In this paper we outline the current technology gap for students studying mathematical subjects who are not able to read standard print.

The amended Disability Discrimination Act (DDA) places a requirement on higher education establishments to make reasonable adjustments to ensure that disabled students are not placed at a substantial disadvantage. The legislation applies to all teaching and requires that universities should anticipate changes required and be proactive in making them. Disabled students may be in receipt of the Disabled Students’ Allowance (DSA) perhaps allowing the purchase of assistive technologies or paying for limited human assistance.

In the case of subjects with little or no symbolic content, there may be a variety of assistive technologies available enabling a student to access already familiar electronic formats and some printed text. For example, a department may only need to produce learning resources in an electronic format such as Microsoft Word. However, assistive technology that provides comparable access to mathematical learning resources is limited. This technology is often the outcome of current research and may not be widely available, sufficiently advanced for practical use or provided by a student’s DSA.

We provide examples illustrating the implications of the technology gap on adjustments made for individual students and note the challenge of providing proactive adjustments. Drawing a comparison with the level of access provided by assistive technology for students studying less symbolic subjects we clarify the nature of this technology gap and the direction of projects addressing the accessibility of mathematical resources.

1. Context

To access resources a student who cannot read standard print might require adjustments made by the higher education institution, for example, provision of resources in a suitable electronic format, together with assistive technology and human support.

The Disabled Students’ Allowance (DSA) [1] is a grant available to many UK students in higher education to meet extra course related costs faced because of a physical or sensory impairment, specific learning difficulty, mental health difficulty or long-term health condition. The DSA can help provide items of specialist equipment, including assistive technology, and non-medical human support.

Once the funding body (typically a Local Education Authority (LEA) or the Student Loan Company (SLC)) has confirmed eligibility, a student would participate in a Study Strategies Assessment (or needs assessment) to identify strategies they can use to participate fully in their course. The funding body receives a copy of the assessment
report, which they use to determine the level of support provided. In addition, the assessment report details advice regarding reasonable adjustments that the student may wish to seek from their higher education institution.

The (amended) Disability Discrimination Act (DDA) [2] obliges higher education institutions in the UK not to treat disabled students less favourably on the basis of disability and also to make reasonable adjustments to ensure that disabled students are not placed at a substantial disadvantage. As stated in the Code of Practice for Providers of Post-16 Education [3] “the duty to make reasonable adjustments is a cornerstone of the act”. Higher education institutions are required to make reasonable unanticipated adjustments for individual students but also to anticipate changes that may be required and be proactive in making them. This requirement, which is considered an evolving duty, applies to all teaching. The Code notes that reasonable adjustments may be required in addition to resources provided by the DSA and that provisions under the DSA might in turn make other adjustments reasonable.

A key example is one in which learning resources are requested in electronic formats for use with assistive technology and it might be reasonable for a department to make this provision. We consider such requests for mathematical resources.

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1.1 Background


Other authors consider technology regularly recommended for dyslexic students. Software allowing simultaneous highlighting and voicing to support reading and writing cannot read mathematics written in common formats [8] and mind mapping software does not allow input of degree level mathematics [9].

Research and development projects are attempting to address aspects of this challenge. Stanley [10] provides an overview of what is required for access in Braille/voice with some useful survey articles [11, 12] summarising research projects considering Braille/voice access to mathematics. There is also work on large print mathematics with voice and highlighting, for instance [13, 14].

2. University of Bath

The University of Bath has a strong science and engineering focus and many courses contain substantial quantities of mathematical material.

Bath has a central Learning Support Service, which acts as a disability advisory service to both students and staff. The service supports students in their application for DSA, in arranging support funded by the DSA and in seeking reasonable adjustments such as those suggested in their needs assessment. The service can also provide advice to departments on providing adjustments for individual students. Departments that need to make reasonable adjustments can bid for funding from the Departmental Adjustment Fund, a central fund put in place following the Special Educational Needs and Disability Act (SENDA) [15] self audit.

