Abstract

The aim of this article is to reflect on and promote discussion of accessibility of teaching university Mathematics. I will describe how certain features of ‘traditional’ Mathematics teaching can unintentionally inhibit the participation of some students with disabilities. I will suggest ways to remove these barriers, for example via adjustments of curriculum design, teaching delivery and the introduction of teaching technologies. I will then briefly discuss specific examples in my own work and finish by outlining current UK initiatives working towards heightening the accessibility of disabled students in the Mathematical Sciences.

The ‘Traditional’ Teaching Approach

The traditional style of teaching university Mathematics is to provide lectures coupled with example classes or tutorials. The lectures are usually delivered using a ‘chalk and talk’ approach, which in the past referred to just using a black board but now similarly refers to white boards as well as overhead projectors (OHPs). Also, given the visual/symbolic nature of the subject at University, the level of verbal explanation is usually much less than that provided in A-levels and Scottish Highers. As a result, students tend to rely on working through their copied notes from each lecture or tutorial, or any recommended texts, to provide any in-depth information on the subject.

The practice of using handouts, or supplementary material, has also been rather slow to take off in Mathematics and, up until very recently, notes were mostly handwritten and therefore of varying quality. The favoured electronic format for a Mathematician is LaTeX [1]. LaTeX is a typesetting program, based on the idea that authors should be able to focus on the content of what they are writing without being distracted by its visual presentation. Document preparation consists of using a text editor to edit a source file, which is then compiled using the LaTeX program to produce a Postscript or PDF version of the document. LaTeX offers the user most of the programmable desktop publishing features as, for example, Microsoft Word, but also contains all the essential features for embedding Mathematical symbols and formulae into text documents.

Potential Barriers Faced by Mathematics Students with Disabilities

I will now describe the barriers created by these ‘traditional’ teaching methods to students with disabilities in general. However, I will pay particular attention to the accessibility issues faced by students with dyslexia, visual impairment and Asperger’s...
syndrome (AS). I will start by highlighting the barriers created by the 'chalk and talk' style of lecturing.

A clear issue with teaching solely from the board (or OHP) is the lack of flexibility in information access. Excluding the rarely used electronic whiteboard, the black board contents cannot be scanned and then transferred to whatever electronic format the student finds most appropriate. Furthermore, the lecture format places the student in a passive learning position, rather than being an active learner, which again restricts the learning experience to that dictated by the delivery style of the lecturer. One of the most highly rated difficulties with mental and physical fatigue in concentration in lectures is with note taking. Many students with dyslexia and AS complain of being overloaded with information [2] and, consequently, have to rush their note-taking, which can sometimes lead to messy, indecipherable notes [3]. Also, students with dyslexia, who often complain about problems with short term memory [4], typically have problems maintaining the meaning of text when reading at speed and therefore listening and taking notes simultaneously can be difficult [2]. A lack of handwriting speed has also been highlighted as a problem by some students with dyslexia and AS [3]. A result of this is that the students will often leave the lecture with an incomplete set of notes [2]. Students may use a tape-recorder or a notetaker, but this then means that the student has to then work through the notes after the event, which is very different from experiencing an example worked through live. Bad or small board-writing, poor board organisation, or glare from an OHP or white board can exacerbate visual perception problems, especially when the board/screen is filled with large amounts of text [4]. Also, a lecturer may highlight parts of a presentation while they are talking by either pointing at it or underlining saying 'this bit is very important'. A student with a visual impairment would obviously be disadvantaged if they couldn't see which part they are referring to [4].

Mathematics is a symbolic language [5,6] but, unlike plain text, the mathematical meaning of the various terms depend not just on symbols but also on their relative positioning. Good quality written notes are, therefore, very important to the student [2,4]. Obtaining notes from lecturers is often not a simple matter for some students, however. Students often complain that they have to 'run around' after the lecturer to get notes or often the notes are provided too late to convert them to the desired format in time for the lecture or they are only made available during, or after, the lecture which means that the student has to constantly catch-up [2,4]. As highlighted above, notes are often handwritten, of varying quality, or the lecturer has only acetate (OHP) copies [4]. Unfortunately, electronic scans of these are usually poor quality, which visually impaired students either can't read directly or find difficult to read using a screen or portable magnifier [4].

Now, the favoured typesetting program for Mathematicians, LaTeX, can also cause some problems. LaTeX tends to create pdf formats that are unreadable by many screen readers. JAWS – a powerful screen reading program – is an exception. JAWS is compatible with version 5 of Adobe Acrobat and can therefore read some LaTeX produced pdf files [7]. Even so, the screen reader will only provide audio for the text, leaving the Mathematics, which will be treated as an image by the screen reader, unread. Accessing the Mathematics will require additional software (such as, for example, InftyProject [8], MathML or OpenMath [9]). Some students turn instead to the LaTeX source file, which is plain text and therefore compatible with the majority of screen readers. However, deciphering LaTeX syntax requires a considerable amount of expertise and this isn’t an approach employed by many students [7]. Another issue with LaTeX is the text size for the Mathematics fonts. Some students with visual impairments complain that they are unable to enlarge the Mathematics text to a level that can be read using a screen magnifier [4]. The \Huge command in LaTeX can enlarge the text to some extent, but the resulting enlarged equations then typically run off the page, making them unreadable. It is possible, however, to insert line breaks in the LaTeX source code so that the equations stay within the page margins, but again this requires a certain level of expertise and it is often difficult to see where breaks should be inserted [4].

