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Technologies Used in the Study of Advanced Mathematics by Students Who Are Visually Impaired in Classrooms: Teachers' Perspectives

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Structured abstract: *Introduction:* This research examined the perspectives of teachers of students who are visually impaired regarding the use and effectiveness of high-tech assistive technology purported to assist visually impaired students in advanced mathematics. *Methods:* The data for this study were collected via a mixed-methods online survey distributed through professional networks to reach teachers with experience supporting students who are braille readers in advanced mathematics. A device matrix was used to ask participants about three interrelated issues. First, which of the 35 assistive technologies presented did they use to aid students? Second, how was the technology implemented? And third, how did they rate the effectiveness of each device used? Open-response items provided space for additional tools and other feedback. *Results:* A total of 82 surveys were completed through the device matrix question. Results conclusively indicated that 20 of the 35 technologies were used; of these, 13 were used regardless of subject. More than half of the participants indicated that the same four technologies were implemented for student information access during class, guided practice, and independent practice. Participants recommended seven technologies not included in the device matrix through the open-response questions. *Discussion:* This survey revealed that teachers of visually impaired students are using assistive technology for multiple functions. A core set of 13 devices emerged, as well as varying subsets for specific tasks across different subjects. Limitations of the study were the small sample size and possible survey fatigue. *Implications for practitioners:* By examining the uses of technology presented in this article, teachers can determine which assistive technology might be worth exploring to use for preparation of materials for students and which to teach others to use independently for reading or preparation of assignments in advanced mathematics courses.

In the last 30 years, the technology boom has produced an abundance of tools to assist with learning and teaching, including those useful to teachers of students who are visually impaired. However, facilitating the study of mathematics for students who are visually impaired (that is, those who are blind or have low vision), specifically braille readers, requires that teachers sift through a growing number of continuously evolving products. High-tech assistive technology includes stand-alone devices such as talking calculators, computer hardware, and the software used within electronic devices. Often, itinerant teachers may have only one braille reader in their entire careers and will have very little time to tackle a trial-and-error approach to teaching such students (Zhou, Parker, Smith, & Griffin-Shirley, 2011).

High-quality teaching incorporates tools to help students with and without visual impairment to access and understand advanced mathematics to the best of their ability. For a classroom teacher who has a student who is visually impaired, the presence of technology in the classroom is not optional but necessary. Yet, according to Pierce and Ball (2009), 24% of classroom teachers agreed or strongly agreed with the statement: "If I use more technology, I won't have time to cover the course." With this sort of mindset, any enthusiasm a classroom teacher may have felt at the prospect of teaching a braille reader could be quickly extinguished.

Many mathematicians, such as Buteau, Marshall, Jarvis, and Lavicza (2010), now believe proficiency in advanced mathematics has become synonymous with proficiency in corresponding technology. Technology can eliminate the tediousness of calculations, allowing students to focus more on conceptual understanding. Students who are visually impaired must have access to technology that provides these same supports. Schweikhardt (2000) noted that requirements for the successful integration of students who are visually impaired into general-education mathematics environments include notation that is simultaneously accessible by both people who are braille readers and those who are print readers.

Numerous projects that focus on the ability to concurrently communicate in braille and print—MathGenie and Lambda systems, for example—incorporate innovations such as the MathML sublanguage, MathType software, audio output, and speech recognition, and are in development around the world (Karshmer, Gupta, & Pontelli, 2009). However, the most functional high-tech assistive technology currently available to consumers, such as the Sense Notetaker v8.2 by HIMS, do not allow for a print reader and a braille reader to synchronously locate and discuss the same parts of two-dimensional problems. Continuous verbal confirmation that they are, in fact, discussing the same element of the problem at the same time is crucial.