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2.1 Case study: Mathematics in Braille and voice

The Learning Support Service has provided support for a blind student studying courses in which the mathematical content increased in quantity and complexity over time. The student used a screenreader (JAWS) and refreshable Braille display to access most text; a Braille embosser, Braille translation software, Optical Character Recognition (OCR) software, a tactile diagram machine and a book scanner were also available. External Braille transcription services produced a minority of material. The student preferred an 8-dot Braille translation table to produce a form of grade-1 Braille they felt was particularly suited to the high volume of computer code and symbols encountered on their course. They had not learned any Braille mathematics code but
had previously read LaTeX source directly, which they chose to continue doing, requesting resources in LaTeX where available.

Many lecturers provided full or partial electronic notes to all students; the student also recorded lectures and had a note-taker available but found that many lecturers voiced mathematics ambiguously, with little structural information, and that following mathematics in this setting placed high demands on memory. This lent extra importance to handouts and note taking. While many resources were available electronically – even some textbooks – many were not available in LaTeX. The student was able to access most English text, sometimes by converting to ASCII form but reading or converting the mathematics was often not possible with the assistive technology available. JAWS, and alternative screenreaders, did not produce correct voicing or Braille for mathematics in Word, PowerPoint, (text or image) PDF or images in web pages and OCR packages that produced adequate output for English text were not able to produce output for mathematics (Fig 1.). The two dimensional nature, non-linear reading order and large symbol set of the mathematical language appeared to be the main cause of this.

Although the student considered various approaches to accessing mathematics, they chose to avoid technology that necessitated using a specialist language or representation of mathematics not already used by staff at Bath. The choice to continue reading LaTeX source in refreshable Braille and voice allowed some resources to be immediately accessible (without transcription and attendant proof reading issues) and supported easy communication with sighted colleagues. However, LaTeX has downsides: the visual presentation commands reduce the readability of the resources and, as mathematics becomes more complex, lengthy expressions can be difficult to navigate and manipulate due to the one-dimensional nature of the representation.

The student worked with Learning Support to source human support (funded by the DSA and the Departmental Adjustment Fund) in the form of mathematically fluent support workers with a technical skill-set. The student led a project to write software to clean up LaTeX sources received, removing presentation commands and substituting notations to form a “human readable” LaTeX; in addition, support workers were able to produce notes directly in this format. Support workers were available as readers, to provide short-term or immediate access to resources, reading which exposed equation structure (to support navigation through equations written in LaTeX) and to support the use of inaccessible or new software. They also provided semi-automatic transcription of resources to “human readable” LaTeX using OCR to extract English text and typing up the mathematics: a time consuming job.

The student and support workers tracked the progress of various research projects, including those collected in [16], looking for software to support the method of accessing mathematics chosen by the student. Some early partial successes came from InftyReader [17], which can now produce a reasonable representation of some scanned mathematics. This can be edited as required and output in LaTeX (Fig 1), MathML or other formats. We are currently trialling this software: the output, like all OCR output, can contain errors. While these have a limited effect on the meaning of English text, errors can radically alter meaning in mathematical text – hence mathematically fluent support workers continue to correct the output. ChattyInfty [18], the InftyProject editor with voice and Braille access is also being trialled. JAWS with MathPlayer [19] can voice output of equations produced in MathML (we used a variety of translators, all produced output which required proof reading) but does not provide appropriate Braille and the resource is essentially passive, not allowing navigation or manipulation. Other software we encountered either did not produce voice and appropriate Braille or required a non-standard representation of mathematics.

\[
\frac{b^2-4a}{p} = -1.
\]

Fig 1 – Extraction of mathematics from PDF. Results obtained with standard OCR package (top), cut and paste/JAWS (middle) and InftyReader OCR package.

2.2 Case study: Mathematics in large print

The Learning Support Service has supported a small group of students studying courses containing substantial quantities of mathematics each of whom required resources in an alternative print format. The students used a wide variety of DSA funded approaches to access lectures and lecture material including magnification, recording devices and note taking. Preferred reading formats included A4 paper, single-sided, a clear font such as Arial/Helvetica (for English text), changes to other fonts and styles, bold print, coloured text and/or paper, additional white space, enlarged diagrams, 1.5 or double spacing and a font size in the range 14pt – 26pt.

