Reading Math: A Comparison of Reading and Listening to Algebraic Problems

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Digital text is being used in elementary and secondary education for students with and without disabilities, but without much consideration as to its impact on student outcomes. This single-subject alternating treatment design sought to understand how the performance of three secondary students with visual impairments was impacted by accessing algebra via a digital textbook in comparison to accessing it via a traditional textbook. The main findings of this study suggested that (a) students tended to solve the algebra equations better when they were presented via their traditional textbook; (b) task completion was longer for all three students when using the digital textbook, although the amount of time differed across students; and (c) two of the three students preferred their traditional textbook and one preferred the digital textbook. The results hold implications for the implementation of digital text in mathematics for students with disabilities and suggest that continued research is needed.

Today's students are part of the digital generation, growing up in an online world (Gray, Davis, & Liu, 2012). In other words, more and more activities and information are being done and conveyed in a digital environment, such as through use of computers or mobile technologies (Anderson-Inman & Horney, 2007; Battro & Fisher, 2012). Reading is among the activities that are increasingly going digital (Biancarosa & Griffiths, 2012; Liu, 2005). Now, one does not need to possess a physical copy of a text to read; one can read a book on his or her Kindle, Nook, iPad, or even smartphone (Daniel & Willingham, 2012; Johnson, 2009; Larson, 2010).

The move to digital text also is occurring in our educational environments (Battro & Fisher, 2012). College students can elect to purchase or rent a hard copy or a digital version of the textbooks for their courses (Reynolds, 2011). Elementary and secondary students are not being left out of this opportunity either; increasingly, publishers are providing digital textbooks for K–12 students (Mardis & Everhart, 2013). Schools also are jumping on the digital text bandwagon through mobile technologies, such as iPads for PK–12 students (Bonk, 2010; Toboni, 2011). In fact, the United States government supports the production of digital textbooks with a push for digital textbooks for every student by 2014 (Toppo, 2012). The move to digital text is fueled by many factors, including greater relevance (i.e., avoid out-of-date textbooks), interactivity, and portability as well as lower cost as compared to traditional texts (Burke & Rowsell, 2008; Reynolds, 2011; Sloan, 2012; Toppo, 2012).

Digital text can be more than a presentation of text on a computer or mobile device such as an ebook. Some digital text—known as supported eText—allows for text to be presented in multiple modalities (e.g., audio, tactile) and provides additional supports or cues (e.g., highlighting, zooming, hyperlinks) for students (Anderson-Inman, 2009; Anderson-Inman & Horney, 2007). While they are becoming available to and used by all in increasing numbers, for students with disabilities digital textbooks (i.e., accessible instructional materials) can be considered an educational right (Zabala & Carl, 2010). The reauthorization of the Individuals with Disabilities Education Act of 2004 (IDEA, 2004) included the National Instructional Materials Accessibility Standard (NIMAS) (National Center on Accessible Instructional Materials, 2011). NIMAS essentially guaranteed that students with print disabilities, such as students with visual impairments, would be provided with accessible instructional materials, including textbooks. Within NIMAS, accessibility was specifically referenced to include large print, braille, audio, and digital text (Zabala & Carl).

Although digital text holds much promise for students with visual impairments, not all content is equal (Power & Jürgensen, 2010). In other words, while it might be relatively easy to provide a digital version of a language arts or social studies textbook, it can be more challenging for mathematics, which is considered a visual language (Alajarmeh, Pontelli, & Son, 2011). Mathematics textbooks include not just the English language in the narrative text but also mathematical language, and as the level of mathematics increases—such as with algebra—the complexity of the mathematics and the mathematical language also increases. Consider the equation:

$$12 = \frac{10 + x}{2}.$$

When presented with a basic text-to-speech program without consideration for the mathematical language, the equation might be read as "12 equals 10 plus x over 2." While the oral rendition may seem straightforward when one can see the equation, without visual cues the oral expression "12 equals 10 plus x over 2" then holds two interpretations:

$$12 = 10 + x/2, \text{ or } 12 = \frac{10 + x}{2}.$$

(Landau, Russell, Gourgey, Erin, & Cowan, 2003; MacGregor & Price, 1999). Hence, students with visual impairments need technology to describe which interpretation is correct.

While not all digital or supported eText readers can support the presentation of mathematics, technology does exist to remove the ambiguity of algebraic expressions and equations (Bouck & Meyer, 2012). One such program is ReadHear™ by gH, LLC (2011). ReadHear is a Section 508-compliant software player designed with accessibility as a priority. In other words, the ReadHear player can read NIMAS files such as Digital Accessible Information System (DAISY) books and other digital formats. In the area of mathematics, ReadHear uses Mathematical Markup Language (MathML) as an input language and relies on MathSpeak™ to serve as an output language (gH, LLC, 2006; Steinman, Kimbrough, Johnson, & LeJeune, 2004). While MathML is for coding, MathSpeak is what one hears when using ReadHear as a mathematics-supported eText player for reading digital mathematics text. MathSpeak takes an equation or expression and provides the one correct interpretation, thus removing any ambiguity (Steinman et al.). With the equation above,

$$12 = \frac{10 + x}{2},$$

MathSpeak would then read the equation as "12 equals open fraction 10 plus x over 2 end fraction" (MathSpeak, n.d.).