Reed and Curtis (2011) conducted a study attempting to understand the issues teachers encountered when students with visual impairments transitioned to higher

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education. Difficulties identified were the inability of students to access and operate accommodations, problems with getting accessible materials in time for class, and the late arrival and poor quality of books transcribed into braille. In some cases, teachers indicated that students who did not have enough training in using technology efficiently avoided its use altogether so as not to draw attention to themselves.

Smith, Kelley, Maushak, Griffin-Shirley, and Lan's (2009) Delphi study attempted to define a set of appropriate assistive technology competencies and corresponding levels of expertise for teachers of students who are visually impaired. After five rounds of deliberations, a list of 111 competencies emerged. Zhou and his colleagues (2011) included 74 of these competencies in their study. They attempted to determine what level of expertise teachers perceived as necessary in each competency to perform their jobs, and whether it aligned with what the expert panelists perceived as optimal in the Delphi study (Smith et al., 2009). Results indicated discrepancies in the priority ranking of some of the competencies between what panelists versus teachers deemed important. Open-response items (Zhou et al., 2011) yielded insights from teachers who said they just "cannot attend to every technology available" until a student actually needs it.

Purpose of study

The purpose of this study was to determine the current state, as perceived by teachers of students who are visually impaired, of high-tech assistive technology being used in advanced mathematics classes to support visually impaired students, particularly braille readers. The research questions addressed were:

1. Which devices are currently being used in secondary school advanced mathematics courses to support students who are braille readers?
2. Does it appear that there is a core set of devices for supporting advanced mathematics students who are braille readers, regardless of specific subject?
3. Are there variations of the core set of devices, depending on the particular advanced mathematics subject being taught?
4. How effective are the devices listed in ensuring access and supporting learning by braille readers throughout typical lesson plan steps?
5. Are there gaps between technologies being used and teaching activities (that is, lesson plan steps that are not supported, either overall or in specific subjects)?
6. What themes emerge from teachers' recommendations of assistive technology that were not listed or used in ways not indicated?

Ultimately, this research attempts to begin to uncover whether a mathematics toolkit for braille readers can be identified.

Methods

Participants and procedure

The target population for this study was teachers of students who are visually impaired who had experience in facilitating the study of advanced mathematics by students who are blind or have extremely low vision, particularly braille readers. Out of an estimated 6,700 certified teachers of visually impaired students (Mason, McNerney, Davidson, & McNear, 2000), only a small number would have worked with students who were exclusively braille readers and had taken advanced mathematics.

Four sources—American Printing House for the Blind (APH) field-testers, *APH News* readers, state residential schools for students who are visually impaired, and APH Ex Officio Trustees (appointed professionals in charge of administering Federal Quota accounts)—were used to recruit eligible participants and provide them with the link to the survey. Respondent criteria were teachers of students who are visually impaired with experience in facilitating the study of advanced mathematics—defined as algebra and beyond—by students who were braille readers.

Instrumentation

The survey instrument, developed using SurveyMonkey, contained three sections: participant information, a device matrix, and open-response questions. The first section contained seven descriptive data questions followed by three or four questions designed to examine the perceived proficiency of participants in integrating technology to support braille readers in these subjects: algebra, algebra 2, geometry, trigonometry, precalculus, calculus, or other. Using a five-point format (1 = novice, 5 = expert), Question 8 asked participants to rate their perceived proficiency in each subject. Question 9 asked participants in which subject they had the highest perceived proficiency. Question 10 asked in which subject they had the second-highest perceived proficiency, and included an eighth choice, "I have only supported students in [q9]," where [q9] was the selection made in Question 9. If this choice was selected, the survey skipped Question 11. Question 11 asked participants to select the subject in which they had the third-highest perceived proficiency, and included an eighth choice, "I have only supported students in [q9] and [q10]."

