A Comparison of Nemeth Code and UEB Math

Presented by:
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Slides at: http://accessibility.pearson.com/braille4math-science
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Agenda

- Definitions
- Brief History of Braille Math
- The Learning of Mathematics
- Input from those in the STEM Fields
- Published Research
- Math and Science Samples of UEB and Nemeth (including a Number Line Graph)
- Code Books and Guidelines
- References

Definitions

- BANA – Braille Authority of North America – Their mission is to assure literacy for tactile readers through standardization of braille and/or tactile graphics. Established in 1976, this group includes national consumer organizations, braille producers, the Library of Congress, transcribing organizations, and others.
- ICEB – International Council on English Braille - Their purpose is to coordinate and improve standards for braille usage for all English-speaking users of braille.

Definitions

- EBAE – English Braille American Edition – Our current braille code. A set of rules that govern the transcription of literary braille.
- UEB – Unified English Braille – a unified code, developed by ICEB, adopted by BANA (November 2, 2012) to replace our currently used literary and Computer Braille Code in January 2016, uses upper cell numbers.
- Nemeth Code – Our current braille code for mathematics and science notation - developed by Dr. Abraham Nemeth, which BANA voted to maintain (November 2, 2012), uses lower cell numbers.

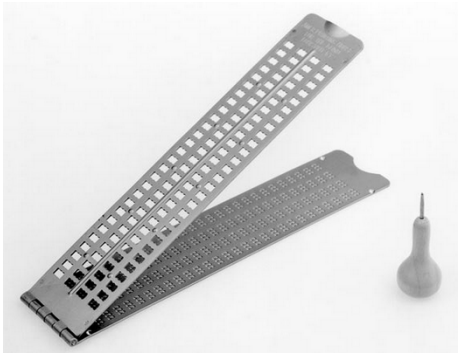
Definitions

- STEM – an acronym referring to the academic disciplines of science, technology, engineering and mathematics. The term is typically used when addressing education policy and curriculum choices in schools to improve competitiveness in science and technology development.
- TVI – Teacher of the Visually Impaired
- ABL – Alliance For Braille Literacy www.all4braille.com/
- NFB – National Federation of the Blind https://nfb.org/

The Way it Was

- Before the 1960s, blind children were usually educated in residential schools for the blind.
- All their teachers knew how to read braille, could create braille materials, and read the students' materials.
- Transcribers could only produce braille by hand, either using a Perkins braillewriter or a slate and stylus. Multiple copies could be produced only using a thermoform machine.

Perkins Braille Writer



Slate and Stylus

Thermoform Machine

Beginning of Change

- Much changed in the 1970s. Public Law 94-142 provided that blind children should be educated in the “least restrictive environment.” This law accelerated the trend toward blind children being educated in the public schools. This led to an increased need for braille transcribers.
- The braille code for mathematics changed several times during the first half of the twentieth century, but by 1972, the *Nemeth Code for Science and Mathematics Notation* was the standard.

What's In Place Today

www.brailleauthority.org

- *Nemeth Code for Science and Mathematics Notation, 1972*
- *Braille Code for Chemical Notation, 1997*
- *Music Braille Code, 1997*
- *Computer Braille Code (CBC), 2000*
- *EBAE – English Braille American Edition, 2002*
- *Guidelines and Standards for Tactile Graphics, 2010*
- *Braille Formats: Principles of Print to Braille Transcription, 2011*

Where are We Going?

