Impact of ICT on the Teaching of Maths to VIP (Visually Impaired People)

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5\textsuperscript{th} JEM Workshop – Joining Educational Mathematics  
Access to mathematics

- There is no reason that mathematical semantics can not be understood because of blindness.
- The biggest barrier is in fact access to mathematical content

Where does lie the problem?
- Non visual representations
- Additional modalities used by the sighted
Access to maths as always been a problem to VIP

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Where does lie the problem?

- Non visual representations
  - *Speech*
  - *Braille*
  \[ \rightarrow \] Linear representations
- Additional modalities used by the sighted
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Where does lie the problem?

- Non visual representations \(\rightarrow Linear\)
  - No global perception (2D)
  - Formulas can be very long and complex
- Additional modalities used by the sighted
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Where does lie the problem?

- Non visual representations $\rightarrow$ Linear
  \[
  \frac{x+1}{x-1} \quad (7 \text{ symbols})
  \]
  \[
  \frac{(x + 1)}{(x - 1)} \quad (11 \text{ symbols})
  \]
  
  In Braille (Nemeth) 9 symbols

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\[
\frac{x+1}{x-1} \quad \text{(7 symbols)} \quad \frac{(x+1)}{(x-1)} \quad \text{(11 symbols)}
\]

In Braille (French)

11 symbols

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Where does lie the problem?

- Non visual representations $\rightarrow$ Linear
  
  $\frac{x+1}{x-1}$ (7 symbols) \hspace{1cm} (x + 1)/(x − 1) (11 symbols)

  In Braille (Marburg) \hspace{1cm} 14 symbols and 4 spaces

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- Non visual representations $\implies$ Linear
- Additional modalities used by the sighted

\[(x + 1)(x - 1) = x^2 - 1\]
Learning maths for Blind kids

Difficulty of Maths + Difficulty of Maths notations

- Goals of Mathematical Notations is to reduce the length of formulas using context sensitive grammars
- Therefore they are extremely complex
- As more and more pupils are in inclusive education, an increasing number can’t learn them (depending on countries)
- A certain number of countries are using, officially or not, a standard linear code, with a set of special symbols...
@Science Thematic Network

Funded by the European Union (eContentPlus Programme)

to facilitate access to digital scientific resources for both visually impaired students and researchers by bringing together and sharing best practises and producing guidelines concerning the accessibility of digital scientific resources.

- Università degli Studi di Milano, Italy (coordinator)
- Johannes Kepler Universität Linz, Austria
- Katholieke University Leuven, Belgium
- Comenius University, Slovakia
- Union of the Blind in Verona, Italy
- Université Pierre et Marie Curie, France
State of the Art

Assistive technology

Since 20 years a number of research projects and commercial tools aim at supporting Visually Impaired people, in 3 main kinds:

- converting producing
- reading, understanding
- manipulating, calculating, solving (doing maths)

see [Archambault et al. 2007] Upgrade (Cepis) paper:
 upgrade-vol-VIII-2.html
Create Braille books for pupils and students

**Mainstream to Braille**
- [Miesenberger et al.] Labrador: LaTeX to Marburg
- [Schwebel] Bramanet: MathML to French Braille
- [Crombie et al.] math2braille: MathML to Dutch Braille
- [Stanley]: MathML to Nemeth
- [Archambault et al.] **UMCL** (Multilingual)

**Maths OCR**
- [Suzuki et al.] Infty: paper, PDF, handwriting to MathML, Japanese Braille, LaTeX...
Allow sighted teachers to access Braille documents created by pupils or students.

**Paper Braille to Mainstream**

- [Gupta et al.] Insight: complete chain to process Braille documents (paper)
  - Braille OCR
  - Mathematical Braille to Latex
  - Merging with text
  - graphical output (printout)
odt2dtbook

odt2dtbook is an OpenOffice.org writer extension, enabling export to DTBook XML (part of the **DAISY** Digital Talking Book specification).

- odt2dtbook is very simple to install and to use.
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- odt2dtbook supports Mathematical content conforming to the MathML Modular extension of DTBook

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odt2dtbook received a Gold Award from Sun Microsystems, at the OpenOffice Community Innovation Program

Help to access/understand long and complex Braille maths expressions

**Maths Player [Design Sciences]**

Internet Explorer plug-in allowing MathML to be displayed graphically.

- Enlarges formulas with specific background: improves readability for partially sighted (and actually to anybody)
- Create relevant sentence to be read by a screen reader: Provide speech synthesis support
- Converts to Braille using UMCL (in development): Provide support for Braille displays
- **Document format: HTML+MathML or xHTML+MathML**
Help to access/understand long and complex Braille maths expressions

Maths Genie [Karshmer et al.]

- Formula browser
  - provides enlarged graphical formulas
  - speech synthesis
  - collapse/expand feature (cf later on)
  - based on MathML
Doing Maths
Manipulating, calculating, solving

The Lambda project [Nicotra et al.]

Specific linear code

- graphical representation “sighted-readable”

\[\frac{x + 1}{x - 1}\]

- 8-dots Braille national representations

- Asynchronous display of graphical formula (\(\lambda\) to MathML)

\(\lambda\text{–}\text{Italian}\)
Now we need to go further and to provide support to students for doing calculations.