In the relevant departments, handwritten presentation of mathematics was common and where electronic notes existed they were either produced in TeX, LaTeX or by scanning in handwritten material. The high volume of mathematics in lectures was particularly hard to follow and for students without note-takers, the precise note taking required was challenging. Full lecture notes, which
could be printed and annotated, were therefore required prior to lectures. In fact, students often communicated the sentiment that without such lecture notes there was no point in being present in the lecture. Bids to the departmental adjustment fund resulted in funding to help produce such notes.

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Producing the required formats was challenging even when electronic notes already existed and direct manipulation of the TeX/LaTeX was required. LaTeX style files are available [20] which allow a less restricted set of font sizes than is usually the case but other font and spacing changes required further work. The most difficult problem was that of re-flowing equations that would not fit across the page width: we are not aware of any mathematical representation standard that can break/restructure equations for re-flow of the text and this work had to be completed by hand (Fig 2). Consequently, we typeset notes specifically for the font and font size required – which limits reuse potential.

Finally, due to the time it can take to create print mathematics, lecturers often did not have full notes in LaTeX. Working from a mixture of LaTeX files, old handouts for which we did not have the source (OCR was not able to compensate for this) and the lecturer’s own notes and instructions we pieced together lecture notes.

Academic support workers with a background in mathematics and fluency in LaTeX re-typeset LaTeX and typed up mathematics from other formats. The aim, at which we did not always succeed, was to ensure that students had hard copy notes prior to lectures. Lecturers were supportive of our work but miscommunication and delays were unfortunately common due to the number of people involved and the short time scale over which we sometimes worked. This underlines the difficulties noted in [4] of providing lecture notes in alternative formats when this requires specialist processing.

Challenges remain regarding how to provide mathematical notes in alternative formats efficiently and proactively as part of the core delivery of the course – and these challenges seem specific to highly symbolic material. We require a file format that allows encoding of the content of mathematics so that presentation can be styled as required, including re-flow of equations. Moreover, to avoid the failures we experienced this format would ideally be the file format used by the lecturer. It would seem likely that MathML was relevant but as argued by Cooper [7] it is unclear that it meets all the necessary requirements.

Fig 2 – Example of re-flowing mathematics by hand. An original equation in 11pt is too wide for the page at 20pt, re-flowing even this fairly simple equation must be done by hand and requires an understanding of the structures involved.
2.3 Case study: Dyslexia and maths

The Learning Support Service found dyslexic students were regularly recommended a recording device to support note taking in lectures; software to support reading and writing and mind mapping software – neither of which could cope with degree level mathematical text. A common question from students studying subjects containing a high volume of mathematics was “What should I do with these?” Many students found it difficult to use recording devices to support note taking in mathematical lectures.

Following the example at Loughborough [21, 22], Bath has provided one-to-one study skills specific to mathematics for students with specific learning difficulties who study some mathematics or statistics as part of their course. Some students received copies of electronic notes prior to lectures, where such notes existed, including notes originally produced in large or alternative print, showing limited reuse of these materials.

We are currently trialling software including mind-mapping software SmartDraw [23], which, with MathType [24], allows flexible input of equations. MathType with Word allows production of web pages containing MathML, together with TextHelp (Read and Write Gold) and MathPlayer this should allow equations to be read aloud with highlighting.

3. The nature of the technology gap

Our experiences, coupled with the experience of other authors, of enabling access to courses containing large volumes of mathematics suggests that there is a significant technology gap despite active research and development in the area.

This gap was characterised at Bath by the difficulty of efficiently creating flexible mathematical text that would allow proactive adjustments; by the limits of current assistive technology; by the slow impact of research and development on both mainstream and assistive technology and by the difficulty of deploying current developments on the ground. It was common for staff to believe that mathematics in electronic formats was already accessible which can hinder the use of human support to allow access. Further, this belief implies a low impact by current research developments preventing the use of research technology to produce and access resources.

LaTeX is primarily a visual, typesetting language and cannot provide sufficient semantic information to allow the flexibility required or to allow assistive technology to work. Research areas such as access but also at those aimed at solving communication and knowledge management problems in the wider mathematical community show an increasing focus on newer mathematical representations such as MathML – which are not yet in widespread use.

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References