Developing a Strategy for Enhancing Accessibility in Mathematics

Simple modifications of lecturing techniques can dramatically heighten the accessibility of students with disabilities. Examples include; facing the students as much as possible when speaking and explaining every visual aid orally in detail [5]; numbering pages and clearly setting out questions and examples [2]; breaking up the text with page breaks or bullet points for better clarity [4]; using sans serif fonts such as arial, which people with dyslexia report easier to read [2]; avoiding justifying text; using coloured overlays to reduce glare from black type on white paper; and, using coloured pens to highlight various aspects of a question, e.g. different colors for each integral calculation within a triple integration. Line readers, which highlight a single line (or lines), with the rest of the page content fading into the background, can also be used to enhance clarity [2].

It is reported that students with AS tend to thrive on material that they find interesting, otherwise students report that they find it hard to concentrate [3]. A perfect stimulating factor, and a useful memory aid, is to motivate the Mathematics in terms of practical problems, that way the student can place the material in the context of something that is more familiar [3]. Students with dyslexia are described as being visual thinkers and learn better from a visual source (e.g. diagrams, charts or graphs) [2]. It is important, therefore to provide sketches of functions, so
that the student then has an immediate visual image, and also provide a gallery of graphs which the student can then refer to as short-term memory aid [4]. Findings suggest that students with dyslexia and AS tend to get overloaded easily and fail to absorb all the information during a single lecture or tutorial [2,3]. This is simply remedied by using frequent recaps of the material so that the same ground is covered several times.

Learning materials should be offered in electronic versions that are accessible for all and made available at the earliest opportunity, i.e. provided in advance on disk, memory stick, or on a Visual Learning Environment (e.g. WebCT) [5], with clear instructions of how to find them. The general advantage is then that the student has a complete set of notes, which, firstly, overcomes the problems outlined above for students with dyslexia with note-taking and, secondly, removes the ambiguity that many students with AS experience in not knowing what to write down from the board [3]. Also, the advantage of electronic notes is that these can be transferred into various file formats [9] and alternative forms (speech, Braille etc). This flexibility, therefore, provides a level of independence for the student – giving them the freedom to organise their personal study time without them having to rely on someone else [5].

Microsoft Powerpoint and Word formats appear the most malleable. It is extremely easy to enlarge print, use different coloured backgrounds and the navigation of a document is straightforward using the ‘Styles’ setting. However, files that contain input from the Microsoft Equation Editor Input have been found to cause some difficulties – it is possible to enlarge the font size in the Equation Editor itself using the graphical user interface (GUI) provided, but some students with visual impairments report the GUI difficult to see [4]. Alternatively, the user can manually stretch the Equation in the Word/Powerpoint file, but this is time consuming and the equations can easily distort [4]. Also, it is not possible to convert the Equation Editor output into Braille, nor can most screen readers handle it [4]. At an additional cost, however, the user can purchase MathType (an improved Microsoft equation editor), which can convert the equations to a wide range of formats to suit (e.g. Tex, LaTeX, word and HTML) [9].

A key way to make the Mathematics accessible is to provide alternative textual descriptions, which can then be simply read by screen readers for speech or Braille output. Cooper [9], however, describes a number of problems associated with this approach. There is currently no automated system to create alternative text for Mathematics so it has to be handcrafted by the authoring lecturer. Unfortunately this then creates a certain degree of ambiguity and inconsistency. Simple mathematical expressions are relatively straightforward; for example: $y = x^2 - 2$ has an alternative text ‘$y$ equals $x$ squared minus $2$’. With more complex mathematics the question is how do you break down the expression into parts that would avoid any ambiguity. For example, the expression: $(-1)^k x^{2k+1}$ could have an alternative text ‘minus $1$ to the power of $k$ times $x$ to the power $2k$ plus $1$’. However, this explanation can equally describe the incorrect expression $(-1)^k x^{2k} + 1$.

Cooper [9] suggests that the best approach is to first give the student an overview of the expression, followed by more detail – a process referred to as ‘chunking’.