- without solving the Maths problems
- helping to cope with the representation specific issue in the same idea that sighted people use additional modalities around the expressions.
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MaWEn is a prototype scientific editor allowing multimodal and collaborative works on scientific documents including mixed text content and mathematical formulas.

MaWEn is a tentative to overcome the problems presented above

- Synchronisation of formulas in Braille and Graphics;
- Bi-directional pointing possibilities;
- Navigation through formulas by collapse and expand functionality synchronised with both views;
- Support of mathematical manipulation.
Support collaborative work

the same content is presented in 2 different modalities:

- it must be the “natural representation” for each user
- the 2 views always display the same content
- support pointing at a location
- support selecting
- ...as well for text and Maths expressions
Synchronisation

Synchronise Graphical and Braille representations of formulas

\[ \frac{x + 1}{x - 1} \]
Synchronisation
Bi directional pointing (1)

\[ \frac{x + 1}{x - 1} \]
Synchronisation
Bi directional pointing (2)
Synchronisation
Bi directional pointing (3)

\[
\frac{x + 1}{x - 1}
\]
Synchronisation

Screen shot: MaWEn-d3

\[(3a + 4b - 6c)^2\]
\[ L_1 = L_0 \cdot \sqrt{1 - \frac{v^2}{c^2}} \]

\[ L_1 = L_0 \cdot <block> \]

\[ L_1 = L_0 \cdot \sqrt{1 - <block>} \]
\[ L_1 = L_0 \cdot \sqrt{1 - \frac{v^2}{c^2}} \]
\[ L_1 = L_0 \cdot \sqrt{1 - \frac{v^2}{c^2}} \]

Eq
\[ L_1 = L_0 \cdot \sqrt{1 - \frac{v^2}{c^2}} \]

**Eq**

\[ L_1 = L_0 \cdot Sq \]
\[
L_1 = L_0 \cdot \sqrt{1 - \frac{v^2}{c^2}}
\]

Eq

\[
L_1 = L_0 \cdot Sq
\]

\[
L_1 = L_0 \cdot \sqrt{1 - F}
\]
Screen shot: MaWEn-d3
Teaching Mathematics the Audio way

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Outline

• What are we trying to do?
• Why relevant?
• Introduction to **prosody**
• Depicting Equations
• Thoughts on teaching.
Why use audio?

- Specific case:
- Many blind people do not read Braille
- Figures for Ireland suggest less than 10%
- We need to find an alternative modality.
- Solution: audio representations created using synthetic speech.
General Case

• The emergence of VLE and other online teaching resources make this relevant to all
• Imagine a lecturer creating online content to which they wish to attach audio content.
• Also, even more generally, communication of mathematics is a problem.
• Would guidelines to verbalisation help students and educators alike?
Problems Representing Math Using Audio

• Mathematics is a 2-d representation The semantics are altered by spatial location.
• Speech is a serial form of communication; so we need to find a way to represent space.
How Do People Read?

• Eyes move in a series of saccades (jumps) and fixations.
• A non-linear progression.
• The book is the passive partner, reader is the active participant.
• Roles reversed in the traditional audio domain.
What is Prosody?

• The unscientific definition is *inflection*
• More precisely, that set of characteristics which lasts longer than a syllable.
• two views: temporal or acoustic.
• Acoustic view broken down into *duration*, *pitch*, *amplitude*.
How to Speak Formulae

Reduce equations to a linguistic approximation
Thus the sub-expressions of mathematics can be mapped to clause boundaries in (for example) English.
So sentence, clause, character = formula, sub-expression, operators or operands
\[ a + b + c + d + e \]

\[ a + \frac{b + c}{d} + e \]

\[ \frac{a + b}{c + d} + e \]
The Linear Versions.

1. \( a+b+c+d+e \)
2. \( a+(b+c)/(d)+e \)
3. \( (a+b)/(c+d)+e \)
What To Speak?

Do we use lexical cues or not?
If yes, then which cues?
However, will cues make the utterance too long?
This will have impacts on cognitive load.
Why? Because speech is a transient signal.
\[ a + b + c + d + e \]
\[ a + \frac{b + c}{d} + e \]
\[ \frac{a + b}{c + d} + e \]
Another Linear Version

1. \( a+b+c+d+e \)

2. \( a+, \begin{ fraction } \begin{ numerator } b+c \end{ numerator } \begin{ denominator } d \end{ denominator } \end{ fraction }, +e \)

3. \( \begin{ fraction } \begin{ numerator } a+b \end{ numerator } \begin{ denominator } c+d \end{ denominator } \end{ fraction }, +e \)
Thoughts on Teaching

• Good communication of mathematics instills confidence, interest and enthusiasm in students.
• One way to improve this, is to be aware of how it is being presented.
• This means not just the visual presentation of the formulae.
Thoughts on Teaching (II)

• What of online delivery of mathematics?
• With no face-to-face contact, the proper presentation in the audio domain becomes even more important.
• Using learning objects containing both auditory and visual information means that to ensure a good learning experience both must be at a comparable standard.
Future Work

• Various experiments to ascertain:
  1. what language to use;
  2. How people decompose (deconstruct) formulae.