Tools for Accessible Math Instruction for Blind Students

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Abstract

Students with severe visual impairments often have difficulty in learning mathematics because of inaccessible handouts with graphs and equations and because of the lack of tools to help them complete assignments. We developed a three-week summer math camp for blind high school students to test several commercial technologies for accessible instruction. We found that many commercial tools work well as instructional aids, though students still require more time to complete assignments than non-disabled students do, even with the best available commercial technology.

Introduction

Students who are blind face many challenges in achieving a degree in engineering or mathematics. These often include inadequate mathematics training in high school, a lack of accessible materials, and a means of effective written communication between the student and instructor. Because of these and other challenges, blind students are often counseled against pursuing college degrees in science, technology, engineering, and math disciplines.

With the support of a grant from the National Science Foundation, we developed a three-week summer math camp for blind high school students to test several commercial technologies for accessible instruction. We hoped to use the knowledge gained to help our faculty begin making their curricula accessible to persons with a visual impairment.

Methods

Participants

Beginning in December 2004, we advertised our summer math camp through the newsletter of the National Federation of the Blind. We selected six blind high school students from applicants from across the United States. We developed a set of training materials on the topics identified by the students as most difficult. The students came to Louisiana Tech University for 3 weeks of study. All costs of attending the summer camp were paid for by the supporting grant.

We prepared for a mixture of vision in our classes, understanding that two of the six students had the use of low amounts of vision. We therefore prepared two sets of materials: Braille versions for blind students, and large print versions for the students with a visual impairment. We also set up computer stations with either access through enlarged print (ZoomText 8 from Ai Squared)[1] or through screen reading software and speech output (JAWS for Windows from Freedom Scientific)[2].

We hired two blind university graduates to check the accuracy of the Braille translations, to grade student homework, and to provide tutoring. One individual had a BA in music, while the other had a BS in Economics. The tutor with the background in Economics was particularly knowledgeable in technology for accessing mathematics equations and graphics; his experience was invaluable to the project directors.

Training Materials

We generated training materials using Scientific Notebook 5.0 from MacKichan Software[3] to create pages of text mixed with equations and graphs. Scientific Notebook was selected primarily for its ability to generate files using the LaTeX typesetting format. We translated these LaTeX files into Braille using the Duxbury Braille Translator for Windows software from Duxbury Systems, Inc.[4]. The Duxbury Braille Translator automatically output Braille using the Nemeth Code, a commonly used variation on traditional Braille specifically used for mathematics. We output the Duxbury Braille files to a Tiger Cub Jr. Braille embosser from ViewPlus Technologies[5]. This process is shown in Figure 1.

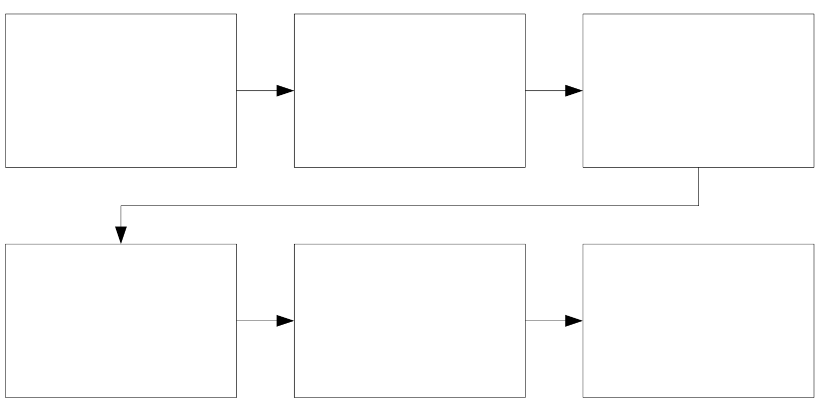

Figure 1. Conversion of training handouts to Braille.