Despite the increased attention to mathematics education for all students, and specifically students with disabilities, coupled with the increased attention in the field of education toward digital text, scant research exists that examines digitally-rendered mathematics text (Bouck & Meyer, 2012). One existing qualitative study involved the impact of ReadHear on the access and understanding of increasingly complex algebraic expressions for three high school students with visual impairments (Bouck, Joshi, Meyer, & Schleppenbach, 2013). All three students were able to access and understand the algebraic expressions presented by ReadHear. However, this study represented just one small step toward critically examining supported eText in mathematics for secondary students with disabilities. For one, the study by Bouck et al. was isolated from students' classroom practices; the students in this study were not using the technology in their mathematics classrooms. Second, the study did not examine the impact in terms of outcomes, such as correctly solving any algebraic equations, but rather students were asked only to answer questions about the presentation of the algebraic expressions.

Given the aforementioned issues with regard to the increased use of technology for all students—let alone students with visual impairments—given a decrease in braille literacy (National Federation of the Blind, 2009), and the increased attention in research to digital text and supported eText for students with disabilities, more research is needed. However, the research needs to go beyond access and explore outcomes. In other words, research is needed to understand how student performance is affected by accessing mathematics via digital textbooks versus accessing it via traditional textbooks. Within the scant previous research involving secondary students with visual impairments and digital text, albeit outside of mathematics, McLaughlin (2013) found that secondary students with low vision read faster and with fewer errors when reading on an iPad as opposed to traditional printed text. No differences were found for students in terms of comprehension. While involving neither mathematics nor secondary students with disabilities, previous research also found no difference in college student performance based on digital and traditional content presentation (Woody, Daniel, & Baker, 2010).

This research project analyzed secondary students with visual impairments solving algebraic equations when presented via a digital mathematics textbook using a supported eText player and the traditional textbook. The research questions for this study included: (a) How does the digital textbook accessed via ReadHear presentation compare to students' traditional textbook presentation method when considering number of problems solved correctly? (b) How does the digital textbook accessed via ReadHear presentation compare to students' traditional textbook presentation method when considering time to complete the task? and (c) What are the perceptions of students with visual impairments regarding the digital textbook and ReadHear?

Method

Participants

Four high school students with visual impairments were initially recruited to participate in this single-subject design study. The researchers omitted one student from the study because only partial results were obtained, as assessment answers saved in her braille notetaker could not be retrieved due to technology errors. The remaining three participating students all met the following criteria: (a) identified as having a visual impairment, including low vision or blindness; (b) enrolled in the State School for the Blind where this study occurred; (c) comprehended and spoke English; (d) enrolled in Algebra I; and (e) obtained consent and assented to participate in the study.

Participation in the study represented all three of the students' first time using the ReadHear program to access digital mathematics textbooks to solve problems. The mathematics textbook was presented to the three students on the ReadHear player throughout the school year, but previously each used his or her traditional textbook when actually solving problems. Amy always followed along in her braille textbook when the text was presented during class (i.e., teacher read the mathematics textbook or taught a lesson) and during reading outside of class. Likewise, Jake and Jose used their traditional small-text textbook; Jake used the small-text textbook with a desktop closed circuit television (CCTV), and Jose used it with a portable ruby (an open source coding language) on occasion.

Amy. Amy was a 22-year-old Hispanic twelfth-grade student with a visual impairment. She had been enrolled full time at the State School for the Blind since 2011, and she lived at the school during the week and returned home every weekend. Amy applied to a university in the state and, at the time of the study, was awaiting notification. She wanted to major in psychology and be a counselor. Amy was identified as legally blind. She had light perception in her right eye. She used braille textbooks and Job Access with Speech (JAWS) on her computer. While no IQ data were provided for Amy in her school file, scores were found for her on the Woodcock-Johnson III Tests of Achievement (Woodcock, Mather, & McGrew, 2001): 112 for Broad Reading and 84 for Broad Mathematics (84 for calculation and 86 for reasoning). Amy spoke two languages: English and Spanish.

Jake. Jake was a 17-year-old Caucasian eleventh-grade student with low vision. He was a resident of the state school for the blind who had been enrolled for less than two years at the time of the study. He returned home on the weekends. Jake was identified with multiple disabilities, including a visual impairment (low vision), Attention Deficit Hyperactivity Disorder (ADHD), anxiety disorder, and Axenfeld-Rieger Syndrome. Jake was born prematurely and his file indicated that he should use a magnifier and large print. His latest vision test data indicated 20/250 in his right eye and no light perception in his left eye. He also was evaluated as having glaucoma. Jake's Verbal IQ on the Wechsler Intelligence Scale for Children®–Fourth Edition (WISC-IV; Wechsler, 2004) was scored as 106 and his Working Memory as 83; his report did not provide a full-scale IQ as subtests requiring vision were not administered. Scores for the Woodcock-Johnson III Tests of Achievement, administered in large print, were reported as 92 for Broad Reading and 86 for Broad Math. Jake's Calculation Score was 95 and 58 for Math Fluency

(Woodcock et al., 2001). After graduation, Jake wanted to attend a culinary school and become a chef.

