WORKSHOP REPORT

Towards Improving the Accessibility of the Mathematical Sciences for Visually Impaired People

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Abstract

Digital accessibility, inclusion and diversity are increasingly becoming a priority in Higher Education (HE), however mathematical accessibility for visually impaired people remains an area in need of improvement. Gaps in accessibility for visually impaired students can deter them from pursuing Mathematical Sciences at HE level, put them at a disadvantage in traditional assessments and mask a student's mathematical ability. Administration, culture and curricula are among the highest-rated obstacles for visually impaired students studying maths implying that alternative pedagogical approaches and technology are needed to address barriers and educators need to understand the challenges faced by visually impaired students to provide appropriate support. The project undertaken at the University of Glasgow started with a consultation with a variety of institutions, professionals, academics and students. This was followed up with a series of discussion groups and culminated with a hybrid workshop. In this paper we will give an overview of the workshop, our findings and discuss the provision of a consistent support system across programmes which can be adapted around individual needs.

Keywords: Accessibility, Mathematical Sciences, support systems, visually impaired, inclusion and diversity.

1. Background

Studies have shown that gaps in accessibility for visually impaired students can deter them from pursuing mathematical sciences at higher education level (Bell and Silverman, 2019), put them at a disadvantage in traditional assessments and mask a student's mathematical ability (Kwon, 2016). Digital accessibility, inclusion and diversity are increasingly becoming a priority in Higher Education (Mannion, 2023). However, Mannion (2023) indicated that a lack of awareness and internal skills and experiences were the most significant barriers for staff to improve digital accessibility in Higher Education. Indeed, to improve accessibility educationally, educators first need to be able to produce learning material that is accessible, and the student needs to then be familiarised with the accessibility features of the material. Although this may be simple to say, creating just one document that meets the accessibility needs of one individual student is complex. Studies have indicated that administration, culture and curricula are among the highest-rated obstacles for visually impaired students studying mathematics, implying that pedagogical approaches are needed to address visual impairments and educators need to understand the challenges faced by visually impaired students in order to provide appropriate alternatives (Aljundi and Altakhayneh, 2020). Brzoza & Maćkowski (2014) point out that only small number of accessible resources containing mathematics are published, and even with the advancements in technology, we still view accessibility features as ‘alternative’ instead of the norm. At present, PDF documents remain the quintessential format for scientific publications, and therefore educators are familiar with producing documents in this way. Pierrès et al (2024) found that while academic journals have accessibility guidelines or requirements, the PDF documents they analysed were still generally inaccessible, predominantly due to the lack of tagging, and conclude that accessibility requirements must be a consideration from the start of preparing a document. Structural elements such as headings, page layout, and design (which includes alternative text for images) were found to be amongst the most useful features for visually impaired students in navigating both PDF and Word documents (Singleton & Neuber, 2020).

Mathematical accessibility for visually impaired people remains an area in need of improvement (Klingenberg et al., 2020). Like other educational institutions, the University of Glasgow offers visually impaired student resources like mentoring, assistive technology, exam papers in a preferred format with extra time, course materials in an accessible format, electronic note-takers for lectures, or help with proofreading. Diagrams or data visualisations can be challenging for assistive technology without providing alternative text, which may not always be appropriate in an assessment. LaTeX is a commonly used typesetting package within science disciplines for writing anything from lecture slides to publications. Thanks to open-source projects like MathJax (Cervone et al, 2023), mathematical notation output from LaTeX is now much more accessible, for instance, the ability to transform maths notation to a sentence to be read aloud by a screen reader. A recent addition to the Speech Rule Engine project is the ability to translate a sentence to Nemeth braille. Additionally, tactile data visualisations and diagrams are a difficult problem for Maths, Stats and indeed all Science and Engineering subjects.

1.1. Students living with a visual impairment

Within Scottish Higher Education (HE), the percentage of undergraduate students registered with a known disability increased from 15% in 2018/19 to 21% in 2022/23 (HESA, 2024). This equates to 41,175 undergraduate students with a known disability studying at a Scottish HE institution in 2022/23. Within the University of Glasgow, during the 21/22 academic session, around 14% of undergraduate students were registered with a disability, and from those registered with a disability, 1.4% were registered as ‘blind or a serious visual impairment’. Across the University, in 2023, 15% of all students (including postgraduate) and 10% of staff had a declared disability (University of Glasgow, 2023).