Using conditional branching (Alreck & Settle, 2004), answers to questions 9, 10, and 11 were inserted into further questions about specific high-tech assistive technology usage. In order to minimize the effects of survey fatigue, the survey had participants enter responses to the device matrix first based on the subject in which they perceived themselves to be most technologically proficient. For example, if algebra and algebra 2 were rated equally in Question 8, "algebra" was selected in Question 9, "algebra 2" was selected in Question 10, and "I have only supported students in algebra and algebra 2" was the response for Question 11, this respondent's Question 12 (the device matrix, described below) would have been based on algebra. Question 13, the first open-response question, would have appeared as, "Indicate any technologies that, in your experience, facilitate the study of *algebra* by students who are visually impaired that were not on the previous list. Include a brief description on how the technologies were used." Question 14 would have appeared as, "Please use this space to provide any additional information you believe is important to educating students who are visually impaired, regarding high-tech tools in *algebra* classes."

The device matrix was the crux of the survey. For each subject identified, participants scanned the high-tech assistive technology list until encountering a device with which they had experience. They then consulted column headings to determine which step or steps of the lesson plan the technology supported. Lesson plan steps, based on Robert Gagne's instructional events (1992), were defined as:

- Preparation of lessons—the device was used by a faculty or staff member to prepare the mathematics lesson, notes, or materials for the lesson before the lesson itself took place.
- Student lesson access—the device was used by the student during the lesson, on the actual day of the class, in order to access the notes or demonstration his or her peers were accessing visually.
- Teacher and student guided practice—the device was used by the student and classroom teacher or teacher of visually impaired students, so they could simultaneously study, discuss, or work on mathematics problems.
- Student independent practice—the device was used by the student in or out of the classroom to work on problems independently.
- Student work submission—the device was used by the student or staff member to create a print document that could be read by the classroom teacher.
- Participants rated the device on a 1 (lowest) to 5 (highest) scale for its effectiveness in supporting the student in each lesson plan step for that particular subject. In the preceding example, Question 15 would have asked if the respondent believed the ratings entered in the device matrix would be different for *algebra 2*. A "Yes" selection would have repeated the device matrix and open-response sections for algebra 2.

The draft of the high-tech assistive technology list was generated during the literature review. Many tools were available for mathematics-related professionals who are visually impaired. Two teachers of visually impaired students, both with math expertise—one itinerant with over 25 years of experience and the other a longtime math teacher at a residential school for blind students—reviewed this version of the survey. Their insights led to the final list and the addition of space for open responses.

Data collected via the device matrix addressed the first five research questions. The intent of the study was to identify a narrower set of devices for future analysis regarding effectiveness. Through collaboration with two experts in the field of assistive technology, it was determined that devices used by many teachers of visually impaired students warrant further examination, as do devices used by very few teachers but with high mean ratings. Therefore, high-tech assistive technology reported as being used by more than 50% of participating teachers or assistive technology with a mean rating of ≥ 3 in any of the lesson plan steps would be considered as members of this core set of devices.

Two open-response items followed the device matrix in order to address the last research question regarding emerging themes about devices not listed or the use of devices. Responses to the second item, Question 14 in the example above, would be analyzed through open coding for emergent themes.

The Texas Tech University Institutional Review Board (IRB) approved the study for exempt review. Settings in the instrument's web page prevented researchers from obtaining IP addresses of respondents, and teachers of visually impaired students were notified that participation was voluntary and anonymous.

Data analysis

The analysis of the interrelationship of subject, effectiveness of technology, and each step of the lesson plan was completed manually. Cross-tabulation analysis was not performed because the purpose of the research was to be inclusive of all types of high-tech assistive technology, even those with very low relationships to the independent variables. This survey was a starting point, and each device identified warranted further examination. Microsoft Excel was used to sort data, create graphs and tables, and calculate means and standard deviations.

Results

A total of 157 surveys were returned, 82 of which (52%) were completed through the device matrix item. Sixteen participants completed at least one open-response item. The data reported in this research are from the 82 completed surveys.