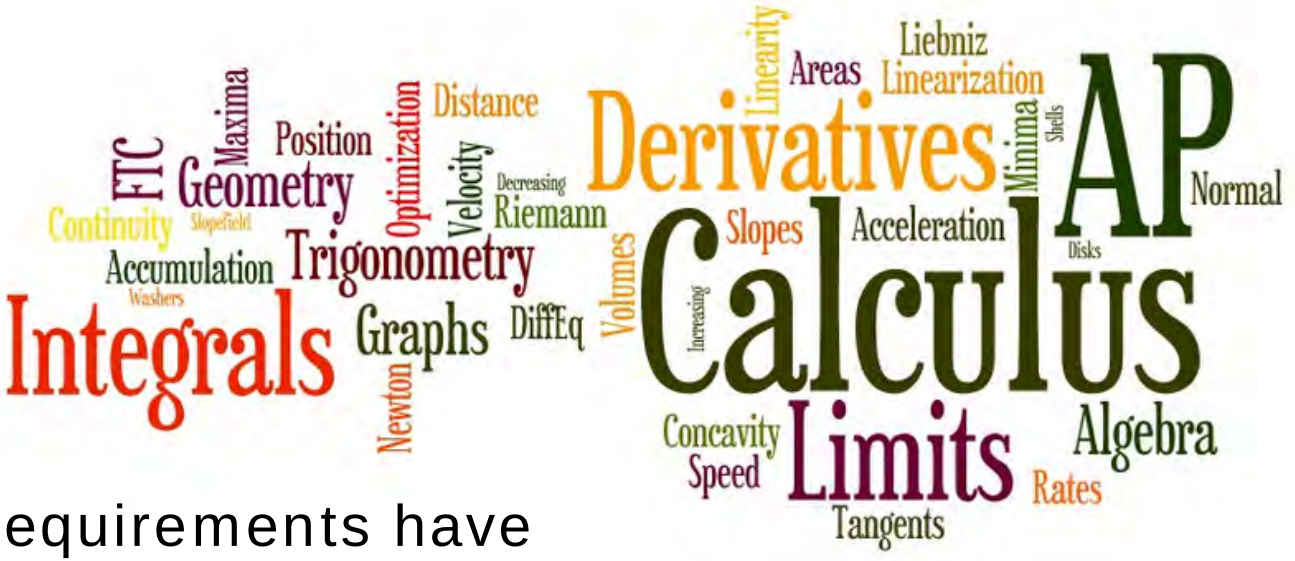
- Now with various combinations of Internet media, speech output, braille displays, scanning and OCR, braille translation software, and braille embossers, blind people can read, in a matter of moments, virtually anything created by anyone, with the exception of the STEM fields. However, *Expanding Audio Access to Mathematics Expressions by Students with Visual Impairments* via MathML is coming.
- Nevertheless, braille under the fingertips is still a requirement for the majority of blind individuals working in the STEM fields.

Comments from a teacher who has lived some of this history ....

Comparing Nemeth and UEB from the perspective of a math specialist who is also a Teacher of the Visually Impaired (TVI)

Comments from a teacher

- Prior to the Nemeth Code, the Taylor Code was used, but it did not support higher mathematics.
- The Nemeth Code is logical and supports print mathematics quite successfully.
- Speaking math from a Nemeth Code perspective
- In 1978, the highest level of mathematics taught at the Texas School for the Blind was a two-year pre-algebra class.



- Math requirements have continued to grow more rigorous, and we expect that trend to persist. At present in Texas, graduation requirements for the recommended high school program are 4 credits in both upper level math and science.

- In 2011, a female braille student at the school scored a 5 on the AP Calculus exam – highest score possible!

More comments from a teacher

- We are now seeing the first generation of adult braille users that were educated by TVIs who only learned Nemeth Code, as opposed to the Taylor Code. These young adults learned Nemeth Code from the beginning and many are showing great success in college, graduate school, and specifically in the STEM fields.
- Losing the Nemeth Code in the United States could set math education for the blind back 40 years, yet some are considering abandoning it (instead of maintaining it) and switching to UEB for math and science.

The Learning of Mathematics

- Highest level of math achieved in high school was shown to be linked with successful completion of a college degree in any field of study (Adelman, 1999 and Hill, 2006)
- Higher level of high school math = higher likelihood of completing college degree

More on the Learning of Mathematics

- Working memory is acknowledged to hold 7± 2 items or bits of information at a time (Kalet, 2005).
- Working memory can only hold this information for about 15-20 seconds (McGee & Wilson, 1984).
- Automaticity: the ability to perform a skill automatically or unconsciously
- Fluency in reading is affected by automaticity; if reading more symbols is required to distinguish numbers from letters, fluency can suffer.

Comments from a College STEM Student on Cognitive Load

"Think of the cognitive load. I must physically touch each one of those characters keeping in mind how the placement of one might affect the meaning of another. Meanwhile the problem must be held in my very limited short-term memory space."

