Technologies That Facilitate the Study of Advanced Mathematics by Students Who Are Blind: Teachers' Perspectives

by

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ABSTRACT

Implicit in the technology boom of the last three decades is the promise of the accessibility necessary to make equal opportunity achievable for all students. It is the role of teachers of students with visual impairments (TVIs) to provide the most advantageous tools and instruction on their use, at the proper time to the student and classroom teacher. This research examines TVIs' perspectives on the current state of high-tech devices purporting to assist students who are blind, in an attempt to appraise the educational value of high-tech tools for practical application in various mathematics subjects.

Six research questions guided the design of the survey instrument. The research examined TVI perspectives regarding which high-tech devices were currently used in secondary school advanced mathematics courses to support students who are blind. Furthermore, is there a core set of devices that is perceived by TVIs as beneficial, and do the contents of that set change depending on the subject? The next two research questions looked at perceived effectiveness of the devices for supporting typical lesson-plan steps and where there were gaps in support. Finally, teachers were encouraged to provide additional insight in order to determine if any themes regarding use of technology emerged.

A mixed-methods questionnaire that included a multiple rating matrix containing 35 devices was distributed electronically to a convenience sample of TVIs. Survey Monkey was used to collect responses, and data analysis was conducted using spreadsheet software. While 157 surveys were returned, a total of 82 were completed through the device matrix question. Results indicated that 21 of the 35 devices were, in fact, used by TVIs. In addition, there was a core set of 13 devices used by TVIs regardless of specific subject. More than half of the participants listed the same four devices, for three of the five typical lesson-plan tasks. Participants recommended another seven high-tech devices in the open response question.

Findings from this study lay a foundation for future research that will ultimately enhance advanced mathematics experiences of students who are blind and interested in going on to post-secondary school.

Keywords: advanced mathematics, students who are blind, high-technology, teachers of students with visual impairments, braille readers

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CHAPTER 1

INTRODUCTION

It has been a widely held belief that “learning to solve problems is the principal reason for studying mathematics” (National Council of Supervisors of Mathematics, 1978, p. 4). The intrinsic value of a solid mathematics foundation is critical for students as they prepare to enter careers in science, technology, business, engineering, and related disciplines, such as the social and behavioral sciences. During the past three decades, the technology boom has produced an abundance of tools to assist with learning and teaching. The growth of the Internet and requisite compliance with Section 508 of the Rehabilitation Act of 1973 have further challenged the world to develop advanced assistive technologies that provide access to learning environments for individuals with disabilities. Facilitating the study of mathematics for students who are blind requires that teachers of students with visual impairments (TVIs) engage in the arduous process of sifting through mass quantities of continuously evolving products. Often, itinerant TVIs may have only one such student in their entire careers and very little time to tackle such a trial-and-error process (Zhou, Smith, Parker, & Griffin-Shirley, 2011).

> I did not require any special methods of instruction. I attended regular classes where I took notes in braille supplemented by tape recordings of the lectures. I developed the Nemeth Code when I found that the other available codes in existence were inadequate as a tool for doing mathematics. (Abraham Nemeth, 1996, para. 2)

For students like Abraham Nemeth, who are passionate about their studies, self-motivated, hardworking, and have no cognitive issues, there are no barriers to learning, not even a nonexistent mathematical braille code. Students who exhibit high self-efficacy demonstrate the confidence in their ability to do something or learn something new (Bandura, 1997). Such students who have a stable social development will find a way to access and master the concepts before them. In Abraham Nemeth's case, challenges that frustrated other students when they were faced with complex mathematics excited him and compelled him to work harder. Abraham Nemeth said he "used the braillewriter as the exclusive device by which I performed mathematical calculations and manipulated mathematics expressions" (Nemeth, 1996). When literary braille was not sufficient, he invented the Nemeth Code.

However, typical students who are blind encounter the same roadblocks to entering technical disciplines as their typical sighted peers, plus additional barriers due to lack of vision. Some of these students may be "at risk," an umbrella term used by researchers such as Bearinger, Garcia, Naughton, Sieving, and Skay (2008) to broadly define those students who have not been diagnosed with any type of disability, yet are not achieving as well as their intelligence would indicate. This lower achievement may be attributed to emotional reasons or problems in their home, which may include poverty, mental illness, drugs and alcohol, and/or physical or emotional abuse. Or, underperformance could result from having attention deficit hyperactivity disorder (ADHD) or some other learning disability that requires intervention. Too many students—especially students who are poor, not native speakers of English, disabled, female, or members of minority groups—are victims of low expectations in mathematics

(National Council of Teachers of Mathematics, 2000). These socioeconomic and learning/behavioral issues present roadblocks across all subjects, not just mathematics.

