathematics and who can develop the proof and utilise it appropriately.

Recommendations:

Thus, such questions should, whenever possible, be avoided so that examinations do not rely on memory, and all necessary theorems and formulae are provided, together with a list of terms and notation used. It is also helpful to have consistent notation across modules and staff within a department. If there is a reduced load on the working memory, students can focus on understanding the mathematics.

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