**Observations from my own work**

Long sections of text seem to be the cause of problems for many students with AS and dyslexia. Students with AS report that they can focus better if the material is broken down, otherwise they find that they can get lost half way through, lose their place or fail to retain the required information [3]. Similarly for students with dyslexia report problems when reading Mathematics when it’s embedded in large amounts of text [2]. Multistage problems in Mathematics can produce a similar effect, with the end result typically being that the student only focuses on one part and fails to answer the question as a whole [4]. Mindmaps (also called tree diagrams) have been shown to help. Trott describes an example of where a student with dyslexia had difficulty with partial differentiation. She describes [2] how the student got lost and often omitted derivatives. They tried a Mindmap and this helped the student identify the various aspects of the problem as well as ways in which they interplay. This imposed an organization to the students work which was previously lacking. Mindmapping allows the user to view information in a way that is selective and make links between the information to give the bigger picture. Mindmaps consist of a series of branches which can contain a specific part of the methodology. Branches can collapse at a glance to hide information so that the user can focus on a particular part and view one branch at a time, without having to sift through large amounts of text.

Numerous lengthy, multistage problems and large sections of text is a current feature of the Mathematics courses that I teach and, for reasons outlined above, these may pose as unintentional barriers to some students with disabilities. Mindmapping may be a way of improving accessibility and incorporating a degree of flexibility that will likely benefit all students. The development of this strategy for my own teaching is work in progress. However, Figure 1 illustrates how a mindmap diagram can help organise an extended piece of mathematics.

The work described in Figure 1 is a summary of the eigenvalue/eigenfunction method for solving two-
Summary: complex eigenvalues

Case 1: \( A \) is a 2 by 2 matrix:

Step 1: Find eigenvalue \( \lambda = \alpha + i\beta \) and its complex conjugate \( \overline{\lambda} \).

Step 2: Find the corresponding eigenvector \( \mathbf{v} \), for \( \lambda \): i.e. solve \((A - \lambda I)\mathbf{v} = 0\) to find \( \mathbf{v} = (\xi_1, \xi_2) \).

Step 3: Find the \( x^{(1)}(t) \) solution by Euler formula:

\[
x^{(1)}(t) = \begin{bmatrix} \xi_1 \\ \xi_2 \end{bmatrix} e^{\lambda t} (\cos(\beta t) + i \sin(\beta t)).
\]

Step 4: The ‘fundamental set’ is then:

\[
u(t) = \text{Re} x^{(1)}(t), \quad \tau(t) = \text{Im} x^{(1)}(t).
\]

Step 5: The ‘general solution’ is:

\[
x(t) = c_1 u(t) + c_2 \tau(t).
\]

Fig 1a – A summary of the eigenvalue/eigenfunction method for solving two-dimensional linear systems with complex eigenvalues.

Fig 1b – A mindmap of the same procedure.

dimensional linear systems with complex eigenvalues. Even the summary of this process is rather lengthy (Fig 1a, top panel). The mindmap equivalent (Fig 1b, bottom panel) provides a clear structure without the distractions of the text, encouraging the student to focus on the key steps before sinking into any detail. The branches of the mindmap also work well as ‘memory hooks’ and thus particularly important for students with poor short-term memory.

One possible way to construct these mindmaps is to use the software package MindGenius. MindGenius combines technology and mindmapping. It is flexible, in that any number of colors, text fonts and sizes can be used, and it has the ability to fit into any environment, i.e. exported directly into any number of formats e.g. Word, Powerpoint, PDF, HTML without any additional re-typing. MindGenius can be used effectively for planning, organising notes and studying or remembering information. It fits nicely with the needs of some students with dyslexia, who report to prefer to learn from a visual source [2], as well as students with AS, who may find it difficult to structure their notes for revision purposes [3]. Additionally, it is possible to attach sound (MP3) files to branches of the map, which may be of great benefit for, for example, a person with dyslexia or a visual impairment to have lecture notes in an aural content.

Current initiatives

UK wide initiatives include the Technology for Disabilities Information Service (TechDis) [10], which works closely with various disability action groups to provide resource materials on assistive technology for teaching in higher education. The TechDis service is provided by the Joint Information Systems Community (JISC) which is co-located in York with the Learning Teaching and Support Network (LTSN). The Dyscalculia and Dyslexia Interest Group (DDIG) [11] was established by Clare Trott (Mathematics, Loughborough University) as a local interest group. Since then DDIG has grown rapidly and there has been a series of events such as lectures and workshops, promoting examples of good practice and raising awareness of the mathematical needs of dyslexic and dyscalculic students. More generally, AccessMSOR is a Working Group established to investigate the needs of disabled students studying Mathematics, Statistics and Operational Research. Members of the group include students, staff as well as disability consultants. The group maintains a webpage of accessibility resources on the MSOR (Maths, Stats & OR) Network webpages [12,13] and meets periodically to bring together expertise in supporting disabled students in the MSOR subjects.

In addition, the Higher Education Academy fund various projects aimed at improving accessibility in higher education. One such project is that lead by Hughes, in collaboration with Pepper, McCall and Milne (all University of Hertfordshire). The project is engaged in producing an aspergers syndrome (AS) ‘best practice’ resource pack for physical science departments in the UK. It is envisaged that the resource pack will include: background information on the typical issues faced by AS students in the physical sciences; case studies of student experiences and teaching methods; and tailored ‘quick pocket sized guides’ that can be used to by staff to quickly reference relevant information [14].

References


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