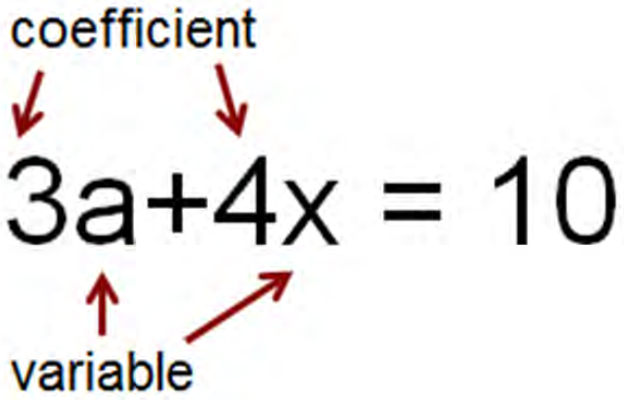
– Amanda Lacy, Computer Science Major, University of Texas at Austin

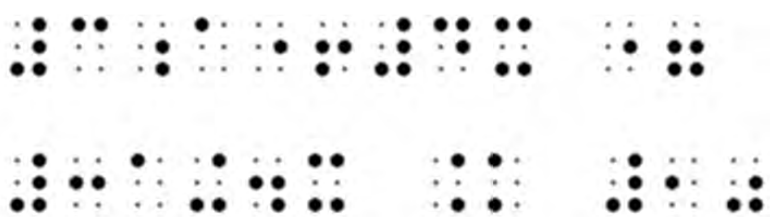
- How many modes and indicators are too many?

Upper Cell Numbers

- The fundamental shortcoming in the development of UEB for math and scientific notation is the use of upper cell numbers which creates conflict with many other symbols in both literary and mathematical notation.
- Use of numbers in the upper part of the braille cell greatly adds to the length of mathematical expressions, especially in algebra, linear algebra, and calculus, where alphabet-number combinations are frequent (20 – 35% more characters than Nemeth Code) (Knowlton & Wetzel, 2006).

Example 1: Upper Cell Numbers





UEB

Nemeth

Lower Cell Numbers

- “Nemeth Code’s use of lower cell numbers allows the upper part of the braille cell to be used for mathematical functions, critical to the overall successful use of the code for mathematics.”

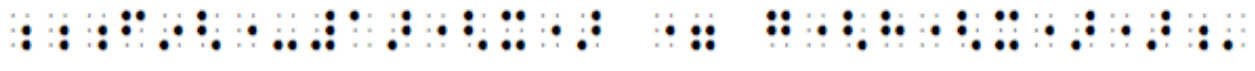
  Cary Supalo, Research Scientist, Department of Chemistry, Purdue University; President, Independence Science; Chair, BANA Ad Hoc Committee on Chemistry
- UEB’s use of upper cell numbers introduces ambiguity by using the same symbols for numbers and letters; this creates a need for a second symbol to distinguish between them.

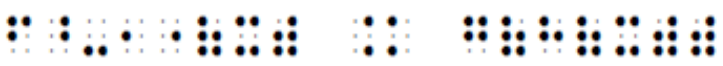
Example 2: Lower Cell Numbers

Inverse and Composite Functions

$$f^{-1}(x) = g(h(x))$$

UEB





Nemeth

Concerns from a Blind Computer Programmer

- English itself is far from unified.
- Teaching UEB math in some states or for some students and Nemeth Code for others is at best impractical and probably impossible. The two systems come from very different places and represent completely antithetical approaches to the presentation of math and science materials.
- Use of upper numbers in UEB
- Computer Braille Code (CBC)

  – Chris Gray, ABL, www.all4braille.com

Thoughts from a Senior Software Developer

Use of UEB math

- will impede online delivery of accessible math to visually impaired students.
- will increase the cost of supporting software. Removal of as many indicators from the code as possible is the recommendation.

More Thoughts from a Senior Software Developer ...

- It is already difficult to make math accessible to people who are blind, but it is even more difficult when the braille is complicated with additional indicators occupying even more space.
- In software, flexibility increases cost, so you have to justify what you get in return. So are you going to justify UEB Math by making it too complicated for any software producer to support it?

