Using Mathematics eText in the Classroom: What the Research Tells Us

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Abstract

This paper discusses the findings from two research studies where middle-school students with learning disabilities used eText containing MathML with assistive technology, and draws conclusion from these combined findings. The University of Kentucky Curriculum Conversion and Implementation research strand was conducted as part of the Mathematics eText Research Center (MeTRC), a federally-funded national research, led by the University of Oregon. This research strand was designed as a follow-up to Project SMART (Supported Math Accessibility Reading Tool), an earlier project at the University of Kentucky. Project SMART indicated the utility of math eText using Mathematical Markup Language (MathML) as an effective accessible format for students with reading disabilities. The subsequent MeTRC/KY research project was a case study examining the pragmatic issues around the utilization of math eText in a middle-school classroom setting, such as the conversion of a complete math curriculum using MathML, training needs for staff and students, hardware and software issues, and technical support needs. While both studies noted implementation challenges in real-world classroom settings, student results nevertheless indicated better utility and improved academic performance when mathematics eText was available.

Keywords

Mathematics, etext, MathML, learning disabilities, assistive technology

Introduction

The utilization of eText with synthetic speech technology has a long history in the disability field. One of the first coordinated efforts to produce accessible eText materials for use with assistive technologies was led by George Kerscher, when he founded Computerized Books for the Blind at the University of Montana in 1988 (Lingane, Noble & Senge, 2002). However, the nature of math notation--which makes extensive use of non-ASCII symbols and two-dimensional layout--the ability to include math equations and elementary 2D math problems in a format that synthetic speech technologies can interpret, the availability and usage of math eText has been slow to emerge. This situation has changed in recent years due to the standardization of Mathematical Markup Language by the W3C, which issued the first MathML specification in 1998. The most current specification, MathML 3.0, was released in 2010, and the 2nd edition was issued in 2014 (http://www.w3.org/TR/MathML3/). The support for MathML in both mainstream and assistive technologies continues to grow, with integration in most of the newest major format specifications, such as DAISY3, HTML5 and EPUB3.

Nonetheless, there are pragmatic concerns and questions within the education community as to the utility and effectiveness of accessible mathematics eText as a viable alternative format for the widespread population of K-12 students with reading impairments. While larger postsecondary institutions and state schools for the blind often have designated staff and teachers with specialized training and experience in alternative format creation and assistive technology support, such personnel are typically lacking in mainstream school districts. Therefore, the findings of research actually conducted in K-12 school settings, as detailed in this paper, are highly valuable to the field.

Discussion

This paper discusses the findings from two classroom-based research studies where middle-school students with learning disabilities used eText containing MathML with assistive technology. The University of Kentucky Curriculum Conversion and Implementation research strand was conducted as part of the Mathematics eText Research Center (MeTRC), a federally-funded national research, led by the University of Oregon. This research strand was designed as a follow-up to Project SMART (Supported Math Accessibility Reading Tool), an earlier project at the University of Kentucky. Project SMART indicated the utility of math eText using Mathematical Markup Language (MathML) as an effective accessible format for students with reading disabilities (Lewis, Noble and Soiffer, 2010). The subsequent MeTRC/KY research project was a case study examining the pragmatic issues around the utilization of math eText in a middle-school classroom setting, such as the conversion of a complete math curriculum using MathML, training needs for staff and students, hardware and software issues, and technical support needs. While both studies noted implementation challenges in real-world classroom settings, student results nevertheless indicated better utility and improved academic performance when mathematics eText was available.

One of the fundamental questions for the field, however, is whether supplying accessible math eText to K-12 students with identified reading disorders (e.g., a specific learning disability affecting reading) who then use it with synthetic speech technology is useful to students as a reading accommodation. Throughout the K-12 education community, one of the most commonly provided reading accommodation--in both classroom instructional and assessment settings--is having a teacher or staff member read aloud to the student whose disability adversely impacts

their ability to read print. This is especially true on end-of-year state assessments (Clapper, Morse, Lazarus, Thompson, & Thurlow, 2005).

The rationale for human readers is easy to see, since it requires little preparation or planning. However, in practice, it is unclear if this form of accommodation is truly useful for students with reading impairments, as it is typically dependent upon students to request a read-aloud each time it is needed. For instance, during classroom observations conducted as part of the MeTRC KY research strand, researchers found that the provision of read-aloud accommodations by human readers in the context of math classroom instruction among middle-school students was very rare, even though included on students' IEPs. This was true even for students who were taught in a resource room setting.

However, one important finding of this study was just how inaccessible printed math material was for these students. The project's testing of students' ability to properly decode mathematics instructional content showed that these students had significant issues with processing the symbolic content of middle-school math. Students in the study sample exhibited an average error rate of 6.7% in reading plain text, but there error rate for reading math symbolic content soared to 36%, which illustrates the significant obstacle these students were facing in reading math content on their own (Lewis, Lee, Noble & Garrett, 2013). In many respects, this finding defies common belief that sighted students with reading disabilities studying math only need to use text-to-speech applications when trying to read word problems. Much to the contrary, students need speech access to the math notation itself, even more so that to the textual portions of math materials.

