Digital versus Traditional: Secondary Students with Visual Impairments' Perceptions of a Digital Algebra Textbook

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Structured abstract: *Introduction:* Digital textbooks are increasingly marketed and used, yet little research examines this medium. Within the limited research, even less investigates the role of digital textbooks in mathematics—a challenging content area for many students, but especially for students with visual impairments. *Methods:* Through a qualitative analysis, this study sought to understand the nature of the use of a digital algebra textbook to support secondary students with visual impairments in algebra. *Results:* The results suggest three main themes: (a) students' dependence on their traditional textbook medium, (b) educators' reactions to the technology, and (c) the benefits of using the digital textbook despite resistance. The three themes culminate in clear student preferences for traditional textbooks. *Discussion:* The general resistance to use of the technology warrants caution in terms of schools moving forward with the adoption of digital textbooks, and it suggests that additional examination of the topic is needed. *Implications for practitioners:* Practitioners can consider using digital textbooks, but they will need to ensure that they and their students are both properly motivated and adequately trained to use such technology.

Digital-based learning is increasingly being used in primary and secondary education, and it is likely to continue (Collins & Halverson, 2010). Publishers are more and more often producing digital textbooks for students—a venture that has been supported by the U.S. government, which indicated the goal of providing a digital textbook for every child by 2017 (Mardis & Everhart, 2013; Toppo, 2012). However, not everyone receives equal access to digital learning. Students with visual impairments face greater challenges in accessing digital learning without readily available, specialized software (Douglas et al., 2011; Siu & Lam, 2012).

Even with digital learning, students with visual impairments do not possess equal access to all information. These students generally experience greater access to digital learning in literacy as compared to mathematics (Nees & Berry, 2013). They regularly use screen readers such as Job Access With Speech (JAWS) and optical-character recognition software such as Complete Reading System to access text (Fichten, Asuncion, Barile, Ferraro, & Wolforth, 2009; Freedom Scientific, 2013).

Screen readers read materials on the screen, such as digital textbooks, and provide aural feedback to individuals. Although screen readers provide quality access to text materials, their application in mathematics is limited (Power & Jürgensen, 2010).

Learning mathematics can be challenging for students with visual impairments because of the typically visual nature of the way in which such content is presented (Alajarmeh, Pontelli, & Son, 2012). For this reason, mathematics is a difficult area for the application of digital text (Bouck & Meyer, 2012; Power & Jürgensen, 2010). With the digital presentation of mathematics, one needs to ensure the interpretation is unambiguous. Many traditional screen readers treat a mathematical expression as an image; semantic cues are left out in order to aid interpretation (Archambault, Caprotti, Ranta, & Saludes, 2012; Cooper, Lowe, & Taylor, 2008). For example, consider the expression, "*y* equals five over *x* plus 2." An individual with visual impairment who hears this expression from a screen reader may infer two different, yet technically correct, interpretations: $y = \frac{5}{x+2}$ or $y = \frac{5}{x} + 2$. Access to one unambiguous interpretation is essential for visually impaired students.

Researchers are focused on providing quality access to digital text in algebra (Bouck & Meyer, 2012). Although the research base is limited, researchers found that technologies offer the potential to provide digital text to students with visual impairments. Bouck, Joshi, Meyer, & Schleppenbach (2013) found that students with visual impairments could understand algebraic expressions presented via digital text using ReadHear—a supported eText program. Students answered questions about an algebraic expression (provide the exponent, describe the expression) after listening to the presentation via the technology. Alajarmeh and Pontelli (2012) found that visually impaired secondary students increased their accuracy when solving algebraic equations using MathPlayer—a mathematical text-to-speech software—as compared to their traditional ways of accessing printed text. Conversely, Bouck & Weng (2014) conducted a single-subject design study to compare the performance of secondary students solving algebraic equations when presented via ReadHear and via the students' traditional means of accessing text. The majority of students preferred their traditional textbooks, and students answered more problems correctly with their traditional textbooks.