Exceptional teachers of advanced mathematics are aware of the variety of issues students may bring with them and have tools for keeping the students engaged and progressing in their classrooms. Additional roadblocks inherent to the complexity of teaching advanced-mathematics subjects are compounded for students who are blind. High-quality teaching incorporates and implements tools to help students with and without vision to access and understand advanced mathematics to the best of their ability. For classroom teachers who have a student who is blind, the addition of technology in the classroom is not optional, but necessary. Yet, according to Pierce and Ball (2009), 24% percent of teachers agreed or strongly agreed with the following statement: “If I use more technology, I won’t have time to cover the course.” This finding was in response to a survey regarding use of technology in mathematics classes for students with vision. With this sort of pre-existing paradigm, any enthusiasm a classroom teacher may have felt at the prospect of teaching a braille reader will be quickly extinguished.

Statement of Problem

Susan Osterhaus (2004) stated:

> How do you teach secondary mathematics to **sighted** students? The same way I teach **blind** students! …. I strive to appeal to as many senses as possible, so I encourage all of my students to read, speak, listen to and look at, touch and feel, sing, and sometimes even smell and eat mathematics— basically completely immerse themselves in the problem at hand. In my experience the more in-roads math concepts have to access the brain, the more likely your student will be able to out-put a correct solution to a problem and transfer that knowledge when learning a new concept. (para. 2)

There are students who are interested in taking college level mathematics courses, such as calculus, in preparation for a career in mathematics, engineering, the sciences, technology, or business, including students who are blind. Yet, according to Lavicza (2010), despite an overall increase in student enrolment, there is a decrease in interest in Science, Technology, Engineering, and Mathematics (STEM) subjects. Furthermore, the emergence of new technologies raises the expectations of secondary school students who anticipate using software and hardware in their further study of STEM subjects. It is therefore crucial that all students with an interest in and aptitude for mathematics have the tools necessary to participate fully in advanced mathematics courses. This access includes students who are totally blind, who may provide unique insights due to their different cognitive skills for the acquisition, storage, integration, analysis, and presentation of mathematical information. Yet there are very real barriers to their continuing to study advanced mathematics.

The barriers for students who are blind in studying advanced mathematics are two-fold: those barriers that make learning advanced math inherently different, and therefore, more challenging than learning other subjects; and those barriers that involve the access, manipulation, and mathematical communication without vision. The first barrier exists for all students, yet many of the teaching strategies used to overcome the complexities involved with understanding mathematics are visual. The second barrier is unique to students who are blind and involves the pragmatics necessary for across-the-board participation in all parts of the typical lesson plan.

It is the role of the TVI to remove the second barrier. In a residential school for students who are blind, the TVI will also be the classroom teacher, teaching the content while providing tools for access, communication, and problem solving. These TVIs must remain up to date in their knowledge of technological progress as it pertains to current studies, as well as post-secondary applications. For students who remain in their school districts, itinerant TVIs are assigned to provide support in all subjects. Through consultation with the classroom teacher and instruction to the student who is blind, the TVI provides a “bridge” of communication that enables learning to occur. Proficiency in use of pertinent technology on the part of the TVI is a critical component to successful communication. The problem is that the combination of the broad range of skills necessary to serve students with visual impairments that TVIs need, the rapid continuous evolution of technology, and the complexity of mathematics in general all add up to confusion about how best to equip the student, TVI, and classroom teacher in their respective roles.

Purpose of Study

> Technology makes braille materials more available than ever before. However, it is unclear whether the greater availability of braille extends to the field of mathematics. Even if mathematical materials are available in braille, the question remains of how blind and visually impaired people actually perform mathematical tasks—solve problems; prove theorems; take tests; and write papers, dissertations, and books. How do blind and visually impaired people communicate mathematically with others? …Just like we provide college classrooms with an overhead projector system for presentations, to use as they please, can we provide schools with one system that will meet all the needs of blind students who want to learn high level math? (Al Maneki, 2010, para. 4)

The purpose of this research is to determine the current status, as perceived by teachers of students with visual impairments, of high-technology devices being used in advanced mathematics classes to support students who are blind. The technology boom of the last 10 years has fueled a surge in development of accessibility tools, many specifically alleging to support learning advanced mathematics by students who are blind. Teachers of students with visual impairments must sift through mass quantities of information and products, often through trial and error, to find a handful of tools that are actually useful, affordable, available, and designed for the specific subjects they will be supporting. This searching is an arduous process for already overextended teachers who may have only one such student in their careers. This research attempts to appraise the educational value of these high-tech devices for various mathematics subjects and various tasks necessary to participate in a lesson.