Descriptive data

The target population for the study was teachers of visually impaired students who had experience teaching and supporting braille readers in advanced mathematics. Thirty-one of the 82 respondents, the highest percentage (38%), indicated they had more than 10 years of experience working with students who are visually impaired in advanced mathematics (see Table 1). The most recent year of this type of experience was 2011–2012 for 54 (66%) respondents. Note that 60 respondents (73%) listed their current positions as itinerant teachers.

Participants' perceived proficiency

As shown in Table 2, many participants indicated that they had proficiency in multiple subjects, and nine participants added "statistics" or "statistics and probability" to the "other" subject for an average proficiency rating of 2.11. Table 3 shows results for participants' highest, second-highest, and third-highest perceived technological proficiencies. Research questions were answered based on data collected from participants' highest proficiency subject.

Answers to research questions

Device usage

In determining which of the 35 types of high-tech assistive technology were being used, the data were analyzed in two ways. First, each device received a score based on the total number of times it was selected for use in various subjects and lesson plan steps, regardless of the number of participants who selected it. According to this analysis, all of the devices were used by at least one teacher, in one subject, for one lesson plan step. The second analysis counted how many participants said they used each device without regard to the number of subjects or lesson plan steps. Every one of the 35 devices was used by at least 9 teachers. Individual examination of the completed surveys revealed these 9

Table 1
Descriptive data of respondents (N = 82).

Descriptive data	n	%
Age		
$<$ 28	4	4.9
29–36	9	11.0
37–44	8	9.8
45–52	13	15.9
53–60	39	47.5
61–68	9	11.0
$>$ 68	0	0.0
U.S. geographic region		
Northeast	15	18.3
Midwest	27	32.9
South	27	32.9
West	13	15.9
Years of experience[1]		
1–3	24	29.2
4–6	19	23.1
–10	6	7.3
$>$ 10	31	37.8
NA	2	2.4
Most recent year		
2011–2012	54	65.9
2010–2011	7	8.5
2009–2010	8	9.8
2008–2009	5	6.1
2007–2008	0	0.0
2006–2007	3	3.7
2005–2006	2	2.4
2004–2005	2	2.4
1998–2004	0	0.0
Before 1997	1	1.2
Current position		
Teacher at a residential school for blind students	9	11.1
Itinerant teacher of students who are visually impaired	60	73.1
Resource room or self-contained classroom teacher	8	9.8
Regional education service center or school district	3	3.7

(cont.)

participants entered a "1" in all of the Likert ratings for every part of the lesson plan in which they did not enter a higher rating. It is likely that some participants did not realize ratings should be left blank for unused high-tech assistive technologies. Since some devices did rate higher than 1, it was impossible to eliminate entire surveys. It can be concluded that 20 devices—the number selected by at least 10 participants—were used by as many as 62 teachers.

Core sets

Research questions 2 through 4 attempt to identify core sets of high-tech assistive

Table 1
(cont.)

Descriptive data	*n*	%
Rehabilitation center	0	0.0
Teacher of students who are visually impaired and working in a supervisory or administrative role	0	0.0
Independent consultant	0	0.0
Other	2	2.4
Previous positions		
Teacher at a residential school for blind students	14	17.0
Itinerant teacher of students who are visually impaired	66	80.5
Resource room or self-contained classroom teacher	18	22.0
Regional education service center or school district	9	11.1
Rehabilitation center	1	1.2
Independent consultant	5	6.1

[1.] Total number of years of experience working with students who are blind in advanced mathematics courses.

technology for first-priority future research. The device must either have been reported as being used by more than 50% of participating teachers of students who are visually impaired or have a mean rating of ≥ 3 in any of the lesson plan steps. Question 2 focused on identification of a core set of assistive technologies for supporting the study of advanced mathematics by students who are visually impaired, regardless of subject. The 13 devices that met the criteria were:

- personal computer (PC)
- scanner or reader
- electronic refreshable braille notetaker (ERBN)
- MathFlash
- talking calculator
- Excel
- talking scientific calculator (TSC)
- audio recording
- Duxbury Braille Translator (DBT)
- optical character recognition (OCR) software
- Scientific Notebook
- Graph-It
- Accessible Graphing Calculator (AGC)

The third research question looked more intently at high-tech assistive technology use for specific subjects. In this case, more devices met the criteria based on the number of participants who selected them as opposed to the mean score (Table 4).