Despite the importance of providing access to mathematics, both the challenge in presenting higher-level mathematics to students with visual impairments and the limited research regarding technology to do so remains. Through this qualitative study, the authors sought to understand the experiences and perceptions of five visually impaired high school students who were accessing algebra via a digital textbook. The study sought to understand the nature of the use of digital algebraic text to support secondary students with visual impairments.

Methods

Participants

Five students with visual impairments from the same state school for blind individuals participated in this study. All five students were enrolled in the same

Algebra 1 class, taking it for the first time, and were the only students enrolled in the class. Human subjects approval was obtained by the Human Research Protect Program at Purdue University, and informed consent was received for all participants.

Ana

Ana (a pseudonym) was a 22-year-old, 12th-grade, Hispanic, female student. She fluently spoke Spanish and English, and was identified in a medical report as legally blind, with light perception in her right eye. Ana's file indicated multiple diagnoses related to her visual impairment, including retinopathy of prematurity with legal blindness, present at birth; nystagmus; strabismus; microcornea; cataract; and scarred central cornea with band keratopath. Ana's achievement data indicated a score of 112 for Broad Reading and 84 for Broad Mathematics (84 for Calculation and 86 for Reasoning) on the Woodcock-Johnson III Tests of Achievement (WJ-III; Woodcock, Mather, & McGrew, 2001); no intelligence quotient (IQ) data were available. Ana read braille textbooks and used JAWS on her computer to access other materials. At the time of the study, she was awaiting acceptance to a state university, where she planned to major in psychology.

Alana

Alana (a pseudonym) was an 18-year-old, female student enrolled in the 11th grade. English was her second language; she was adopted from Ethiopia as a teenager. Alana was identified in a medical report as blind, reportedly having lost her eyesight at the age of 8. She had no light perception in either eye, and her left eye was enucleated. Alana was also identified with scoliosis and muscle contraction at the waist and hip. She primarily used braille, and recently learned to use JAWS on a computer. No ability or achievement data were available. Alana wanted to be a teacher.

Kim

Kim (a pseudonym) was a 17-year-old, Caucasian, ninth-grade, female student with total vision loss; she was totally blind with bilateral prostheses, caused by a hereditary condition. Kim's IQ data—from the Wechsler Intelligence Scale for Children, Fourth Edition (WISC-IV; Wechsler, 2004)—indicated 91 for Verbal Comprehension and 94 for Working Memory index. Her file indicated that no additional testing was deemed appropriate. On the WJ-III (Woodcock et al., 2001), completed using the braille adaptation version as well as with an abacus and Perkins Brailler, Kim's standard scores were 97 for Brief Reading, 95 for Reading Comprehension, 81 for Brief Math, 92 for Math Reasoning, and 98 for Basic Writing Skills. Kim wanted to pursue music as a profession.

Josh

Josh (a pseudonym) was a 17-year-old, Caucasian, male student in the 11th grade who was identified in a medical report as having low vision. Josh's individualized education program (IEP) identification was multiple disabilities, including visual impairment and ADHD. He was also identified with anxiety disorder and Axenfeld-Rieger syndrome. Josh's vision data indicated that he possessed 20/250 vision in his right eye, no light perception in his left eye, and that he had glaucoma.

On the WISC-IV (Wechsler, 2004), Josh's Verbal IQ was 106 and his Working Memory was 83; a full-scale IQ was not available for Josh, since certain subtests were not administered. Achievement scores for Josh included 92 for Broad Reading and 86 for Broad Math (95 for Calculation and 58 for Math Fluency) on the WJ-III (Woodcock et al., 2001). Josh used large print and a desktop CCTV magnifier. He wanted to attend culinary school and become a chef.