Within the School of Mathematics and Statistics, 0.3% of undergraduate students were registered blind or with a serious visual impairment (University of Glasgow, 2024). We note that more broadly, 13% of students within the School were registered with at least one disability with the most common disability being either a learning difficulty (e.g., dyslexia, dyspraxia or AD(H)D) or mental health condition. We refer to the HESA defined categories of disability and the numbers provided here are based on students who identify themselves as blind or have a severe visual impairment and register with Disability Services. We believe that the nature of mathematical sciences is inherently inaccessible, however pedagogically, changes can be made to minimise systemic barriers (Hayes & Proulx, 2024).

1.2. Aims

This project endeavoured to improve the accessibility of Mathematical Sciences for visually impaired people. In the paper, we will address the following:

1. Based on a sample of material containing mathematics and data visualisations, we wanted to understand the perceived accessibility of the document from identified interested

communities which included academic staff, educational and learning developers, support staff and students;
2. If we could produce a mathematical document that meets current legal accessibility requirements, what additional interventions would be needed?

To address question 2, the main minimal requirement is that we meet legal accessibility requirements, and we relied on WCAG2 Guidelines (Web Accessibility Initiative, 2023). More specifically:

- Perceivable - users should be able to accurately see and read content;
- Operable - content responsive and simple to navigate;
- Understandable - easy to use and navigate, contain language understandable to all;
- Robust - compatible with wide range of technology including assistive technology tools.

We also checked against current local University of Glasgow accessibility guidelines for writing content (University of Glasgow, 2023).

2. Project

2.1. Phase One: Consultation with participants (November-December 2023)

The project team established contact with organisations and institutions that were identified as most likely to reach visually impaired people interested in Mathematics and Statistics. Emails were sent to the identified mailing lists and individuals with a survey containing a short example of coursework containing text, mathematical notation and data visualisation(s) compiled using the existing accessibility tool at the University of Glasgow followed by a set of questions (Appendix 6.1). This tool enables text, mathematical notation and alternative text associated with images to be read aloud by a screen reader.

The example coursework, not shared here, based on one of the taught programmes at the School of Mathematics and Statistics, was reviewed to gather examples of plots and other mathematical content found not to be optimised for visually impaired people.

2.2 Phase Two: Consulting with participant during online discussion groups (January-March 2024)

Based on the feedback we received from Phase 1 of the project, our team compiled emerging themes and invited participants to online discussion groups. This allowed us to further understand the main considerations when producing an accessible document containing mathematical content for a student who is blind or has a severe visual impairment.

2.3. Phase Three: Hybrid workshop (20th June 2024)

The University of Glasgow hosted a workshop in June 2024 where we heard from a variety of working groups within maths accessibility. During the workshop, our team presented an updated version of the example coursework that was revised based on the feedback from Phase 2 (Appendix 6.2).

3. Results

The survey was written using Qualtrics (web-based software freely available to University of Glasgow students and staff) after obtaining ethical approval from the College of Science and Engineering ethics committee. In total we received 156 responses. 65% of respondents identified as academics, 25% as developers, 5% as students and 5% as student support.

Figure 1 provides the results from question 3 of the survey (see Appendix 6.1). We found that across all roles identified, around 1/3 of respondents rated the material as 'Good' or 'Average' and 2/3 of the respondents rated the material as 'Poor' or 'Terrible'.