From Flexibility to Complexity

- An authoring tool for math such as an equation editor must establish conventional behavior for each math operator it supports.
- It is convenient to express these behaviors as transformation rules, and if each operator has its own set of rules, and if there are only a small number of such rules for each operator, the number of rules is proportional to the number of operators.

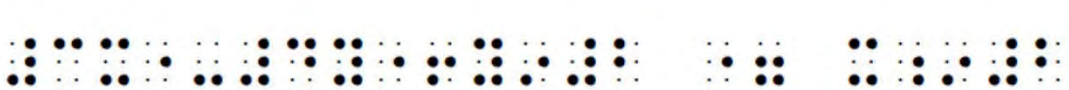
Exponential Complexity

- 100 rules for 100 operators is reasonable
- 10,000 rules or 1,000,000 rules for 100 operators is not
- When rules become dependent on the behavior of other rules, then we add exponential complexity.

Example 3: Flexibility

$$3x-4y+y^2 = x^2$$

Note that this particular equation could also be written in UEB as:



Nemeth Braille - Ahead of its Time

- TeX math typesetting (1978)
- Mathematica computer algebra (1988)
- W3C content MathML (1997)
- Unicode math symbols (2002)
- STIX math fonts (2008)
- Nemeth Braille math encoding - 1946 !

The Nemeth Braille Encoding System

- provides a more stable and reliable encoding for mathematical notation than Donald Knuth's TeX math typesetting system, widely regarded as one of the most stable tools in all of scientific computing.
- provides a more extensive system for capturing the notation for a mathematical expression, and a more precise system for capturing the structure of a mathematical expression, than the World Wide Web Consortium’s (W3C's) content and presentation markup language.
- includes math symbols that are not included in the Unicode standard for character encoding.

More About the Nemeth Braille Encoding System

- includes math symbols that are not included in the STIX math fonts.
- includes techniques to address issues in mathematical usage that are still problematic in other languages. (recursive structures, constructed symbols, unit abbreviations, textual content)
- was designed in a way that enables efficient processing and translation by computer software.

– Sam Dooley, Manager, Software Development, Pearson

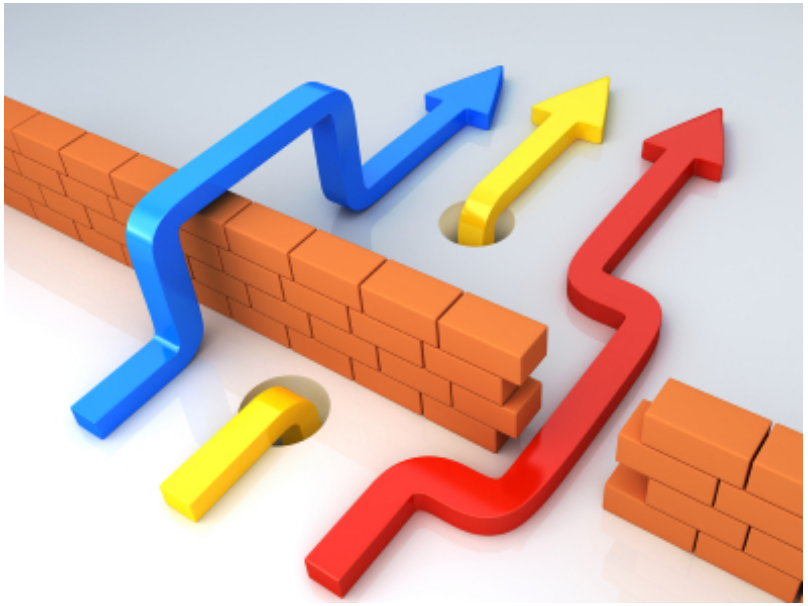
Issues Identified by Carlton Walker: Parent, Attorney, and Teacher of Blind Students

Currently, all math and science materials are in Nemeth Code. Adding UEB Math will:

- be duplicative and expensive
  - Having two codes will mean that all materials will need to be produced and available in each code. This could lead to shortages in materials.

Adding UEB Math will:

- erect barriers to relocation within the United States



- Families needing to move for employment or security reasons risk putting their children behind in math due to the need to learn a new braille math code.
- Due to the need to teach new math code to move-ins, Teachers of the Visually Impaired will have LESS time to instruct children.