Jose. Jose was a 16-year-old Hispanic ninth-grade student with low vision. Jose's file indicated that he had 20/400 vision in his right eye and 8/400 in his left eye. Jose said that his eyes had trouble focusing, especially with numbers. He also said that he had difficulty seeing the fraction symbol and the negative sign. Jose was a resident of the state school and went home on the weekends. In terms of assessment data from the WISC-IV (Wechsler, 2004), Jose's Verbal IQ was identified as 110 and his Working Memory as 97. On the Woodcock-Johnson III Tests of Achievement, which was provided with large print, Jose's Broad Reading was 89 and Broad Math was 86 (Woodcock et al., 2001). The Woodcock-Johnson III Tests of Achievement scores for math indicated Jose's grade level equivalent was 5.1 for Calculation and 3.1 for Math Fluency. Jose spoke both English and Spanish. He had been enrolled in the school for fewer than two years at the time of the study. While Jose's file indicated he needed large print with a magnifier or CCTV, during mathematics Jose indicated he used a small-print textbook. He did not use a CCTV but occasionally used a portable ruby.

Setting

The study took place at a state school for the blind and visually impaired. The school consisted of an educational building where all classes from kindergarten through Grade 12 were held; an administration building, which also housed a postschool transition program; a recreational building; and cottages where the students lived during the week. The school served approximately 70 students on campus. Students who attend the state school receive a state-accredited diploma that is recognized by postsecondary educational institutions, including four-year colleges. In addition to face-to-face classes, the state school offers many distance-learning classes to students on as well as off campus.

The study took place in a small conference room within the school's library. The conference room contained a round table in the middle of the room and a desk on one side wall. Researchers worked with students either at the round table or the desk; each student worked on his or her own project-provided laptop throughout the study. Each student worked one-on-one with a member of the research team. The round table held the respective student's laptop, a talking calculator, and a CCTV. The desk held each student's laptop and a talking calculator. Students were provided with their traditional textbook, either small print or braille, as well as an answer sheet.

Materials

Mathematics textbook. The mathematics textbook used in this study, Algebra I, was published by Glencoe McGraw-Hill (Holliday et al., 2008). For purposes of this study, two versions of the traditional textbook were used: small print and braille. Jose and Jake used a small-print textbook. Jake used a CCTV to enlarge the font, while Jose opted not to use any technology. Jake also used a CCTV to write answers for the assessments, while Jose did not use any form of assistive technology when working on the problems on white paper. Amy used a braille version of the textbook. For purposes of the study, the company that produced the supported eText player—gH, LLC—rendered a digital version of the textbook.

Assessments. Students completed 12 mathematics assessments throughout the study; 10 of the assessments occurred during intervention and two during maintenance. Each assessment involved four questions, and the direction for each question was to solve the equation. The 48 questions were selected from exercises at the end of each of four sections in Chapter 2 of the algebra book (Holliday et al., 2008). Chapter 2 was selected because all students had already learned the material, which comprised the basics of algebra (i.e., solving linear equations). As the questions came from four sections within Chapter 2, each assessment involved one randomly selected question from the exercises from each section; no question was repeated throughout the assessment. Randomization of questions for each assessment and then the order of assessments was done to control for difficulty in the questions; the questions within each section typically became more difficult (i.e., Question 19 was typically more difficult than Question 12 in Chapter 2, Section 2). The assessments did not contain any algebraic equations, only the paper number and problem number for each question. Researchers also verbally told students the page number and problem number for each question.

ReadHear. ReadHear is a supported eText software player developed by gH, LLC (2011). ReadHear is designed to read DAISY, Digital Talking Books, NIMAS formats, and MathML-embedded format (i.e., an input language used to code mathematics content; gH, LLC, 2006). The program can read various kinds of digital text, although in this study the ReadHear program presented mathematics (i.e., algebra), which uses the output language of MathSpeak (gH, LLC, 2006). In addition to the function of orally presenting mathematical content, ReadHear offers several other key features to enhance accessibility and individualization for students with visual impairment: (a) choice of six synthesized voices; (b) color adjustment for background, text, highlighting, and tracking; (c) adjustment for reading speed and volume control; (d) zooming screen up to 16×; and (e) multiple navigation modes (e.g., navigating content by word, sentence, chapter, and page). All of these features can be accessed by using hot keys or a mouse.

Other technology. Students used other technology throughout the study. All the students used a Dell laptop computer to access the ReadHear program; each student used his or her own project-provided computer that was set with his or her specifications for ReadHear (i.e., voice, rate, volume, zoom) as well as other programs. With the laptop computer, Amy used an external keyboard, whereas Jake and Jose used the laptop computer keyboard. Jake used the track pad on the laptop for navigation, and Jose used a mouse. All the students wore a headset connected to the laptop when listening to the ReadHear program. Additionally, Amy used a BrailleNote Apex by Humanware. She used this technology to type in the problems and her answers as well as to serve as a calculator. The answers were then embossed and transcribed by the mathematics teacher. Jose and Jake had a talking calculator available to them; Amy was offered this option, but preferred to use the calculator on her BrailleNote Apex.