Jorge

Jorge (a pseudonym) was a 16-year-old, Hispanic, male student in the ninth grade who was identified as having low vision in a medical report. Jorge's vision was 20/400 in his right eye and 8/400 in his left eye; his visual conditions were identified as microphthalmia; retinal, optic nerve coloboma; and nystagmus. Jorge self-disclosed that he had trouble focusing visually on numbers as well as on certain mathematical symbols (such as a fraction symbol or a negative sign). On the WISC-IV, Jorge's verbal IQ was 110 and working memory was 97 (Wechsler, 2004). His achievement data, on the WJ-III (Woodcock et al., 2001), were an 89 for Broad Reading and 86 for Broad Math. Jorge's WJ-III scores represented a 5.1 grade-level equivalency for Calculation and 3.1 for Math Fluency. Jorge accessed print via large print with a magnifier, CCTV, or portable RUBY handheld video magnifier. Jorge wanted to pursue a career in computers, music, or science.

Setting

The study occurred at a state school for blind individuals, which enrolled students in kindergarten through 12th grade. The majority of the students resided at the school during the week and returned home on the weekends. Researchers collected data in one Algebra 1 class, which typically met for a 70-minute period each day in a five-day week; observations occurred on 23 different days throughout one academic year. The classroom was a large room with desks arranged in a "U" shape facing a large television screen. The course itself was provided by a "teacher-in-a-box," as described by the school. The students came to the class, but the teacher was not physically present. Regan (a pseudonym), a certified mathematics teacher for students with visual impairments, taught the course remotely in a distance-education model. She appeared on a television screen, connected to a computer equipped with a webcam. Each student in the class typically had a desktop computer; for the purposes of the study, each student used a laptop. The teacher accessed each student's individual computer through Microsoft Lync. During all lessons, an aide was in the classroom to provide face-to-face assistance to the students.

Materials

The Algebra 1 course used the textbook *Algebra 1* from Glencoe McGraw-Hill (Holliday et al., 2008). The textbook was rendered as a digital version to be played on the ReadHear player produced by gh, an assistive technology company; the digital version was rendered by gh in DAISY format. Students also had access to their braille, and large- or standard-size print versions of the textbook. ReadHear is a supported electronic text player developed by gh (2011) that was designed to read digital text—specifically formats such as DAISY, Digital Talking Books, and National Instructional Materials Accessibility Standard (NIMAS). ReadHear supports MathML-embedded format with the output language of MathSpeak (gh, 2006). ReadHear offers accessibility and customization features: zooming; panning; different voices; color adjustment for background, text, highlighting, and tracking; speaking rate and volume control; and multiple navigation modes.

Procedures

This study used qualitative research methodology to explore students' use of a digital algebra textbook via a supported eText player (ReadHear) to learn the Algebra 1 curriculum. Specifically, researchers examined the role of the digital textbook to enact the algebra course and algebraic understanding. Data were collected through online surveys and observations (Bogdan & Biklen, 2008).

Training

Prior to students' using the digital textbook, they were trained as a group by the researchers on how to use ReadHear and the digital algebra textbook during an extended class period. The researchers demonstrated the accessibility features of ReadHear and how to use it (for example, open the algebra book, read the text, skip to a new section). The training included the different aspects of navigation, such as keyboard shortcuts or using the mouse. The researchers also discussed the MathSpeak language and provided examples. During the training, students selected their individual accessibility preferences and demonstrated that they could open, navigate, read, and close the digital algebra textbook using ReadHear. Training was complete once they could perform each of these steps without assistance. The in-class aide participated in the training.

Online survey

Students completed 16 preintervention and 20 postintervention questions—primarily open-ended—using the SurveyMonkey website; the website was recommended because of its compatibility with screen readers. The first questionnaire at the beginning of the school year consisted of four parts: students' current school experiences and their future plans; students' perception of learning mathematics and algebra, specifically; the strategies or technology used in learning content domain knowledge, including mathematics; and students' initial thoughts on the technology. The second online survey questionnaire, administered at the end of the school year, contained three parts: students' perceptions regarding learning algebra online and via a digital format; students' experiences on using the specific technology; and 10 three-point Likert-scale (agree, disagree, no opinion) statements about algebra, types of textbooks, and ReadHear (see Table 1).