Adding UEB Math will:

- create a problem with accessible math textbooks
  - All current math textbooks have been produced in Nemeth Code.
  - There is no certification for UEB Math transcription in the United States.

NFB Resolution 2015-29

July 9, 2015 Complete resolution is available at: https://nfb.org/2015%20Resolutions

- NFB calls upon state departments of education to eliminate needless confusion and unnecessary cost by using the Nemeth Code for Mathematics and Science Notation, with BANA's guidance for Nemeth in UEB contexts, as the standard for math Braille.
- NFB urges BANA quickly to clarify that although timelines and processes for UEB implementation are set at the state level, Braille code standards are not set by individual states; and to indicate unequivocally that the Nemeth Code, with the guidance for Nemeth in UEB contexts, is the standard for mathematics Braille in the United States.

Published Research

Wetzel and Knowlton

JVIB, April – May 2006

- “The participants clearly stated that any changes to the code that would make braille more difficult to read would not be in the best interest of the current population, many of whom could be greatly hampered by learning a code that these professionals considered to be more complex.”
- “... the [UEB] study lacked input from professional braille users in the fields of mathematics and computer science.”

More from Wetzel and Knowlton

- “There is a significant question remaining as to the impact of eliminating multiple contractions in a passage. It is a question that should be addressed before global changes to the braille code are made. These issues can be most effectively addressed by conducting further research.”
- “Perhaps some of the most significant research on any braille code needs to address a vast array of cognitive issues that are related to learning and using braille as a reading and writing system.”

Even more from Wetzel and Knowlton

- “The field would benefit from studies that address limits to short-term memory (working memory) as they apply to the reading, recall, and writing of braille.”
- “Writing braille is an area of research that is yet to be addressed.”
- “When one looks at the results collectively, it is clear that much more research is necessary before professionals will have sufficient knowledge to make wise decisions regarding changes to the braille codes.”

Furthermore, Wetzel and Knowlton Say

- “To date, no studies have addressed the transcription and comprehension of graphic material in braille. A unified code needs to address this kind of information in addition to pure literary text.”
- UEB would be more expensive to produce than EBAE or Nemeth Code due to longer passages.
- Arithmetic computation “required 17% more characters and algebra required 20%-35% more characters.” This would mean more expense to produce the books. Arithmetic and algebra books are the longest ones.

Holbrook and MacCuspie

JVIB Sept. 2010

- Study of UEB Technical Material involving 5 adult participants
- “The participants were required to be braille readers who were employed in highly technical fields; had limited previous knowledge of the UEB code; and did not have a strong opinion, pro or con, about the UEB code. Thus, we had a limited pool of individuals from whom to draw.”
  - Anyone who had a strong opinion about Nemeth was rejected.
  - Few people met the criteria (5 participants found for the study)
  - Two of those participants didn't even currently use Nemeth code

More on Holbrook and MacCuspie

- Did not look at it from the perspective of whether UEB would meet the same needs as the current Nemeth code
- Only done over 2 days
- Participants were asked about transition for adults who use braille, not for students learning math and using UEB
- Participants did talk about their concern for transition because of the UEB using symbols from previous codes in entirely different ways.
- Participants mentioned back translation as a strength of UEB, but efficient back translation has not been fully verified within the field of blindness technologies.

Suggestions

- Consider development of better and more uniform TVI personnel preparation programs and higher state certification requirements. (Pogrund & Wibbenmeyer, 2008)
- Conduct research comparing Nemeth and UEB - What is the relationship between success in math and science courses and the braille code students use?

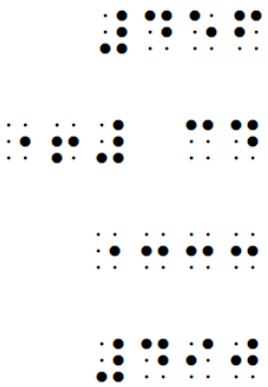
Braille Code Comparison (The Basics)