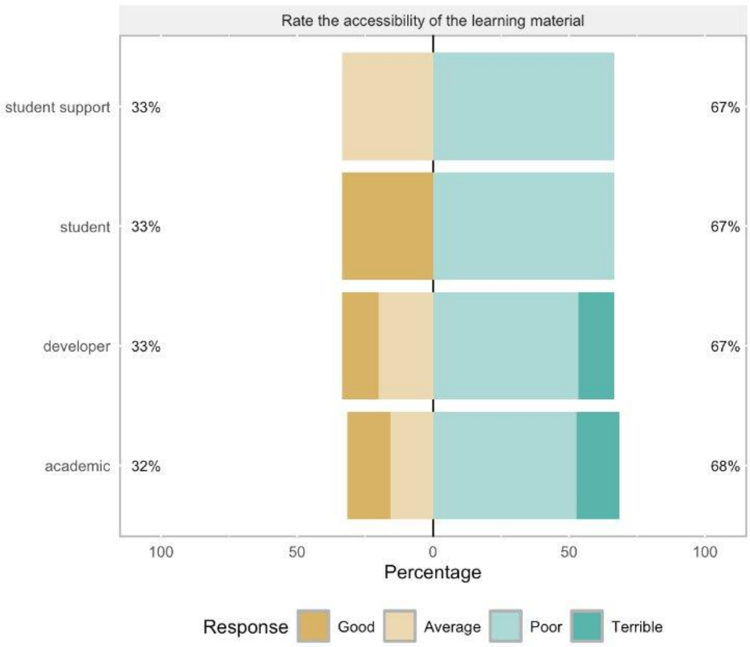

Figure 1. Results obtained from question 3 of the phase 1 survey "How would you rate the accessibility of the learning material". Respondents are categorised as student support, student, developer or academic (y-axis) and the percentage of respondents who selected 'Good', 'Average', 'Poor' or 'Terrible' are provided on the x-axis.

Based on the results obtained from the survey (phase 1) and follow-up discussion groups (phase 2), we categorised responses into the following themes.

Theme 1: Maths. Some respondents mentioned that they either believed MathJax was enabled, or it was not enabled. It was discussed that although educators would typically rely on a compatible screen reader to read mathematics aloud, this may not always coincide with how we communicate mathematics in terms of the language we use. Language in mathematics is a growing area in mathematics educational research (Planas & Pimm, 2024). If students are to experience mathematics verbally, via a screen reader for example, then educators should be considerate of the language used to ensure students can experience mathematics similarly to a sighted person.

Theme 2: Plots. The material provided contained several diagrams and plots (Appendix 6.2) and the issue of providing alternative text was discussed extensively. Depending on the nature of the diagram, figure or visualisation, and indeed what the student should obtain from this, was raised several times. For example, in the instance where the student needs to obtain information from a diagram in order to engage with the material or answer a question then we noted a variety of excellent guidelines from various sources (see for example Diagram Centre, 2015 or Cliffe, 2020 to name just a few). However, when we consider plots or figures, and the expectation of students to both create and interpret plots of data, then the nature of how this information is communicated should change. For example, we would want students to understand the structure of a plot (say a scatterplot of two variables), understand why this type of plot might be useful, know how to interpret the information provided in the plot and be able to create such a plot themselves, as described by Zong et al (2022), see Appendix 6.2 for an example. For R users, the BrailleR package (Godfrey et al, 2024) provides a set of useful tools for breaking down standard plots compatible with screen readers. The question of interpretability of plots for a visually impaired person raised questions about pedagogy and if all plots are necessary.

Theme 3: Legal Requirements. In some cases, participants commented that the materials provided did meet legal requirements whilst others specified that the material did not meet legal requirements. In this instance, we referred to WCAG2 Guidelines (Web Accessibility Initiative, 2023). It was the assumption that participants may have different expectations of what a legally accessible document might look like and we postulate if mathematics educators familiarised themselves with accessing documents in a variety of digital formats that were deemed accessible legally, then it would become second nature (we include ourselves in this bracket as we too navigate this space).

Theme 4: Screen readers. While most participants used screen readers to check if they believed the material could be easily read by their choice of screen readers, this was not true of all participants. In some instances, participants indicated that this can be an effective way to navigate the accessibility of a document.