Four devices met the criteria to be included in the core set of assistive technologies in three of the five lesson plan steps; the PC, ERBN, talking calculator, and TSC. More tools met the mean score criteria than the 50% participant criteria, and no lesson plan tasks were completely unsupported (see Table 5).

Themes

Table 6 summarizes additional devices not included in the matrix but recommended in the open-response Question 13, which was answered by 16 participants, respectively. Half of the 14 devices listed are low-tech. Coding analysis of the

Table 2
Perceived proficiency of participants—scale of 1 to 5, with 1 being lowest.

Answer options	1	2	3	4	5	Average	*n*
Algebra 1	12	9	35	15	11	3.02	82
Algebra 2	15	15	21	18	6	2.80	75
Geometry	18	10	26	13	8	2.77	75
Trigonometry	28	10	13	7	4	2.18	62
Precalculus	31	10	17	3	3	2.02	64
Calculus	38	12	8	2	1	1.62	61
Other	4	1	3	1	0	2.11	9

37 responses to Question 14, completed by 18 participants, is available in Table 7. The table shows 4 themes emerging; low-tech devices, teacher training, mathematics complexity, and high-tech devices. All of the 9 responses regarding low-tech devices were positive. Six responses had to do with teacher training, while math characteristics and high-tech assistive technology each had 11 responses related to them.

Discussion

The device matrix and open-response questions were designed to determine which devices were being used, which warranted first priority in future research, in what subjects they were being used, and how and when they were being used. A large portion of high-tech assistive technologies were used very infrequently. The number of braille readers in advanced mathematics courses is small. Therefore, the use of a device, even by one teacher, warrants further investigation of the tool's potential benefits. It is possible for one teacher working with one student to discover a technological solution beneficial to other educators working with similar students (Maneki, 2010).

Of those 20 devices conclusively identified as being used, 13 met the core set criteria regardless of subject (see Table 4). Results also indicate this core set of high-tech assistive technologies varied depending on subject. In geometry, seven devices met the criteria, whereas only four did in algebra.

Task analysis of lesson plan components enables understanding of how high-tech assistive technology was used, and by whom. Results displayed in Table 5 indicate that 11

Table 3
Participants' perceived proficiencies ranked.

	Highest		Second highest		Third highest	
Subjects	*n*	%	*n*	%	*n*	%
Algebra 1	57	69.9%	16	20.5%	1	1.4%
Algebra 2	11	13.3%	34	41.0%	19	25.7%
Geometry	11	13.3%	19	22.9%	25	33.8%
Trigonometry	1	1.2%	2	2.4%	6	8.1%
Precalculus	2	2.4%	0	0.0%	3	4.1%
Calculus	0	0.0%	1	1.2%	1	1.4%

Table 4
Number of participants who selected devices by subject.