Research Questions

The following questions were developed to guide this study:

1. Which high-tech devices, according to TVI perspectives, are currently being used in secondary school advanced mathematics courses to support students who are blind?
2. Is there a core set of devices that is perceived by TVIs as beneficial for supporting advanced mathematics students who are blind, regardless of specific subject?
3. Are there variations of the core set of devices, as perceived by TVIs, depending on the particular advanced mathematics subject involved?

4. According to TVI perceptions, how effective are these tools, in supporting learning throughout the following lesson-plan steps:
    - Preparation of materials
    - Accessing the lesson
    - Guided practice
    - Independent practice
    - Submission of work

It is important to note that the value of high-tech devices is not determined solely by student use. A device used by a teacher's assistant to transcribe printed notes into braille so the student can follow along with the class during demonstration is also valuable. In essence, a device is considered potentially valuable if it is used to support a student who is blind in any advanced mathematics subject, regardless of who the actual user is.

5. Are there gaps between technologies being used and teaching activities? Are there lesson-plan steps that are not supported, either overall or in specific subjects?
6. Are themes emerging in TVIs' recommendations about high-tech devices that were not listed or used in ways not indicated?

Theoretical Framework

Advanced Mathematics

The challenges of learning advanced mathematics for all students have been studied by many researchers. The multimodality of the content itself, the steps of the modeling process, and accessibility in the classroom are all key factors.

Multimodality in mathematics, according to Hammill (2010), refers to the three components necessary to solve word problems: verbal, symbolic, and graphic. O'Halloran (2005) asserts that the different modes are complementary, each providing a different way for achieving meaning in mathematics. According to Sfard (2008), it is unique to mathematics that no single mode would suffice to accurately convey information and meaning. In many problems, one or more modes—like verbal and/or symbolic—may be embedded in another, like graphic. A graph may have symbolic and verbal label components, for example. Reading symbolic expression in mathematics, like reading written English, generally occurs from left to right. However, the process is much more complex than reading English (Gillan, Barraza, Karshmer, & Pazuchanics, 2007). In mathematics, a significant amount of backtracking happens as both the symbols and syntax in which they occur are examined and reexamined for details like parentheses and exponents.

Formulation and translation may be discrete but are often concurrent parts of the modeling process—the first steps in analysis of information in order to set up a mathematical equation or choose a formula. Translation would occur if the verbal components of the problem could be translated directly into mathematical notation. However, just like in language translations, a certain amount of interpretation is required in order for accurate formulation to occur. This stage is where many students have difficulties in translating the word problem into the mathematical formula, and then deciding which mathematics they should use (Klymchuk, Zverkova, Gruenwald, & Sauerbier, 2010). Clement, Lochhead, and Monk (1981) pointed out that "rather than being an immediate aid in learning mathematics, the process of 'translation' between a practical situation and mathematical notation presents the student with a fresh difficulty that must be overcome if the application (or the mathematics) is to make any sense to the student in the long run" (p. 287).

In recent years, there has been a focus on making all lessons accessible to all students. Universal design for learning (UDL), designed by the Center for Applied Special Technology (CAST, 2011), includes three components: multiple forms of representation, multiple means of expression (responding), and multiple types of engagement. These components should be integrated into the process of lesson planning from the beginning so that all students have multiple means of accessing and participating in the curriculum (Spooner, Baker, Harris, Ahlgrim-Delzell, & Browder, 2007). UDL provides a foundational philosophy that ensures diverse student populations can engage in curriculum. The three components are embedded in the recommended lesson-plan format. This foundation also serves as a scaffold to students with additional assistive technology (AT) needs, unique to their own cognitive, sensory, or other disability.

In addition to the challenges faced by all students learning advanced mathematics, students who are blind must wrestle with the added complexities associated with not having vision. Braille readers need tools for mathematical linearization, for facilitating problem solving, and for mathematical communication. With a single glance, a student with vision looking at mathematical content can quickly obtain a lot of information (Stöger, Batu, & Miesenberger, 2004). For students who are blind, the content of the problems must be linear. In addition, the relevant graphic may be a drawing with notes or dimensions, a formula with operators and parentheses, or a graph with labels. When the same information needs to be presented to a student who is blind, it must be interpreted through tactile or audio communication. Both of these modes, according to Karshmer, Gupta, and Pontelli, E. (2009) are linear—that is, only one syllable or character in audio or tactile information can be received at a time. This process will require linearization of the two-dimensional information and result in a longer stream of information that requires more processing time and is prone to processing errors. Around the world, different mathematical braille notations have been developed, including Nemeth Code, resulting in the loss of universal components intrinsic to printed mathematics. For international mathematics conventions attended by people who are blind, this code diversity is a significant limitation to mathematical communication (Stöger et al., 2004).