This realization of a true access barrier to the comprehension of mathematics materials in print form helps to set the state for an understanding of what happens when these same students have access to accessible digital math content instead of printed math. Students in both the prior SMART study as well as MeTRC/KY research exhibited marked improvement in math performance when given math eText which included MathML, which allowed their assistive technology software (in this case, Read&Write Gold by TextHelp) to read both the text and the math expressions in a seamless manner. In the case of Project SMART, when 8th grade students using MathML-encoded eText versions of the pre-algebra textbook "Say it with Symbols" (from Pearson's Connected Mathematics 2 Program) were given pre-post unit tests, intervention students from all three different schools in the study fared better than those in the control group who received standard read-aloud accommodations, ranging from an average increase of 8%, to 14% to 16% among the intervention students when compared to the control group (see Table 1 below). The fact that the other textbooks in the study which had lesser amounts of symbolic math content (and hence, a lower MathML density as referenced in Table 1) showed less consistency in student outcomes helps to confirm the fact that for such students reading the plain text is not near as much of an issue as reading the type of symbolic math notation commonly found in middle-school and later math content.

Table 1. Comparison of Pre-Post Test Difference in Intervention vs. Control Samples for Students Using Math eText with MathML (Difference Intervention vs. Control in Four Classroom Settings (3 semesters))

Book Title	**Notational Complexity**	**MathML Density**	**CW-Spring 08**	**CK-Spring 08**	**SE-Fall 08**	**SE-Spring 09**
Say it with Symbols	High	10.95	+14%	+16%	+8.01%	--
Filling/ Wrapping	Low	0.86	+16%	--	--	--
Samples	Very Low	0.35	-3.4%	+10%	--	-5.4%

The results from the MeTRC study revealed similar results. In this case, both the intervention classroom and the control classroom were taught by the same teacher using the identical curriculum, the primary difference that the intervention group used MathML-encoded eText while the control group used standard read-aloud accommodations. Students using math eText outpaced students who did not by more than double, with a yearlong average gain in MAP (Measure of Academic Progress) math scores of 16.67 points for the students using math eText and only 8 points for the control students. One remarkable aspect in this study was that the special education students who used the math eText outpaced even the whole seventh grade as an average, in which the special education students represented the students who--before the study--had the most trouble with math performance. In a sense, these special education students with a history of struggling in math were able to compete on par with their non-disabled peers when they had access to their math content in MathML. That finding is certainly noteworthy.

Table 2. Comparison of MAP Math Scores for Intervention vs. Control Samples for Students Using Math eText with MathML

Students' Math Class	**October Math Score**	**January Math Score**	**April Math Score**	**Oct-Jan Math diff**	**Jan-Apr Math diff**	**Oct-Apr Math diff**
2nd period res. avg. (control group)	196.60	196.20	204.60	-0.40	8.40	8.00
5th period res. avg. (intervention group)	**187.00**	**193.177**	**203.67**	**6.17**	**10.5**	**16.67**
7th grade overall avg.	223.4	226.8	238	3.4	11.2	14.6

Furthermore, qualitative data tracked by both research projects indicated that both students and teachers found math eText to be highly effective in providing access to math instructional content. Positive factors for teachers included that not only did students seem to do better with math eText, but it also freed up more teacher time for real teaching rather than reading text out loud to the class. In addition, students generally preferred reading support through the computer as a independent access to text and which gave opportunities to reread passages at their own pace, something which has been noted in other research (Flowers, Hong Kim, Lewis, and Davis, 2011).

Conclusions

On the down side, both research studies uncovered problems related to the reliability of hardware and software in school settings. These problems actually had no connection to using MathML per se, but were rather connected with the fact that using any digital content requires access to computer technology of one form or another. In both of these studies students used

laptop computers which were connected to the school's wireless networks. Common issues included dead laptop batteries, wireless access problems, forgotten passwords, and IT updates which caused previously working software installations to suddenly stop working. Furthermore, teachers and students even found the time it took to start up and shut down computers problematic. Of course, these issues can occur with any technology, but such problems--if pervasive enough--can be a motivating factor for schools, teachers, and students to abandon use of eText of any form and revert back to the "old reliable" human read-aloud accommodation.

Additional questions which these studies uncovered include:

- How do schools support technology and train staff and students when there's only one teacher? Again, this would be true of any use of technology, but it is a question which must be addressed before an effective implantation of eText usage can occur.
- Where do schools get math eText content already made and ready to use? Only a few publishers are doing this now, so this continues to be a question to consider.
- How can teachers create their own math eText? Some teachers still use pen and paper and chalk boards to write math. While many math teachers have figured out how to use word processing applications like Microsoft Word to write math equations (or perhaps use products like MathType), most don't understand how to export those documents to MathML so that assistive technologies can render the math as speech. Training and support of teachers in creating their own accessible math materials is an area needing much more attention in the field.

What's next?

To further support schools wanting to implement math eText, a number of steps have become evident to move the field forward:

- The need for awareness and training resources on the use and creation of math eText. There are precious few resources available to teachers and support staff which discuss all the steps and software needed to create and use math eText.
- The need for publishers to adopt MathML in mainstream eBook production. One great help to schools would be the availability of accessible eBooks that are "ready to use" from the publisher complete with MathML. Though Pearson has started to do this with their HTMLBooks collection, few other publishers have done the same.
- The need for MathML support in OCR scanning applications. Other than a little-known application called InftyReader, none of the standard OCR applications support MathML.

In conclusion, while some aspects of the need for supporting teachers and schools in the use of mathematics eText using MathML still need further attention by the field, the outcome of classroom-based research projects like the two discussed here demonstrate the growing evidence of promise for accessible digital mathematics content. With the growing support for MathML in both mainstream and special technology applications and growing adoption among publishers, the education community will be well served by embracing efforts to implement math eText for all educational mathematics materials.

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