Observations

Observations were conducted in the classroom by the researchers primarily through video recordings via students' Dell laptops using Camtasia software (TechSmith, 2012). Seventy-three separate Camtasia files existed, totaling 2,240 minutes of recordings. Researchers took field notes from the videos, noting activities, actions, and statements of the participants. Researchers documented the time of each observation and objective

Table 1
Students' end-of-school-year survey responses regarding ReadHear and traditional textbooks.

Participant	Easily understand algebra with traditional textbook	Easily understand algebra with ReadHear	Would rather use ReadHear than traditional textbook	Want to keep using ReadHear	Want to keep using traditional textbook	Easy to understand and use ReadHear
Josh	Agree	Agree	Agree	Agree	Disagree	Agree
Ana	Agree	Agree	Disagree	Disagree	Agree	Agree
Jorge	Agree	Neutral	Neutral	Neutral	Agree	Agree
Kim	Agree	Agree	Neutral	Disagree	Agree	Agree

Note: One student, Alana, opted not to complete the survey at the end of the school year.

observations (what was objectively occurring in the video, such as 0:13 "Josh opens the start menu" and 0:16 "Josh closes the start menu") in the field notes. Researchers also noted subjective observations, where researchers noted inferences. In the objective example above involving Josh, for instance, the researcher wrote, "Is Josh confused?" given that Josh was opening and closing the incorrect menu for opening the ReadHear program, which is what he was asked to do.

Data analysis

Researchers analyzed the data by reading the field notes from the video recordings and interviews. The field notes were organized into a binder chronologically. The observations formed the basis of the data, although the interviews and survey responses were used to corroborate. The researchers repeatedly read the data to identify inductive codes. The inductive codes were condensed to develop themes, and the data were coded into the themes. The researchers sought typical analytical vignettes to support their assertions (Bogdan & Biklen, 2008). The researchers also calculated frequencies for the Likert scale survey responses.

Context

The school, in collaboration with the authors and other entities, received a grant to implement and investigate digital algebra textbooks for students with visual impairments. The course was to be taught through the use of the digital textbook. This study represents the second year of data collection, but the first year of full implementation; year one of the study involved implementation with different students for one chapter of an algebra textbook.

Results

Three main themes emerged from the data: students' dependence on their traditional textbook medium, educators' reactions to the technology, and benefits of using the digital textbook despite resistance. The first two themes demonstrated that most students preferred their traditional textbooks, despite their acknowledgements of the benefits of the digital textbook. The preference for print varied among students and was not neatly parsed by severity of visual impairments.

Dependence on traditional

Students demonstrated a dependence on their traditional textbooks—braille, large print, or standard-size print. Not only did the majority of students indicate a preference for using their traditional textbook on the survey administered at the end of school year (see Table 1), but students also repeatedly sought to use the traditional textbook, despite the intention for students to use the digital textbook as the only textbook throughout the year.

Alana, a student who particularly struggled with the technology (with JAWS and hot keys, for instance), would request and receive a traditional textbook in class, as evident in the following vignette.

> At the start of class, Regan was explaining what the students were to do. "Right on page 70. We're going on pages 70, 71, 72, 73. All the way to check your understanding. There are two, three, four, five questions you are to answer as you listen [via the digital textbook]. I want you to listen to the section, view the problem, listen to the next example, and if you don't understand, I just want to see you do the best you can without asking for help." Alana requested a hard copy text, "Do we have a textbook for that?" And again, five seconds later, "Can I have a textbook too?" When the classroom aide brings her a textbook, she flips to the book to get the correct page (field notes, 11/1/12).

In another example, Regan wanted to discuss the assignment with students at the end of class. One of the students asked if they could close the digital textbook, to which she replied, "Unless you want to use it to read your assignment." Both Kim and Ana verbally responded no; the four students, minus Josh, then completed their assignments using their traditional textbooks (field notes, 10/1/12).