Parts of problem solving involve manipulating algebraic equations by moving terms around an equal sign, simplifying, and performing identity operations on it.

Students are traditionally taught to build the equation down, continuously looking for opportunities for simplification and rewriting their results on the line below. This inability to access the entire problem at once and position algebraic terms in proper alignment for cancellation, subtraction, and other operations is another barrier to advanced mathematics for students who are blind. Nemeth (1996) stated that using the braillewriter for all his problem solving was the closest thing to paper and pencil. Yazzalino (2006) used the same strategies, a tribute to her high motivation. Simple and useful methods of converting graphs and other visual images, matrices, and drawings into tactile graphics still require time, planning, and preparation (Osterhaus, 2010).

The ability for students who are blind to communicate with each other despite language differences extends to their ability to collaborate with sighted peers. In print mathematics, students for whom English is not their first language may still point to an exponent or a coordinate on a plane, and the natural representation of the expression is understood despite the language barrier. This type of synchronization in mathematics—the understanding of mathematical representations at the same time as their sighted teacher and possibly several sighted schoolmates—must also exist for students who are blind (Archambault, Stöger, Batu, Fahrengruber, & Miesenberger, 2007).

Schweikhardt (2000) noted that requirements for the successful integration of students who are blind into regular education mathematics environments include computer-usable notation that supports use by both people who are blind and those who have vision and notation that supports joint education of students who are blind and those who are not. Ideally, the notation created by a student who is blind is simultaneously converted into its corresponding printed symbol, and a student with vision should be able to easily understand the mathematical meaning.

Technology and Advanced Mathematics

Many mathematicians, like Buteau, Marshall, Jarvis, and Lavicza (2010), now believe that to some degree, being proficient in advanced mathematics has become synonymous with being proficient in corresponding technology. Benefits of using technology like Computer Algebra Systems include elimination of the tediousness of calculations, allowing students to focus more on conceptual understanding. Work becomes more motivating and realistic. These skills are useful in work roles after graduation. Students who are blind must have the same opportunities to benefit from CAS, other software, and high-tech tools so they can focus on conceptual understanding.

In order to understand the technology that has been developed specifically to support students who are blind, it is helpful to look at the history of computer technology in general. In 1963, the American Standard Code for Information Interchange (ASCII) was developed by a joint industry–government committee (Computer History Museum, n.d.). This was the first universal standard for computers, permitting machines from different manufacturers to exchange data. For braille readers, ASCII played a big role in the development of braille translation software, such as Duxbury Braille Translator (Sullivan, 1999) and the transmission of braille through telephone lines to embossers.

In the mid 1980’s, the original LaTeX was developed by Leslie Lamport at Digital

Equipment Corporation to enable authors to create electronic-publishing-ready works (Mittelbach & Rowley, 1999). Text, including mathematical formulas, input linearly, could be shown on screen or printed, a prerequisite step to creating Nemeth notation for embossing. ASCII and LaTeX are not products that a TVI would acquire for his/her students. However, they exist within other products, such as the German Labradoor, which enables a mathematically based LaTeX document to be converted to Marburg braille for embossing.

Aside from conversion of print material into accessible braille, advanced mathematics students who are blind in academic classes need to be able to fully engage in the same calculations their classmates are making, at the same time, with their teachers' guidance. Numerous projects that focus on this aspect of learning—MathGenie and Lambda systems, for example—incorporate other technologies, like MathML and MathType. Other various audio and speech capabilities projects are in development around the world (Karshmer, et al., 2009).

Teachers, Technology, and Mathematics

Pierce and Ball (2009) attempted to reveal mathematics teachers' perceptions of possible barriers and enablers to their use of technology in their teaching. Results regarding attitudes about using technology in mathematics classes indicated that teachers felt positive about its potential to motivate students, make math more enjoyable, assist students in gaining deeper understanding, and work real-world problems. Adopting available and accessible technology to support teaching and learning requires teachers to change their teaching practices (Pierce & Ball, 2009) from being solely paper and pen based to integrating technology. Once teachers and their students learn how to operate a device, they must continue to plan for how it will be integrated into daily lessons, homework, and assessments. If they do so, cost to students and families must be considered for initial purchases, as well as for replacement, troubleshooting, and additional training. Implications of results of this survey are that professional development cannot only focus on teaching technological skills, attitudes and perceptions of impacted staff members need to be addressed as well (Pierce & Ball, 2009).