Dependent Variables and Independent Variables

The independent variable was the format of the textbook: digital textbook (i.e., presented via ReadHear) and a traditional textbook (e.g., a small-print textbook with and without additional technology such as CCTV, or a braille textbook). The dependent variables were the points received for questions answered correctly per assessment and the task completion time.

Procedures

This study employed a single-subject alternating treatment design; the conditions compared using two types of textbooks—students' traditional textbook, and digital textbook presented via ReadHear—to solve algebraic problems. An alternating treatment design was considered appropriate because of the ease of rapidly alternating and comparing two conditions across sessions (Barlow & Hayes, 1979; Wolery, Gast, & Hammond, 2010). The alternating treatment design employed in this study met the principles proposed by Kratochwill et al. (2010), as it compared two conditions that alternated in presentation and involved at least five data points per condition.

Training. Prior to the study, participating students received a group training session on how to use ReadHear. Researchers demonstrated features of the ReadHear software program and MathSpeak language. All three students were provided time and opportunities to navigate through the ReadHear key features (e.g., reader voice, book voice, volume, reading rate, zoom, contrast, text color, font, panning, tracking, colors for contrast, and colors for tracking) and ask questions regarding the technology. Amy, who was blind, mainly used hot keys to navigate ReadHear, while Jake and Jose—both identified with low vision—used hot keys and a mouse. In addition, during the training session, students set up their preferences for each key feature. The preference settings of ReadHear key features were saved on students' individual laptops.

Intervention. For each student, the intervention consisted of 10 sessions, five sessions per condition (digital textbook, i.e., ReadHear, presentation, and traditional textbook presentation). The researchers randomly alternated the two conditions, ensuring that no more than two consecutive sessions dealt with the same condition (Wolery et al., 2010). Each student worked on one assessment per session, one-on-one with one of the two authors. At the start of each session, a researcher instructed the students as to whether they were using ReadHear or the traditional textbook and then ensured the materials were accessible. Next, for Jose and Jake, the researcher provided a blank sheet of paper to use for solving the problems and writing answers; Amy entered the problems and answers into her BrailleNote Apex. To start the assessment, the researcher provided the direction, "solve each equation," and told the students that they could use a calculator. Next, the researcher provided a page number and a question number and the students navigated to that question via the assigned textbook condition. Students prompted the researcher when they were done, and the researcher then provided the next page number and question number.

During each session, the researcher took notes on what the students were doing. For example, with Jake and Jose, the researcher recorded their answers, as she could see what they wrote down; this was not possible with Amy, as she was using BrailleNote Apex. The researcher also recorded any student comments made during the assessment. The researcher also used a stopwatch app on a smartphone to record the task completion time. The researcher pushed Start when she began to read the first page number and problem number and stopped when each student had completed the last problem.

Maintenance. The maintenance phase consisted of two assessments. The condition during maintenance was based on each student's preference for the textbook presentation: digital textbook or traditional textbook. Amy and Jose chose the traditional textbook presentation as their preferred means of delivery; Jake selected the digital textbook presentation. The same procedures used during intervention were used during the maintenance phase.

Social Validity. Social validity data were collected to assess the usability and preference of the different textbooks. The social validity questions consisted of two parts. First, students were prompted to determine if they understood and liked the presentation of algebraic equations after each session for both conditions. After the intervention phase, students were asked five questions: What method was more effective? What worked well? What challenges did you have with the traditional textbook presentation and the ReadHear textbook presentation? Would you rather use ReadHear or your traditional textbook presentation? Do you think other students could benefit from ReadHear? The two questions after each session typically took each student less than a minute to answer; the five-question social validity interview took students less than 10 minutes.

Interobserver Agreement and Treatment Integrity

Interobserver agreement on the results of the assessments was determined. Three assessments (i.e., 33% of assessments) for each student were randomly selected and graded by a second rater. Interobserver agreement was 100% for each student. Treatment integrity was evaluated using a checklist for a total of 33% of assessment sessions for each student; treatment fidelity was 100% for each student.

Data Analysis

Visual and quantitative data analyses of two types of textbook conditions were employed. The main visual analysis in an alternating treatment design study is to compare two series of data points representing accuracy of answers and the length of completion time per session under the two textbook conditions (Barlow, Nock, & Hersen, 2009). Jake and Jose wrote their steps and answers directly on the assessment sheet or on blank sheets of white paper; the researchers were able to assess their original answers and written work. One the other hand, Amy entered her answers into her BrailleNote Apex; the researchers assessed the translated work from her mathematics teacher. For each assessment, which consisted of four questions, students received one point per question if answered correctly. Partial credit was given if students demonstrated the steps of solving a problem correctly except for the final step (e.g., $n = 4 - 23$), or if students marked the wrong positive or negative sign only in the final step. Accuracy of answers per assessment was then obtained by summing full credit (i.e., 1 point per question) and partial credit (i.e., 0.5 point per question) with the maximum score (i.e., 4 points). For intervention (both conditions) and maintenance, students' average across sessions was calculated. The length of time to complete each of the assessments was recorded per session. Individual session times were reported as well as the averages across both conditions of intervention and the maintenance phase.