Of the five students, only Josh was in favor of the digital textbook on the surveys and in classroom observations. The other students disagreed or were neutral about using the technology versus their traditional textbooks, as well as about continuing to use the technology (refer to Table 1). All of the students, with the exception of Josh, felt it was easier to use physical books "to look at things" (Jorge, survey, 5/21/13); to "look back at errors, graphs, and maps by touching" (Kim, survey, 5/31/13); or just for their own comfort—"I am more comfortable using braille" (Ana, survey, 5/21/13).

Educators' reactions

The second theme, educators' reactions to the technology, was surprising given the teacher's initial positive perspective towards implementing the digital textbook and her involvement since the beginning of the overall project. The teacher and her in-class aide supported, and at times appeared to encourage, the students' preferences for traditional textbooks. For example, at the start of the second semester, the teacher stopped asking the students to use the digital textbook in class; instead, students could access the digital textbook in their cottages in the evenings. Although in theory this construction more closely resembled a typical classroom situation, with students being expected to read the material prior to coming to class, it also subtly reinforced some disdain for the technology, particularly when coupled with staff members trying to discourage students from using the digital textbooks, as illustrated in the following vignette.

> Regan instructed the students to read the section on evaluating algebraic equations and expressions. Josh is listening to the text via the digital textbook, including going through two examples as requested. When Josh is done listening, he tells his teacher[,] and she begins writing on her whiteboard and asking the students questions about order of operations. After completing one example, Regan instructs the students to independently do another one from the text. Josh puts on his headset and the classroom aid[e] asks, "Do you have your textbook with you?," [sic] to which Josh replies "My dog ate it." The aide responds by telling him his textbook is right next to him and to turn on the CCTV to see the textbook. Josh listens to the digital textbook and does not open the hard copy (field notes, 9/19/12).

Benefits despite resistance

The final theme that emerged from the data involved students acknowledging the benefits of digital algebra textbooks, despite their own and educator-enhanced resistance. In terms of redeeming qualities, students noted that it was easy to understand and use the digital textbook, and that they wanted to learn more about technologies that would help them access algebra (see Table 1). All of the students felt other students could benefit from using digital textbooks. For example, Kim said that other students could benefit because "They can carry less things on their back and not have to worry about forgetting anything." Kim was referencing the large number of braille volumes that make up a single textbook that would be replaced by a single digital textbook, as well as the benefit of being able to carry all classroom materials inside a computer. Kim felt the physical trade-off of not having to carry so many braille volumes was a positive feature of digital technology (Kim, survey, 5/31/13). In terms of physical comparison, the students also spoke positively about the ease of navigation of the digital textbook. Many of them commented that they could find the correct pages more easily or that, "Navigation within the book is quite easy and fast" (Ana, survey, 9/18/12).

Discussion

Given the increased access and use of sophisticated technology in all education, let alone in the education of students with visual impairments, it is important to understand if and how such technology works. Specifically, it is necessary to examine the use of technology for specific content areas and how it affects student learning. This study sought to understand the nature of the use of a digital textbook to support secondary students with visual impairments in algebra. The results suggest that the majority of students preferred and used their traditional textbooks. The general resistance to the use of technology warrants caution in terms of schools proceeding with the adoption of digital textbooks and suggests additional examination on the topic is needed.

For all but one student, there was a clear preference for using a traditional textbook. Although the students began the study with optimism in their views of the digital textbook and expressed the desire to replace their traditional textbooks, after only a few uses of the digital textbook, they were reluctant to use it and opted to use their traditional textbooks when given the opportunity. With the exception of Josh, all students spoke of the need to look at or touch things, such as numbers or graphics, within a physical textbook. Note that the digital textbook verbally described graphs, figures, tables, and pictures, but students could not receive any tactile information from it. Although the majority of the students said that the digital textbook presented algebra in an easy-to-understand and sometimes simple manner, resistance occurred regarding their inability to physically hold the textbook.