Math and Science Samples of UEB and Nemeth

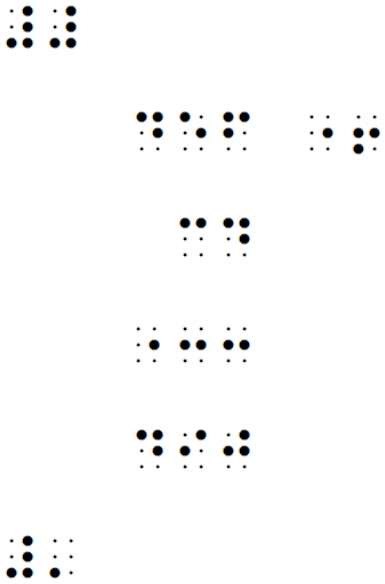
Example 4: Spatial Addition

$$\begin{array}{r} 456 \\ +\ 34 \\ \hline 490 \end{array}$$

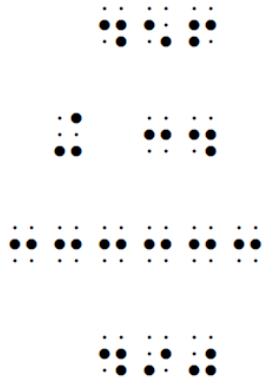
UEB 1st Version



UEB 2nd Version



Nemeth



Example 5: Linear Addition

3 + 5 = 8

UEB 1st Version, 14 cells

UEB 2nd Version, 12 cells

Nemeth, 10 cells

Example 6: Simple Chemical Formula

H_2O

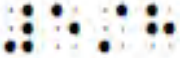
UEB, 8 cells

Nemeth, 5 cells

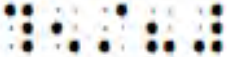
Example 7: Simple Numeric Fraction

$$\frac{5}{8}$$

UEB, 4 cells



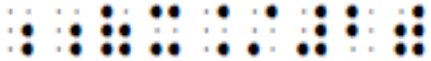
Nemeth, 5 cells



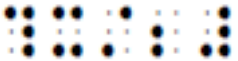
Example 8: General Fraction

$$\frac{x}{2}$$

UEB, 9 cells



Nemeth, 5 cells



Example 9: Superscripts

x^2 (x squared)

UEB, 5 cells

Nemeth, 3 cells

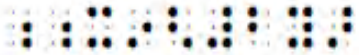
x^2y (x squared times y)

UEB, 6 cells

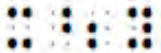
Nemeth, 5 cells

x^{2y} (x to the 2y)