The workshop had 13 invited presentations, 35 people participated in the workshop in-person and 40 people attended online. The group discussed ongoing projects aimed at improving accessibility in education, such as the use of AI tools, the development of open-source accessibility tools, and addressing the social and emotional needs of individuals with vision impairments in HE. The workshop highlighted the need for a focus on proactively connecting with accessibility groups and networks, user research, proactive approaches to student support, and the future of visual mathematics. The key main takeaways from the workshop were:

- Promoting Accessibility: raise awareness with colleagues to understand accessibility and create a minimal benchmark that can be adapted to meet individual needs;
- Collaborative research: continue to build networks with staff and students, share knowledge and develop new teaching approaches, and improve university administration and pedagogy;
- Software: develop accessible tools that can convert materials created using LaTeX or Markdown, aimed at easing lecturer involvement but with an understanding of document structure;
- Formatting: emphasise individualised support and automation, for example, introduce concepts using 'single line math';
- Visual tools: advocate for interactive tools and sonification to make mathematical education more inclusive and accessible;
- AI and tactile resources: use AI tools to generate accessible content and highlight the effectiveness of tactile teaching resources;
- Support: enhance support, addressing the social and emotional needs for visually impaired students in HE.

We noted that achieving 'accessibility' requires bespoke solutions for individuals and therefore there is neither a one-size-fits-all solution nor is meeting legal requirements alone sufficient to support some students as they learn. Figure 2 provides a visual representation of the journey to not only providing a Latex (or Markdown) document in an alternative format (that is alternative to PDF) but illustrates that this is not the end goal, nor should it be.

Figure 2: "make it accessible" - an infographic to illustrate the journey to create a document that meets legal requirements (what we have called the benchmark) but with the acknowledgement that this alone cannot meet the individual needs of the user.

4. Discussion

Higher Education Institutions need to ensure learning materials are accessible not only to support the University's aims of civic engagement and inclusivity, but they also have legal obligations under the Equality Act 2010 and Digital Accessibility Regulations 2018. The reasonable adjustments duty is an anticipatory and continuing one that is owed to disabled students, regardless of whether it is known whether a particular student is disabled.

Our interpretation of the legislation has two parts— one proactive and one reactive. Coursework handed to students should be converted to an accessible 'baseline' HTML document, which has configurable options to assist in the most common impairments such as dyslexia, colour-blindness, visual impairment, and screen reader support. The second reactive part is for students whose needs are not met with the baseline document, is having a trained alternative formats team ready to help. The long-term aim is to fold as much of the reactive work into the proactive HTML document as possible, enabling students to configure their coursework as needed without the delays associated with reactive help from the alternative formats team. The design and structure of documents should adhere to the minimal benchmark with a bespoke solution adopted to tailor learning materials to suit specific needs.

Through the growing interest and literature on mathematics accessibility, the outcomes of the workshop advocate for educators to think about the structure of all learning content from its inception such that it can meet the needs of the learners as opposed to the status quo, see for example the JISC Accessible Maths Working Group for a collection of resources from a variety of institutions (JISC Accessible Maths Working Group. 2024) and highlight Chirun for creating flexible material from a LaTeX or Markdown sources (Chirun, 2025).

The concluding remarks from the workshop were that meeting accessibility needs is an interdisciplinary problem that requires support for students on a variety of levels. Miesenberger et al (2023) involved expertise in disability, mathematical software and interactive proof assistants. Joy et al (2024) is a collaboration between a blind maths student, a tutor and a learning technologist. The student experience should be at the core of these endeavours and therefore understanding how students experience learning. While Dogucu et al (2023) discuss the experience of visually impaired students during lecture interactions, Croft (2020) describes bureaucratic, accommodation and social interactions to be significant barriers for visually impaired students at UK HE institutions, all of which affect all students before any interaction with learning material. Manitsa & Doikouv (2022) further emphasise the need for social support, both from staff for academic support or inclusion and from peers for social acceptance.

5. Acknowledgments

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6. Appendices

6.1. Survey questions

The survey contained the following questions

1. How would you best describe your current role?
2. Do you consider yourself blind or have a severe visual impairment uncorrected by glasses?

Based on the same learning material provided to you (participants were given a link to click)

3. How would you rate the accessibility of the learning material rated from Terrible to Excellent? (see Figure 1).
4. Please describe any positive features of the learning materials (open question).
5. Please describe any features you believe would cause barriers in learning for someone with a severe visual impairment (open question).

6.2. Sample material

Below you can find a link to the material presented to workshop participants.

Sample Material.

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