Teachers, Technology, and Students Who Are Blind

Reed and Curtis (2011) conducted a study in Canada attempting to understand the issues teachers encountered when students with visual impairments transitioned to higher education. Difficulties identified were in students' abilities to access accommodations, getting accessible materials in time, and late arrival and poor quality of books transcribed into braille. In some cases, teachers indicated students who did not have enough training in using technology efficiently did not want to appear different from peers. Inadequate support in providing accommodations was evidenced by the too few technologists available, as well as their frequent inability to solve problems. Lack of time or funding for substitutes prevented teachers from attending trainings. Most of the training was offered to teachers of students with visual impairments and not the classroom math teachers, impacting classroom teachers' ability to support accommodations in their classrooms. Two-thirds of the respondents suggested that students need further accommodations, more education about visual impairment, and more teachers of students with visual impairments. Researchers have attempted to determine the technology competencies appropriate for professional TVIs.

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 with visual impairments. After five extensive rounds of deliberations, an exhaustive list of 111 competencies emerged. Panelists commented that the combination of evolving technology and changing roles of teachers of students with visual impairments would necessitate continuous dialogue and updating of the list. Additionally, it was recommended that the competencies be used by universities developing training programs and by professional organizations for professional development.

Of those 111 assistive technology competencies, 74 competencies were included in the Zhou, Smith, Parker, and Griffin-Shirley (2011) study that attempted to determine what level of expertise in each competency TVIs perceived as necessary to perform their jobs and whether it was aligned to what the expert panelists perceived as optimal in the Delphi study (Smith et al., 2009). Also, the 2011 study compared the perceptions of the TVIs versus expert panelists in regards to levels of importance of six assistive technology domains. Results indicated discrepancies in the priority ranking of some of the competencies between what panelists versus TVIs deemed important. Open-response items (Zhou et al., 2011) yielded insights from TVIs who said that they just "cannot attend to every technology available" until they actually need it for a student. In addition, the continuous evolution of technology makes it inefficient to attempt to learn everything until it is relevant. Thus, the teachers of students with visual impairments thought it was more important to be able to access a variety of professional development resources for assistive technology at any time.

Teachers, Technology and Advanced Mathematics for Students Who Are Blind

Tanti (2006) noted in his case study, "I made use of non-technological and low-technological tools to teach. Since the time frame was very limited, it was difficult to find suitable software and to teach both the mathematical concepts and how to use the software at the same time" (section 4.4).

In the Tanti case study (2006), the student, John, was an adult with visual memory of standard print operators. In this unusual case, the teacher and student agreed that taking time for John to learn Nemeth Code was not possible. Student proficiency in the Nemeth braille Code is considered critical to student success in advanced mathematics classes (Osterhaus, 2010).

Rosenblum and Amato (2004) conducted a study that examined the experiences of TVIs with the Nemeth Code. Results of the survey indicated a need for university programs to provide intense preparation in Nemeth Code. Researchers also recommended that university programs provide their students with access and skills in using tools to produce materials in the Nemeth Code. The most common text, *Learning the Nemeth Braille Code* (Craig, 1987), was found to provide inadequate information on higher-level mathematics (Kapperman & Sticken, 2003).

Assumptions

The following assumptions were made in regard to this study:

1. Participants responded truthfully, to the best of their ability.
2. There are TVIs who have taken a strong interest in the newest high-tech devices and who proactively seek effective ways of using them to support students who are blind, as well as their classroom teachers.

Definition of Terms

Technology: This study looks specifically at high-technology (high-tech) tools defined as: "scientific technology involving the production or use of advanced or sophisticated devices, especially in the fields of electronics and computers" (Merriam-Webster, 2012, para. 1).

Students who are blind: Students who have no useful vision and are braille readers.

Advanced mathematics: Courses such as algebra 1 & 2, geometry, statistics and probability, trigonometry, precalculus, and calculus, or any course for which algebra 1 would be a prerequisite.

Limitations

There are certain limitations in this study that should be considered in interpreting the findings. They include the following:

1. The list of devices created for the data-collection instrument was dependent on cumulative research plus input from education professionals.

High-tech interest often has some geographic tendencies. It is possible that in a geographic area in the US not reached by this survey, there are high-tech devices that researchers were not aware of. It is the intent of the open-ended items to encourage participants to include such devices.

2. Information regarding the exact number of TVIs who have worked with braille readers over the last 10 years was not uncovered. Therefore, estimates about the percentage of the population in the sample survey are very rough.
3. Participation in the study was purely voluntary, and despite attempts to reach the entire target population, actual respondents were self-selected.
4. While the instrument uses objective measures, there is a degree of participant interpretation of the meaning of the questions.

Significance of Study

An implications of this research is that as the technology that supports students who are blind improves, it is vital to make sure that TVIs have adequate training in state-of-the-art devices in order to communicate higher-level mathematics to these students. Training in both Nemeth Code, the mathematical language for the blind, and training in all the technologies and software their students need are necessary so that students with visual impairments can access, manipulate, solve, and demonstrate their understanding of math problems.