Results

Amy

On average, Amy performed better under the traditional textbook condition than under the digital textbook condition (see Table 1 and Figure 1). Under the traditional textbook condition, Amy obtained a total of 10 (i.e., 9 full points and 2 partial points) out of 20 points, with a mean of 2 points per session. Under the digital textbook condition, she received a total of 7 (i.e., 6 full points and 2 partial points) out of 20 points, with a mean of 1.4 points per session. Under the maintenance condition, using her preferred textbook (the traditional textbook) Amy obtained a total of 3.5 (i.e., 3 full points and 1 partial point) out of

8 points. Amy received partial points (i.e., 0.5 point) for two questions with the traditional textbook condition, two questions with the digital textbook condition, and one question during maintenance because she wrote the incorrect sign only in the last step.

Amy's task completion time ranged from 6 minutes, 2 seconds (maintenance, traditional textbook) to 16 minutes, 10 seconds (intervention, digital textbook; see Figure 2). Amy's average task completion time during the digital textbook presentation was 12 minutes, 15 seconds and her average during the traditional textbook presentation was 11 minutes, 52 seconds. Amy's average task completion time during maintenance was 10 minutes, 31 seconds under her preferred means, the traditional textbook.

Jake

On average, Jake answered more questions correctly during intervention under the traditional textbook condition than the digital textbook condition (see Table 1 and Figure 1). He received a total of 9.5 (i.e., 8 full points and 3 partial points) out of 20 points under the traditional textbook, with a mean of 1.9 points per session. Jake received partial points for three problems because his work showed that he had the incorrect sign in the last step (i.e., he forgot to carry a negative to the final answer, but included it throughout the solution up until that point). Jake received a total of 5 (i.e., 5 full points) out of 20 points under the digital textbook condition, averaging 1 point per session. During the maintenance phase, he received 5 (i.e., 5 full points) out of 8 points under his preferred textbook medium, digital textbook.

Jake's task completion time ranged from 9 minutes, 31 seconds (intervention, traditional textbook) to 30 minutes, 15 minutes (intervention, digital textbook; see Figure 2). Jake's average task completion time during the digital textbook presentation was 22 minutes, 2 seconds and his average during the traditional textbook presentation was 14 minutes, 10 seconds. Jake's average task completion time during maintenance was 15 minutes, 15 seconds under his preferred means, the digital textbook.

Jose

Throughout the entire study, Jose answered no questions correctly (see Table 1 and Figure 1). Neither textbook presentation condition, digital or traditional, appeared to impact Jose's results with respect to correctly solving algebraic equations. Jose received a total of 1 (i.e., 0 full points and 2 partial points) out of 20 points under the traditional textbook and 1.5 points (0 full points and 3 partial points) out of 20 points under the digital textbook. During maintenance, he received 0.5 (i.e., 0 full points and 1 partial point) out of 8 points under his preferred textbook,, the traditional textbook. Partial credit was given when Jose's work showed he was solving the problem correctly but did not complete the final step. For example, Jose solved $n + 23 = 4$ by answering the problem $n = 4 - 23$ instead of -19.

Jose's task completion time ranged from 5 minutes, 26 seconds (maintenance, traditional textbook) to 11 minutes, 10 seconds (intervention, digital textbook; see Figure 2). His average task completion time during the digital textbook presentation was 9 minutes, 37 seconds and his average during the traditional textbook presentation was 8 minutes, 41 seconds. Jose's average task completion time during maintenance (traditional textbook presentation) was 7 minutes, 4 seconds.

Social Validity

In terms of effectiveness and understanding of two forms of textbook, all three students reported that they understood the algebra problems presented in their traditional textbook across the intervention phase and two of the three students (i.e., Amy and Jose) indicated their traditional textbooks were more effective. Both Amy and Jose also reported that they understood the presentation of the algebra equations in the digital textbook, although Jose did struggle at one point with regard to hearing the MathSpeak mathematics language presented in a brief version (e.g., "L-par") instead of the verbose version (e.g., "open parenthesis") that he was more familiar with, which caused him some frustration. Jake reported understanding the presentation of the algebraic equations via the digital textbook throughout the study, but reported that his understanding of the equations in his traditional textbook decreased the more he worked with the digital textbook (i.e., during the second baseline phase). Jake was the only student who preferred the digital textbook to the traditional textbook and increasingly expressed a desire to use the digital version.