Device	Algebra 1 (N = 57)	Algebra 2 (N = 11)	Geometry (N = 11)	Trigonometry (N = 1)	Precalculus (N = 2)
Personal computer*	41	8	10	1	2
Electronic refreshable braille notetaker*	42	7	9	1	1
Audio recording*	19	4	5	0	1
Talking calculator*	35	7	10	0	1
Talking scientific calculator*	38	9	6	0	2
Accessible graphing calculator*	22	5	6	0	2
Optical character recognition software*	15	2	2	0	0
Scanner or reader*	18	4	7	1	1
Nomad Pad or Tablet	5	2	2	0	0
Talking Tactile Tablet	5	2	2	0	0
Talking Tactile Pen	6	2	2	0	0
Tactile AudioGraphics TagPad	5	2	2	0	0
MathPlayer (Design Science)	5	2	2	0	0
MathSpeak	6	2	2	0	0
ReadHear	5	2	2	0	0
ClickHear	5	2	2	0	0
TRIANGLE	5	2	2	0	0
AudioMath	5	2	2	0	0
Graph-It*	6	4	3	1	0
GRAPH	6	3	2	0	0
AsTeR	5	2	2	0	0
MathTalk with MathPad	5	2	2	0	0
MathTalk with Scientific Notebook	6	2	2	0	0
AudioCAD	5	2	2	0	0
AudioPIX	5	2	2	0	0
MegaMath	5	2	2	0	0
Duxbury Braille Translator*	33	6	8	1	2
IVEO	6	2	2	0	0
Math Program	7	2	3	0	0
Scientific Notebook*	26	5	5	1	2
MathTalk	6	2	2	0	0
MathFlow	5	2	2	0	0
MathDaisy	5	2	2	0	0
MathFlash*	9	2	3	0	0
Excel*	11	2	5	0	0

* = devices that met the core set criteria regardless of subject.

devices support preparation of materials, which entails converting print to braille or the Nemeth Code for Mathematics and Science Notation (hereafter, Nemeth). As the tasks incorporate more back translation and student involvement, fewer such technologies met the criteria. Independent practice and submission of work by students was supported by the fewest number of assistive technologies, with seven each. One participant commented, "The general problem, which applies to all the math areas, is that there isn't a Nemeth back translator so students can write their math in Nemeth braille and translate it back to print." This finding, supported by the open-response answers,

Table 5
Devices with mean ≥ 3 in at least one lesson plan task.

Preparation of materials	Student lesson plan access	Teacher- or student-guided practice	Student independent practice	Student work submission
PC	PC	PC	ERBN	PC
Audio recording	ERBN	ERBN	Talking calculator	ERBN
Talking calculator	Audio recording	Talking calculator	TSC	Talking calculator
TSC	Talking calculator	TSC	AGC	TSC
AGC	TSC	AGC	Scanner/reader	AGC
OCR Software	AGC	DBT	Graph-It	DBT
Scanner or reader	Scanner or reader	Scientific Notebook	DBT	Excel
Graph-It	DBT	MathFlash		
DBT	Scientific Notebook	Excel		
Scientific Notebook	Excel			
Excel				

Note: AGC = Accessible Graphing Calculator; DBT = Duxbury Braille Translator; ERBN = Electronic Refreshable Braille Notetaker; TSC = Talking Scientific Calculator.

reflects the shortage of technology that allows for real-time back-translation from braille and Nemeth into print (Karshmer et al., 2009).

It is interesting to note that despite the high-tech boom, all open-response clauses regarding low-tech devices were positive, whereas all clauses within the

Table 6
Open-ended responses to technologies.

Device	*n*	High-tech?
Software		
MathType	3	Y
MathTrax	1	Y
Notetakers		
Refreshable braille notetaker with display	1	Y
Perkins braillewriter	7	N
Embossers and thermal printers		
Tiger Embosser	3	Y
Picture In A Flash	4	Y
ViewPlus	1	Y
Tactile boards		
APH Graph Board	2	N
APH Draftsman	6	N
APH Magnetic Board	1	N
Manipulatives		
Math Window Braille Basic Math Kit	2	N
Geometric manipulatives	5	N
Other		
Abacus	2	N
Digital cameras	3	Y

Note: APH = American Printing House for the Blind.

Table 7
Themes.

Themes	Codes
Low-tech devices	Simpler, most effective, concept development
Teacher training	Unfamiliar, need training, training unavailable
Math characteristics	Need many tools, need immediate tactile representation, need real-time transcription, students not interested in math
High-tech devices	Inadequate graphing calculators, unavailable technology, too expensive, glitches

teacher and high-tech assistive technology categories were negative. Three teachers of visually impaired students indicated they were open to training and would like to integrate more such assistive technologies. In some cases, devices or training are not available due to expense, and school districts could not keep up with the latest devices (Zhou et al., 2011). The possibility that the perception of the amount of time necessary for training is inaccurate must be considered. The rapid evolution of technology in general, and the assumption that there are more relevant tools to sift through than there actually are, may lead teachers to resist integrating assistive technology.