Additionally, while there is a wide array of technology available to facilitate studying advanced mathematics by students who are blind, there is confusion about its current state of development and purpose, and reluctance in integrating it into classroom teaching in general. Research has shown that TVIs have indicated a need for professional development in assistive technology, but the range of needs is so vast, and it is very difficult to time the appropriate training to the perceived need. It is not clear how well teachers are functioning at this point in time with all these factors with which they have to contend. Are there teacher-created useful systems from the various high-tech tools available to enable students who are blind to fully engage in their advanced math courses? As state-of-the art equipment continues to evolve, the trend in colleges of having digital textbooks is making its way to secondary schools. How do students who are blind sufficiently prepare to handle these college-level challenges, particularly in mathematics? Are they getting adequate introduction to the tools they will have to use while they are still in high school? This study will provide a starting point, a baseline of the current state of high-tech usage for supporting students who are blind in advanced mathematics. These results can be used as guidance for both preservice and inservice future training of TVIs.

CHAPTER 2

REVIEW OF THE LITERATURE

Mathematics has held a privileged status in most school curricula due to the idea that, according to Inglis and Simpson (2009), studying mathematics—more than any other subject—develops thinking skills more generally. The study of advanced mathematics by students who are blind is a multifaceted issue with many factors. There are the challenges inherent in the material itself, compounded by complete absence of visual capabilities. These challenges lead to barriers accessing the material and understanding the concepts that would normally be presented visually. The next level of complexity is the actual working of a problem that is typically grasped at a glance and now has to be carefully dissected, line by line and character by character. There are a myriad of high-tech tools that promise to make parts or all of this process intuitive, concluding with a print document to submit to a teacher with vision for a grade. The TVI must manage the student(s), the mathematics content, the classroom teacher, the technology, and any transcribers involved in the process. All of these elements and their interrelations are examined in this chapter.

Learning Advanced Mathematics—General Challenges

Students who are blind wrestle with the same complex issues of learning advanced mathematics as students with vision. The mathematical modeling process can be described as "consisting of structuring, generating real-world facts and data, mathematising, working mathematically and interpreting/validating (perhaps several times round the loop)" (Niss, Blum, & Galbraith, 2007, pp. 9-10).

A researcher in Malta, Tanti (2006), who teaches mathematics including algebra to students planning to sit for the equivalent of a General Education Diploma, conducted a case study with an adult student who was blind and wanted to take the exam. Tanti (2006) explains:

> On introducing Algebra, I met almost the same problems as those encountered by the sighted students. That is the understanding of what algebra is all about and why is it so useful. I started this part by introducing the generalized letters *x* and *y* through concrete examples so that the participant would not get the impression that they are something artificial. (Section 5.3.2)

Formulation and Translation

A key step in the modeling process—formulation, which happens concurrently with translation—entails analyzing the information in the problem. The problem may include numbers, expressions, and the text that describes the numbers' and expressions' relationships. *Formulation*, then, is the process of either constructing or choosing a formula. In some cases, students may only have to choose appropriate formula from a given set. In other cases, it becomes the mathematical equivalent of interpretation in the language translation process, requiring more than one-to-one conversion of terms. Formulation is the stage where many students have difficulties in translating the word problem into the mathematical formula and then deciding which mathematics they should use (Klymchuk, Zverkova, Gruenwald, & Sauerbier, 2010). Students typically begin studying the mathematical modeling process in pre-algebra, yet many continue to struggle with the formulation step throughout more advanced mathematics courses.

Klymchuk et al. (2010) examined university engineering students' difficulties in the formulation step of solving a typical application problem from a first-year calculus course. During a mid-semester test, a total of 104 students in New Zealand and Germany completed a questionnaire designed to uncover the reason for the difficulties. It was found that students either struggled with understanding the language or identifying and using the formula. When asked how they thought they could improve their ability to formulate the problem, over 80% of the students responded that more practice solving similar problems was needed. For students who are blind, the formulation step would entail reading and rereading the problem several times, assuming it was accurately transcribed, perhaps requiring more time since they cannot quickly see the formulas from which they will choose.

Clement, Lochhead, and Monk (1981) pointed out that "rather than being an immediate aid in learning mathematics, the process of 'translation' between a practical situation and mathematical notation presents the student with a fresh difficulty that must be overcome if the application (or the mathematics) is to make any sense to the student in the long run" (p. 287). In their study, Clement et al. (1981) developed a set of simple mathematical translation problems and put them to freshman engineering majors, most of whom were taking calculus. One of the problems was:

> Write an equation using the variables C and S to represent the following statement: At Mindy's restaurant, for every four people who ordered cheesecake, there were five who ordered strudel. Let C represent the number of cheesecakes ordered and let S represent the number of strudels ordered. (p. 287)

It was mistakenly assumed that college students could translate into and out of algebraic notation accurately, yet only 39% of the students' answers were correct. Because so many of the students reversed the variables in their equations, answering 4C = 5S instead of 5C = 4S, Clement et al. (1981) could not attribute this reversal error to misunderstanding English.