In terms of advantages and challenges of using the digital textbook, all three students acknowledged some positives from using digital textbooks (e.g., as greater portability,

Table 1

Average Correct Answers and Average Completion Time Across Assessments within Each Condition

	Digital Textbook		Traditional Textbook		Preferred Textbook	
	Correct Answers	Completion Time (min)	Correct Answers	Completion Time (min)	Correct Answers	Completion time (min)
Amy	1.4	12:15	2	11:52	1.75 (Traditional)	10:31
Jake	1	22:02	1.9	14:10	2.50 (Digital)	15:15
Jose	0.3	09:37	0.2	08:41	0.25 (Traditional)	07:04

easier to locate pages, the ability to work on one's own pace, and the ability to assess information aurally). Due to Jake's eye condition, he preferred to read via the digital textbook. He also stated, "It is a lot more enjoyable to read because I can listen to it instead of looking at a boring textbook." Amy stated that the simplified version of mathematic language (e.g., L-par, R-par) was sometimes confusing. However, she felt she would be more comfortable with the digital textbook given greater practice. Amy also stated that she would likely use a digital mathematics textbook in college, despite her preference for the traditional textbook. Jose expressed that it was sometimes cumbersome to have to use a keyboard or mouse to control the digital textbook.

Discussion

The purpose of this study was to explore how use of digital algebra textbooks influences a student's mathematics performance. The study compared the performance (i.e., correct answers) of secondary students with visual impairments when algebraic equations were presented via two types of textbook formats: a traditional textbook (i.e., braille or small-print textbooks) and a digital textbook. The study also sought student perspectives on the two mediums of presenting algebraic material and examined task completion time between the two textbook alternatives. The main findings of this study suggested that: (a) students tended to solve the algebra equations better when they were presented via their traditional textbook; (b) task completion was longer for all three students when using the digital textbook, although the amount of time differed across students; and (c) two of the three students preferred their traditional textbook and one preferred the digital textbook.

Because academic content textbooks increasingly are becoming digital, a critical evaluation of the effect of digital textbooks is needed (Bonk, 2010; Toboni, 2011; Toppo, 2012). In other words, does student performance differ according to the medium in which they receive information? In the case of this single-subject design study, the students tended to answer more algebraic equation problems correctly when the equations were presented via their traditional textbook (i.e., traditional print or braille). However, it also should be noted that the students answered few problems correctly overall, despite the algebra content in this study being a review of material previously taught in the same academic year. Hence, the students' ability in algebra is of concern.

It would be premature to conclude at this time that digital textbooks result in lower performance, although there is a need to make sure the impact of digital textbooks is examined carefully prior to any full implementation in classrooms and for all students. In fact, previous research with digital textbooks and college students taking a psychology course found no difference in performance between digital textbook users and traditional print textbook users (Woody et al., 2010). The tendency to answer more questions correctly when the algebra was presented via a traditional textbook could be due to student familiarity and more experience with it (Goldberg & Pedulla, 2002; Ross & Johnson, 2012). The difference in performance could be negated or the scales tipped in the opposite direction

Figure 1

Points received for answering algebra equations correctly out of four points per session.

