Accessibility of mathematics content

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Access to learning resources

To access learning resources a student might require

- Reasonable adjustments made by the institution

together with

- Assistive technology
- Human support

Lectures and note taking

Mathematics can be specially difficult in lectures...

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Provide electronic notes prior to lectures:

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Provide electronic notes prior to lectures:

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In a format which can be made accessible!

> *I thought a PDF would be accessible since it is an electronic format...*

Reading and doing mathematics

Short term: a *mathematically fluent* reader who can voice mathematics without ambiguity

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For independent study we might want to produce:

- Flexible visual electronic format
- Audio with or without synchronised highlighting
- Braille

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Does MSOR software work with assistive technology? What about the technicalities of *doing* mathematics without pen and paper?

Large print mathematics

Large print doesn't just mean large...

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- For mathematics?

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Large print doesn't just mean large...

- RNIB clear print guidelines
- For mathematics?
- Using LaTeX or Word:
  1. Producing required formats in print is challenging!
  2. Re-flow problem
  3. PDF an inflexible format
  4. Neither format works well with some assistive technology

11pt

Example 1. *Find the quadratic mean of* $1, 2, 3, 4, 5, 6, 7, 8, 9, 10$*:*

$$\begin{aligned}\sqrt{\frac{1}{10}\sum_{i=1}^{10} i^2} &= \sqrt{\frac{1^2+2^2+3^2+4^2+5^2+6^2+7^2+8^2+9^2+10^2}{10}} \\ &= \sqrt{\frac{1+4+9+16+25+36+49+64+81+100}{10}} \\ &= \sqrt{\frac{385}{10}}\end{aligned}$$

14pt

Example 1.
Find the quadratic mean of $1, 2, 3, 4, 5, 6, 7, 8, 9, 10$:

$$\sqrt{\frac{1}{10}\sum_{i=1}^{10} i^2} = \sqrt{\frac{1^2+2^2+3^2+4^2+5^2+6^2+7^2+8^2+9^2+10^2}{10}}$$

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17pt

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$$= \sqrt{\frac{1+4+9+16+25+36+49+64+81+100}{10}}$$

$$= \sqrt{\frac{385}{10}}$$

20pt...

$$\sqrt{\frac{1}{10}\sum_{i=1}^{10} i^2}$$

$$= \sqrt{\frac{1^2 + 2^2 + 3^2 + 4^2 + 5^2 + 6^2 + 7^2 + 8^2 + 9}{10}}$$

$$= \sqrt{\frac{1 + 4 + 9 + 16 + 25 + 36 + 49 + 64 + 81}{10}}$$

$$= \sqrt{\frac{385}{10}}$$

20pt?

$$\sqrt{\frac{1}{10}\sum_{i=1}^{10} i^2}$$

$$= \sqrt{\frac{\left(1^2 + 2^2 + 3^2 + 4^2 + 5^2 + 6^2 + 7^2 + 8^2 + 9^2 + 10^2\right)}{10}}$$

$$\sqrt{\left(1 + 4 + 9 + 16 + 25 + 36\right)}$$

A more flexible format?

- Use MathType to create Word documents?
  - Equations can be read on screen
  - But re-flow still a problem when printing...
  - Still won't work directly with assistive technology
  - But we can convert to other formats
- Convert LaTeX to MathML?

Mathematics in Braille and voice

Screen reading software sometimes doesn't work:

- **Example: JAWS reading a PDF**

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Access to the LaTeX source is **required**:

- Just Braille? See *MSOR LaTeX and Braille project*
- Some people choose to read LaTeX source directly:
  1. Complex mathematics difficult to navigate
  2. Commands for presentation mixed with content

Cleaning up LaTeX sources

```
\noindent {\bf 5.}\quad {\bf $\Theta$-notation (reminder)}
\medskip

\noindent {\bf Definition} ($\Theta$-notation).
$ \Theta \bigl( g(n) \bigr) = \{ f(n):$ there exist constants
$c_1>0, c_2>0, n_0>0$ such that $c_1 g(n) \le f(n) \le c_2 g(n)$
for all $n \ge n_0 \}$.
\medskip

\noindent {\bf Convention.}\quad If $f(n) \in \Theta \bigl( g(n) \bigr)$,
then we write: $f(n) = \Theta \bigl( g(n) \bigr).$
\medskip

\noindent {\bf Lemma.}\quad {\sl If $f(n) = \Theta \bigl( g(n) \bigr)$,
then $g(n) = \Theta \bigl( f(n) \bigr)$.}
\medskip

\noindent {\bf Proof.}\quad The inequality
$$0 \le c_1 g(n) \le f(n) \le c_2 g(n)$$
for $n \ge n_0$ implies
$$0 \le (1/c_2) f(n) \le g(n) \le (1/c_1)f(n).$$
```

Cleaning up LaTeX sources

```
 5.  \Theta-notation (reminder)

Definition (\Theta-notation).
 \Theta ( g(n) ) = \{ f(n): there exist constants  c_1>0, c_2>0, n_0>0
such that c_1 g(n) <= f(n) <= c_2 g(n)
for all n >= n_0 \}.

Convention.  If f(n) \in \Theta ( g(n) ),
then we write: f(n) = \Theta ( g(n) ).

Lemma.  If f(n) = \Theta ( g(n) ),
then g(n) = \Theta ( f(n) ).

Proof.  The inequality
0 <= c_1 g(n) <= f(n) <= c_2 g(n)
for n >= n_0 implies
0 <= (1/c_2) f(n) <= g(n) <= (1/c_1)f(n).
```

Moving to MathML?

We can convert mathematics in LaTeX or Word to MathML:

- HTML + MathML read using IE and **MathPlayer**

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We can convert mathematics in LaTeX or Word to MathML:

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But

- Complex mathematics is difficult to navigate
- Description of notation rather than name of the object
- There is no Braille support

Accessing print mathematics

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- Image PDF: inaccessible
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Images $\xrightarrow{\text{OCR}}$ Text which might contain errors

Optical character recognition

For instance, suppose we need to recall that

$$(x+a)^n = \sum_{k=0}^{n} C_k^n x^k a^{n-k}$$

where

$$C_k^n = \frac{n!}{(n-k)!k!}$$

Optical character recognition

- Standard OCR:

```
For instance, suppose we need to recall that
k=0
where
/-yn
kn-k
(n-k)\k\
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- **Example: InftyReader and ChattyInfty**

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- **Example: InftyReader and ChattyInfty**

  For mathematics this would be the OCR of choice — to stick in a piece of paper that you didn't know the context of... knowing that InftyReader is powerful — this is the most powerful thing that I have.

The technology gap

The production of accessible mathematical resources is difficult

and

There is a lack of effective assistive technology available to students:

- Typically recommended technology provides limited access to mathematics
- Slow impact of research and development