Most respondents, 73%, listed their current position as itinerant teachers of students who are visually impaired. This finding is important because in a residential school, teachers of visually impaired students are the mathematics classroom teachers. This arrangement allows these teachers to gain expertise in integrating technology that reinforces content with braille readers learning mathematics. In addition, the need for transcription technology is lower when such teachers teach mathematics because the classroom teacher can read braille and Nemeth immediately, while students work out problems. Itinerant teachers must work with students of all ages in many different subjects and settings. They are less likely to have opportunities to become proficient in knowing the technologies that need to be integrated for various subjects. Also, itinerant teachers must equip the mathematics teachers in general education classrooms who do not read braille and their braille-reading students with high-tech assistive technology that is capable of facilitating real-time mathematical communication.

Implications

Practical implications of these results are that school districts or regions can maintain a core set or sets of high-tech assistive technologies and make relevant devices available according to subject. In addition, training for such technologies can be targeted. Although optical character recognition software training is important for those who prepare materials, use of electronic refreshable braille notetakers is not (see Table 5). It is feasible that school districts can anticipate when students will take an advanced mathematics subject, provide training, and prepare the corresponding toolkit accordingly.

The study presented here shows that the devices that met criteria for potential inclusion in a core set of high-tech assistive technologies were all developed more than five years ago; therefore, most are familiar to teachers of students who are visually impaired. One implication for teachers reading this study is the provision of a narrower list of high-tech assistive technology with which to experiment when they work with braille readers in advanced mathematics courses. When an obstacle is encountered, teachers may be encouraged to try one of the core devices used by their peers for a specific task.

Finally, it is critical that successful integration of high-tech assistive technology be documented for analysis and dissemination. Unlike other subjects—such as history, which evolves over time, or the subjective topic of literature—the principles of advanced mathematics are consistent. A manual documenting when and how to successfully use devices in the core set of assistive technologies would provide a single source of information on a limited number of tools and how to apply them to each topic. Training videos on how to use each device in the core set of assistive technologies with students in a particular mathematics subject could also be developed.

Limitations and recommendations for future research

Several limitations of this study should be considered when interpreting the findings. The list of devices created for the data-collection instrument was derived from the review of literature and input from two visually impaired professionals and may not be comprehensive. The matrix consisted of a long list of devices, potentially leading to order bias through routine answering strategies or respondent fatigue (Alreck & Settle, 2004). Although the instrument used objective measures, there is a degree of interpretation of the meaning of questions by participants.

With regard to participants, the sample size was small and respondents self-selected. It is possible that other teachers of visually impaired students, who may have more expertise using high-tech assistive technology, did not participate. In addition, the higher-level subjects had extremely low response rates. It is important to note that the reasons a device was chosen, which could have been availability or comfort level, were beyond the scope of this study.

Future research to gather detailed information on the who, why, when, how, and what of high-tech assistive technology use is necessary for successful lesson plan integration. In addition to the identification of toolkits, the development of user-friendly, subject-specific manuals for teachers of visually impaired students, classroom teachers, and students is recommended. Teachers of visually impaired students identified as working in advanced mathematics with students who are visually impaired could be equipped with a prototype toolkit and asked to document high-tech assistive technology use throughout the year.

At this time, there is no device that translates between complex print and Nemeth and allows for simultaneous visual and tactile viewing of the mathematical manipulation. Research into the development of high-tech assistive technology designed to support braille readers in advanced mathematics needs to continue. These study results provide a starting point for developing a plan that ensures students who are visually impaired obtain the maximum benefits from our high-tech world.

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