The formulation process is introduced to students as "story problems." They translate a story into mathematics, solve it algebraically, and translate their answers back to words. But simple one-to-one translation of terms is not always accurate. The mental processes that must take place in the creation of a new equation on paper are not communicated, either from the students to their teachers or visa versa. Symbolic representation of language must entail interpretation in order to be accurate, not direct translation. Because explanation of the thought process is difficult, teachers often present partially formulated problems or a choice of formulas that requires minimal decision making. Mathematicians must be able to translate ideas into algebraic notation. However, many students continued to have the same types of reversal errors even after a semester or more of calculus (Clement et al., 1981, p. 289).

Recognizing when to switch from translation to formulation, and back, is extremely complicated. For students reading braille, the context of the problems they are working on will dictate the notation to some extent. They will have another layer of terms around the mathematical symbols and operators, necessary for linear presentation of the Nemeth Code elements.

Multimodal Analysis

In the process of solving real-world problems, diagrams, and text must be analyzed and understood to create and solve symbolic expression that can be used to construct graphs (Hammill, 2010). Graphs, in turn, may lead to new interpretations that must be related to the original problem. There are three components that come into play in mastering problem solving, that are seldom taught explicitly: the verbal component, the visual component, and the symbolic component.

If understanding the mental processes used by students in the formulation process is important, emphasis on clearly defined terminology is key. Mathematical text is complex and has specialized meaning. Some terms, like “square roots,” do not make sense in the non-mathematical world, even though each separate word does. Others, like “polynomial,” are not encountered at all during day-to-day life (Meaney, 2005). Visual displays, including diagrams, graphs, and drawings are key to the acquisition of mathematical meaning. However, understanding of the images cannot occur without understanding of the concepts inherent in them. As a result, the visual cannot be treated autonomously, but must be considered in context (Hammill, 2010).

Reading symbolic expression in mathematics, like reading written English, generally occurs from left to right. However, the process is much more complex than reading English (Gillan, Barraza, Karshmer, & Pazuchanics, 2004). Students must spend a significant amount of backtracking in order to examine and reexamine both the symbols and syntax for details like parentheses and exponents. According to Hammill (2010), the process of learning the symbolic component of mathematics text is not well understood. Whether symbolic mathematics is primarily verbal, visual, or a hybrid of these modes, and how cognition and linguistics entwine in the learning process are also not understood. Hammill goes on to say, "As well, little research has yet been undertaken into the two-dimensional visual structure of mathematical expressions" (p. 5).

Various researchers have similar perspectives on the multimodality of mathematics. Some, like O'Halloran (2005), assert that the different modes are complementary, each providing a different way for making meaning in mathematics. One interesting view is that of Schleppegrell (2007), who claims that the verbal component, the actual word problem, provides the context of the problems; the symbolic component, including the operators, describes the patterns or relationships between terms; and the visuals or graphics connect the concepts to the physical world. According to Sfard (2008), mathematics is different from other subjects because no single mode would suffice to accurately communicate meaning.

For students without vision, the visual component is completely absent. Connections to the real world would have to be made using three-dimensional objects they can understand tactually. The verbal and symbolic portions of the problem must be very accurately transcribed into braille/Nemeth Code. In essence, there is no way they can have the same experience of a word problem as a student with vision. However, that does not mean students without vision cannot have another multimodal experience of mathematics—one that is tactile, verbal, and symbolic—that can lead to correct formulation and solutions.

Accessibility

Learning mathematics happens when the learner is able to think and use the relevant prior knowledge to solve the problem at hand with understanding (Orton & Frobisher, 1996). Universal design for learning (UDL), designed by the Center for Applied Special Technology (CAST, 2011), includes three components: multiple forms of representation, multiple means of expression (responding), and multiple types of engagement. All three components, according to UDL, should be integrated into the process of lesson planning from the beginning, so that all students have multiple means of accessing and participating in the curriculum (Spooner, Baker, Harris, Ahlgrim-Delzell, & Browder, 2007).

Spooner et al. (2007) investigated the application of this model by providing a 1-hour training on UDL-lesson-plan principles to 72 graduate and undergraduate students enrolled in general or special education classes. None of the subjects, who were randomly assigned to either the control or intervention group, had previously written a lesson plan using the UDL principles. The same rubric—including total scores and scores for each of the three components of the lesson-planning process—was used to score pre- and post-training lesson plans. The results indicated significant differences in the scores for participants from both groups, general education and special education, who were in the intervention group, indicating that even a simple training could improve the abilities of all teachers to apply UDL principles that promote accessibility for all students.