Assistive Technology

We tested several commercial math aids with the students, including:

- Talking Calculator. The Orion Talking Scientific Calculator from Orbit Research[6] is essentially a TI-34 Scientific Calculator with an added speech pack. (It should be noted that this product is no longer available; it has now been replaced by a newer, more expensive version with the same name that is based on the TI-36X scientific calculator.) The speech module provides options such as how numbers are spoken. For example, "1,230" can be spoken as "one two three zero" (the default mode) or "one thousand two hundred and thirty" (descriptive mode). The speech module also provides a training mode that lets the user find the appropriate key on the calculator without the calculator attempting to act on the input from the keyboard.
- Two graphing calculator software programs. Both the Accessible Graphing Calculator (or AGC), available from ViewPlus Technologies[5], and MathTrax[7] attempt to provide access to graphs by giving the user the ability to input an equation which is immediately plotted on the screen. The programs both use rising and falling pitches to denote the relative position of the dependent variable; time is used to denote movement along the axis of the independent variable. The AGC also offers a calculator mode and a scratchpad for entering equations with named variables[8]. MathTrax is a free download, but requires the user to supply his or her own screen-reading software for voice feedback. The AGC is sold commercially, but is self-voiced. MathTrax does offer one advantage over the AGC: it is able to interpret the form of the equation and automatically provides a text box describing some of the chief characteristics of most forms of equations that middle and high school are likely to encounter.
- Two physical aids for preparing tactile 2D graphs. Both the Graphic Aids for Mathematics, available from the American Printing House for the Blind[9], and the Raised Line Drawing Kit, available from LS&S, LLC[10], provide tactile methods for blind students to prepare graphs independently. Users of the Graphics Aids for Mathematics place pushpins on a rubber board embossed with a 34 x 30 grid. Users can use rubber bands placed around the pushpins to represent straight-line graphs, or flat spring wires to represent circles or conic sections. The Raised Line Drawing Kit provides a rubber board to which 8 ½" x 11" mylar polyester film sheets can be attached. The user can write or draw on the film sheets using a pen-type stylus, which causes the film to pucker as the stylus is pressed onto the paper. The film sheets that come with the Raised Line Drawing Kit are not marked; we created paper sheets with a grid that our students could use for creating graphs.

Results

Training Materials

We found that the translation of instructional materials from Scientific Notebook to Braille was very effective, after we discovered and eliminated some minor formatting problems. For example, though the multiplication symbol can be written in a variety of ways, such as a dot, an "x", or an asterisk, only the dot was translated correctly into Braille. We found that substituting a single space for a tab, and adding extra lines between sections, improved the readability of the

Braille documents. Once we eliminated these formatting issues, our tutors only found one additional error in the Braille materials we generated.

Assistive Technology

We found that the Orion Talking Scientific Calculator was a very effective tool for performing math calculations. The training mode helped students unfamiliar with the calculator to learn the location of the functions quickly. Though the number keys are concave rather than convex, as are the rest of the keys, the students would like to have had a raised dot on the number 5 key to help them reposition their hands. In addition, the students preferred to use the calculator in the fixed-decimal mode; however, the calculator lost this setting after automatically shutting itself off when not in use.

The two graphing software programs are each somewhat useful; however, both rely on sound to provide auditory cues about the shape of a graph. The students had some difficulty grasping the shape of the graph based only on the audio-only display. Though the author of MathTrax worked to find an optimal method for auditory-only display of graphical information[11], researchers have found that graphs are more easily interpreted by a combination of modalities, particularly auditory displays combined with a haptic display[12 13 14]. Though both programs offer users the ability to print graphs to a tactile printer such as a Braille embosser or thermal expansion printer, neither program provides an easy mechanism for changing the default font for labels to Braille, even when Braille fonts are installed on the host PC.

Both physical aids for preparing 2D tactile graphs are useful. Students enjoyed the large working surface of the Graphic Aids for Mathematics, with the wide spacing provided between grids. The Raised Line Drawing Kit was harder to use, requiring some effort to draw the lines on the pages we created with grids. However, the Raised Line Drawing Kit is smaller, and therefore more portable. It also offers a permanent record of the graph in case the teacher needs to explain his or her grade for a graph.

Discussion and Conclusions

We were pleased that much of the technology that we tried worked quite well for instruction. With the system we implemented for creating Braille notes, a sighted instructor can be confident that by following a few simple rules he or she easily can provide Braille versions of handouts or worked-out examples for blind students. However, the technology is still quite expensive; the Braille embosser alone that we used costs $4,000.

Though we were fortunate to have knowledgeable math mentors who could read and grade Braille assignments, an instructor who does not know Braille or the Nemeth Code can simply ask the student to read their homework aloud so that the instructor can check their work.

Finally, we were disappointed that we were only able to cover about half the material we had planned for the three-week camp. Even with the best technology available, the students required much more time to complete their assignments than we had expected.

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