The preference for using a physical textbook over a digital textbook is supported in previous research. Woody, Daniel, and Baker (2010) found that college students without documented visual impairments preferred physical textbooks to e-books, despite students possessing the technological expertise and experience to successfully use e-books. Although the preference for traditional textbooks of students in the present study mirrors results from previous research, which largely involved college students without disabilities (Precel Eshet-Alkalai, & Albertson, 2009; Woody et al., 2010), the rationale may be different. Previous researchers found technological limitations with e-books, such as the discomfort students reported from reading text on a computer screen (Spencer, 2006). However, any potential discomfort in this study was likely experienced differently, since participants listened to the text rather than reading it. Although the students indicated access to graphics via listening as opposed to touching was difficult, there is also the possibility that the change was difficult and that these high school students were not ready to change from something they knew worked pretty well (their traditional textbooks) to something that was an unknown for mathematics course work.

A logical consequence of the lack of preference for the digital textbook was an underutilization of the technology, at both the teacher and student level. The underutilization contributed to the underappreciation or devaluation of the digital textbook. As noted, during the second semester the students never used the digital textbook in class; if textbooks were needed, students used their traditional ones. Again, although reading the digital textbook in the evenings reflects what typically occurs for students in mathematics classes, one has to wonder why the technology was not also taken advantage of during class time. To best illustrate, after using the digital textbook for six months, the majority of the students stated that they had yet to actually solve a problem read from the digital textbook. When asked to independently solve algebraic problems, such as for homework, students used their traditional textbooks.

Implications for practitioners

This study holds implications for practice. It suggests that educators should proceed with caution when implementing, or when considering the implementation of, digital textbooks. Student preference, including willingness to use digital textbooks, is an important aspect of assistive technology considerations and decision making for students with disabilities (Bryant & Bryant, 2003). It is important that educators select technology that students will actually use, which helps to decrease assistive technology abandonment (Johnston & Evans, 2005). Educators also need to consider the pros and cons of students with visual impairments accessing mathematics solely via a digital textbook. Although reliance on audio for students who are blind and audio and visual for students with low vision is potentially concerning, given the value of tactile feedback, previous research suggests the reliability of accessing mathematics aurally and students' ability to understand mathematics presented aurally (Bouck et al., 2013; Wongkia, Naruedomkul, & Cercone, 2012). Support exists for the oral reading of mathematics assessments as an accommodation for students with learning disabilities, indicating that an understanding of mathematics through listening is possible (Bolt & Thurlow, 2007). However, oral presentation is not without its challenges (Nees & Berry, 2013).

Limitations and future directions

This study has limitations. For one, given its qualitative nature, the results are not intended to be generalized to a larger population, but represent the experiences encountered by the students in this case study. Another limitation is the lack of involvement of the teacher in the study in terms of participating in interviews. The data represent the students' perspective, but fail to fully account for the teacher's point of view. In addition, the teacher—while initially interested in and willing to implement the digital textbook—appeared to grow quickly and increasingly reluctant to do so. The results, as with all qualitative case studies, are limited to the situation examined. Most likely, if the case study had involved a teacher who had been more willing to implement the technology—or more willing to enforce students' use of the technology—the results would have been different and might have present a more positive proof of concept. Another potential limitation, although the authors viewed it as data, is the teacher's discontinuation of the digital textbooks in the class during the second semester. Finally, perhaps the amount of training time provided or the overall quality of the training was insufficient for students' sustained use of the technology or their preference for doing so.

Clearly, additional research is needed regarding the access, use, and impact of digital textbooks in algebra for students with visual impairments. Within the increased adoption of digital text in and out of schools (Mardis & Everhart 2013; Toppo, 2012), it is imperative that educators understand the issues and impact of such decisions for all students, including students with visual impairments. An area of need for future research includes additional studies comparing learning outcomes for students who access algebra through digital textbooks as compared to traditional textbooks.

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