UEB, 9 cells

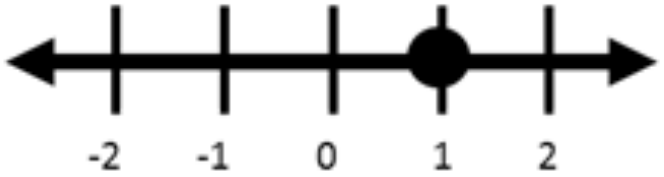


Nemeth, 4 cells

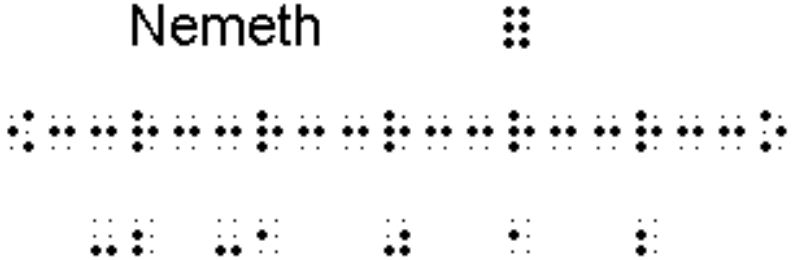


Example 10: Number Line Graph x = 1

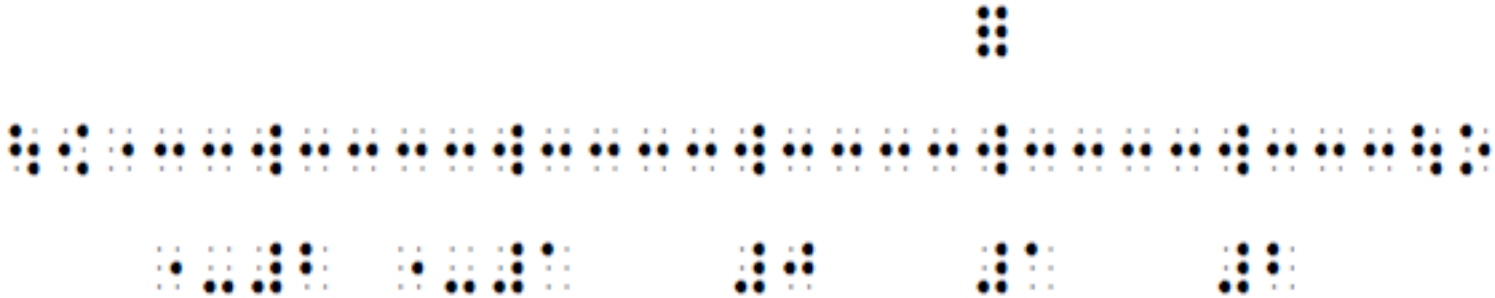
Print



Nemeth



UEB



Code Books and Guidelines

Nemeth

- *The Nemeth Braille Code for Mathematics and Science Notation*, 1972 Revision, 255 pages
- *Braille Code for Chemical Notation, 1997,* 147 pages

UEB Math

- UEB Guidelines for Technical Material, 2008 version updated August 2014, 87 pages
- [Section]16 Chemistry, UEB Guidelines for Technical Material, 2008 version updated August 2014, 9 pages

More on Code Books and Guidelines

Nemeth

- *Graphing Calculator Guidelines,* March 2015 proposed guidelines, 58 pages
- *Braille Formats: Principles of Print to Braille Transcription, 2011,* currently being revised to align with UEB, 675 pages

UEB Math

- [Section] 3.5 Calculator keys, *UEB Guidelines for Technical Material, 2008 version updated August 2014,* 1/3 page
- *Braille Formats: Principles of Print to Braille Transcription, 2011,* currently being revised to align with UEB, 675 pages

Even More on Code Books and Guidelines

Nemeth

- *Guidelines and Standards for Tactile Graphics, 2010, 362 pages*
- *Guidelines and Standards for Tactile Graphics, 2010 Supplement: Examples 1 - 35*

UEB Math

- [Section] 4.4 Diagrams, *UEB Guidelines for Technical Material, 2008 version updated August 2014*, 3 pages
- ICEB Resolution 6, May 2012 recommended the BANA Guidelines and Standards for Tactile Graphics and Supplement (currently being revised to incorporate UEB) be considered. www.iceb.org/gares12.htm

Nemeth within UEB Context

- To ensure that the Nemeth Code can continue to be used as UEB is implemented, a method has been developed to switch between Nemeth code (for the mathematical expressions) and UEB (for the text around the mathematics).
- This is similar to our current use of switching to computer braille code for email addresses and the like.
- The symbols used to show the switch between the codes are included in the official rules of UEB.

More Nemeth within UEB Context

- Guidance on how to use Nemeth Code within UEB entitled: *Provisional Guidance for Transcription Using the Nemeth Code within UEB Contexts* is available at www.brailleauthority.org/mathscience/math-science.html
- BANA continues to refine the guidance based on suggestions from those who use it.

  - Jennifer Dunnam, Representative of the NFB to the BANA Board and BANA Board Chair

Why We Think UEB for Math and Science is Problematic

- Upper cell numbers
- Numerous new indicators
- Longer expressions
- Insertion of superfluous braille grouping symbols that do not appear in print
- Use of terminology that is not used by mathematics teachers
- Ambiguity of how to write fractions dependent upon the presence of variables.

If you want additional information:

Please contact me at:

Texas School for the Blind and Visually Impaired
Outreach Programs
1100 West 45th Street
Austin, TX 78756 U.S.A.
susanosterhaus@tsbvi.edu

Or check out the following resources:

www.tsbvi.edu/math

www.tsbvi.edu/distance/osterhaus_math_intro.html

http://library.tsbvi.edu/Browse/Category/9

A Big Thank You to Those Behind the Scenes Providing Steadfast Support:

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- Jan McSorley, Head of Accessibility, School Line of Business, Pearson Assessment Centre, for assistance with recording and production

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- International Council on English Braille. (2008 version updated August 2014). *Unified English Braille, Guidelines for Technical Material*.

In Summary...

- References and braille files are available at http://accessibility.pearson.com/braille4math-science

Thank you for your kind attention!