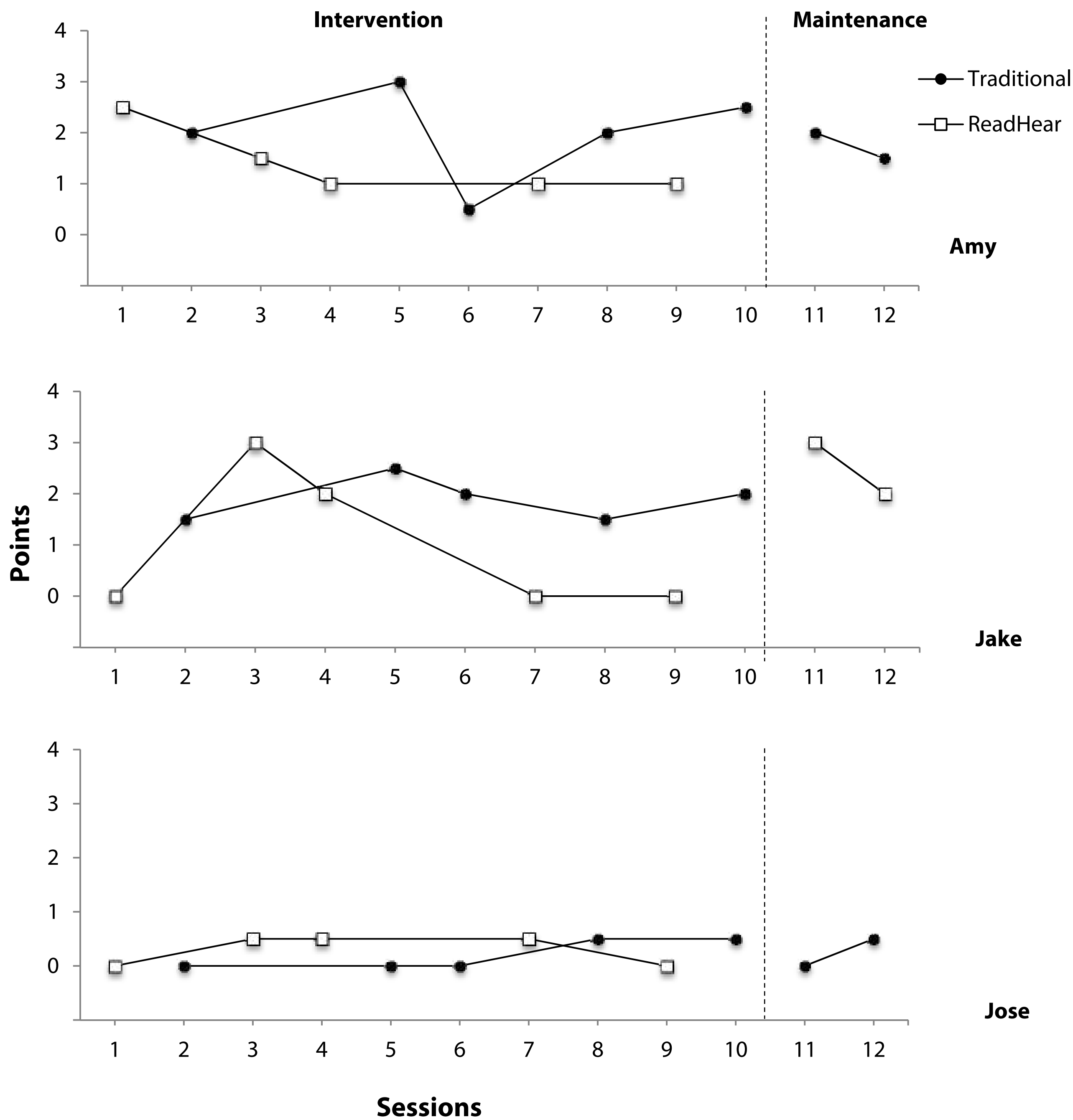
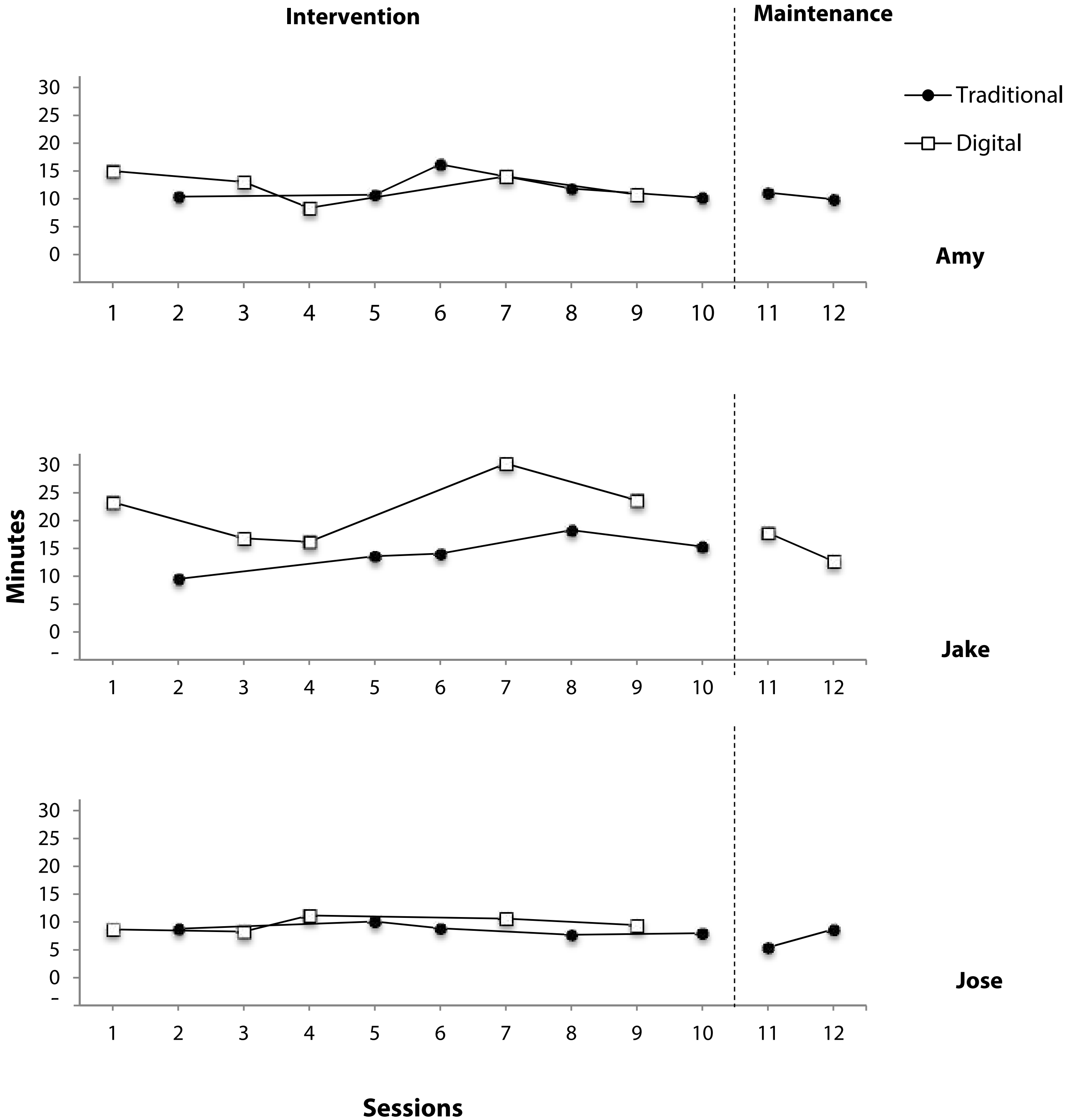


Figure 2

Completion times per session for answering four algebra equations.



once students engage with a digital textbook for a longer period of time and become more use to it as well as its language (e.g., MathSpeak), at least for mathematics.

In addition, the difference—albeit small—with regard to task completion time also could be explained by student familiarity. Although the students in this particular study previously worked with the digital textbook, they did not use that format to solve problems. Greater experience and time to become familiar with the digital mathematics textbook medium may result in equal if not less time to solve algebraic equations when presented in that manner. However, previous research with college students found that students took longer to read digital textbooks than traditional print textbooks (Daniel & Willingham, 2012; Woody et al., 2010). It may be that task completion time is sacrificed for other advantages (e.g., cost, portability, accessibility) when using digital textbooks.

Perhaps not surprising, given the data regarding accuracy and task completion time, two of the three students preferred their traditional textbook to the digital textbook in terms of the presentation of algebraic equations. The preference toward traditional textbooks over digital textbooks is consistent with the limited previous research on digital textbook use in education, which suggests familiarity as the main reason for deference to traditional textbooks (Rockinson-Szapkiw, Courduff, Carter, & Bennett, 2013; Ross & Johnson, 2012; Shepperd, Grace, & Koch, 2008). Woody et al. (2010) found that college students preferred traditional print textbooks over digital textbooks, and the preference had no relationship to previous experience with reading digital books for pleasure (e.g., eBooks on a Kindle or iPad). Student preference—in this study and previous research—is not affected by the advantages digital textbooks offer, including lower cost, increased accessibility options, inherent flexibility, and added features (Woody et al.).

Implications for Practice

The results of this study provide several implications for practice. One implication is the need to heed caution when implementing digital textbooks. For example, despite potential presumptions of students to favor digital textbooks research to date tends to support the opposite, with students preferring traditional textbooks to digital textbooks (Daniel & Willingham, 2012; Gregory, 2008; Ross & Johnson, 2012). However, the scant existing research suggests that use of both digital textbooks and traditional textbooks tends to result in similar academic performance (i.e., no statistical difference in performance; Rockinson-Szapkiw et al., 2013; Schugar, Schugar, & Penny, 2011; Woody et al., 2010). In sum, teachers need to critically evaluate individual student readiness and willingness to use digital textbooks (Daniel & Willingham).

Although we suggest critical examination of digital textbooks for students with visual impairments as well as other students, we also recognize that this is a movement that is unlikely to be stopped or slowed. Digital textbooks are being used increasingly in university settings and supported in PK–12 settings (Bonk, 2010; Toboni, 2011; Toppo, 2012). The move toward digital text may be especially strong for students with visual impairments, with data to support the use of digital textbooks and digital materials for students with visual impairments in college (Fichten, Asuncion, Barile, Ferraro, & Wolforth, 2009; Reynolds, 2011). In addition, increased use of computer-based testing materials is evident in college (Fichten et al.). Hence, educators of secondary school students with visual impairments need to consider providing students with exposure to such text and materials prior to leaving high school.

Another reason to prepare students with visual impairments to use digital text is to prepare particular students for adjustment or transition when dealing with the degeneration of vision. It is not uncommon for students with low vision to gradually lose their eyesight around adolescence or young adulthood due to degenerative eye diseases or conditions (e.g., cataracts, glaucoma, macular degeneration; Breitmeyer, 2010; Dominguez & Dominguez, 1991). However, students with low vision may not be braille proficient. The introduction of other modalities of text, such as digital textbooks, can support such students. For example, although Jake was able to read print, he stated that printed words "get blurry." He was finding it increasingly difficult to rely on reading printed textbook, yet he was not braille proficient.

Limitations and Future Directions

Although this study attempted to explore an underresearched area, it did contain limitations. One limitation existing in this study was the unequal exposure to digital and traditional textbooks. Although the participating students used the digital textbook in class after being trained to do so, it was mainly to access the narrative text; students still used their traditional textbooks to access and solve algebra problems. Another limitation pertained to the familiarity of mathematics language used in the study—MathSpeak. The ReadHear player and the MathSpeak language provide different levels of verbosity to verbalize mathematics languages. Not all the students were as familiar with the Nemeth Code-based way of speaking mathematics, and particularly the more simplified version of the MathSpeak language (e.g., L-par for left or open parenthesis, frac for fraction, sup for superscript or exponent). The final noted limitation involved the collection of task completion time data. Students were not required to finish each of the questions; they could stop working on a question at any time. Hence, a shorter completion time per trial did not necessarily mean a student completely answered four questions in a shorter period of time.

Future research needs to continue to explore the impact of digital textbooks on student performance. The move to such textbooks without an established research base is disconcerting. Future researchers need to design studies that strive for equality of student familiarity between the two textbook mediums. In addition, researchers in the area of mathematics and digital textbooks need to ensure that students have the necessary background knowledge (i.e., knowledge of the mathematics language). Finally, future research should examine the impact of digital textbooks within the actual confines of the classroom and the impact on student assignments and assessments.

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