UDL provides a foundation for students to have multiple means of access and engagement in the curriculum. This foundation also supports students with additional assistive technology needs, unique to their own cognitive, sensory, or other disability.

Learning Advanced Mathematics—Challenges for Students Who Are Blind

Linearization of Mathematics

With a single glance, a student with vision looking at mathematical content can quickly obtain large quantities of information (Stöger, Batu, & Miesenberger, 2004). The relevant graphic may be a drawing with notes or dimensions, a formula with operators and parentheses, or a graph with labels. When the same information needs to be presented to a student who is blind, it must be interpreted through tactile or audio communication. Both of these modes are linear—that is, only one syllable or character in audio or tactile information can be received at a time. This will require linearization of the two-dimensional information, and result in a longer stream of information that requires more processing time and is prone to processing errors.

In the case of tactile conversions, 6-dot braille alone is very limiting. There are only 64 possible patterns of the dots, so it quickly becomes necessary to combine several patterns to convert all the mathematical symbols encountered. In addition, a prefix is usually added to a series or patterns to indicate the following patterns of dots are numerical. Expressions such as fractions have start and end symbols. Around the world, different mathematical braille mathematical notations have been developed (Stöger et al., 2004). However, in the process of providing these solutions to students who are blind, much of the universality of mathematics is lost. There is Nemeth Code (Nemeth, 1951), a mathematics code that requires text in literary braille, the German Marburg developed in 1930, and the Unified English Braille Code, attempting to provide one international braille code. No one system has been accepted universally for both mathematic notation and literary braille. In addition, John Gardner's DotsPlus, was developed as a mathematical notation alternative in 1993, with a 6-dot an 8-dot version.

In the case of fractions, block markers identify the numerator and the denominator, making it necessary to reach the fraction symbol to determine that the expression is in fact a fraction. In Italian, the numerator and the denominator markers are not the same, and there is no fraction symbol. Then when the first block marker is read, the user immediately knows it is a fraction. In the same kind of idea, Nemeth uses three braille characters: the beginning of fraction, the fraction bar, and the end of fraction. Often, the mathematical braille notation of each country incorporates its country's linguistic and cultural history. For international mathematics conventions attended by people who are blind, this is a significant limitation to communication (Stöger et al., 2004).

Problem Solving

Manipulating algebraic equations by moving terms around an equal sign, simplifying, performing identity operations on it, is traditionally taught by building the equation down, continuously looking for opportunities for simplification, and rewriting results on the line below. This inability to access the entire problem at once and position terms in proper alignment for cancellation, subtraction, and other operations is another barrier to advanced mathematics for students who are blind. Both Nemeth (1996) and Yazzalino (2006) stated that using the braille writer for problem solving was the closest thing to paper and pencil.

When considering using a braillewriter for their algebra problem solving, Tanti (2006) said the following:

> John did not suggest the use of braille writer to jot down notes and workings. He preferred the use of cork and pins to it because on a braille writer one cannot correct errors whereas on the corkboard, it is just removing or adding pins, so it is not time consuming. Moreover the use of pins can be easily read by touch whereas small embossed dots could be very difficult to read while working. He suggests that if there was appropriate computer software to use, it would have facilitated more work although he does not understand how a complicated diagram can be explained on a computer. (section 5.5)
>
> John worked out word problems much the same way as sighted students. He was able to move the pins around, with different shaped heads to distinguish numbers from variables, much the same way students with vision move numbers and variables on a page. He created a new line of pins below the previous line, step by step. He had to continuously read from the start of each line, and sometimes back to the previous line in order to determine the next step. While the concept was similar to algebraic pen-and-paper problem solving, it required more time for rereading and moving pins. (section 5.3.2.1)

Communication

The ability for students who are blind to communicate with each other despite language differences extends to their ability to collaborate with sighted peers. In print mathematics, students for whom English is not their first language may still point to an exponent or a coordinate on a plane and the natural representation of the expression is understood despite the language barrier. This type of synchronization in mathematics must also exist for students who are blind in their understanding of mathematical representations among each other, as well as for their sighted teacher and possibly several sighted schoolmates. Archambault, Stöger, Batu, Fahrengruber, and Klaus (2007) believe:

> Synchronization must allow each person to point at a location on the document, in the textual part as well as in a mathematical expression, to show it to the other, in order to highlight an idea or to explain an error. With a graphical view this pointing should be done using the mouse by clicking on the desired location. The specified location would then be highlighted on the alternative view. In the other mode the blind user must be able to make a selected location display with a different background on the screen.
>
> The synchronization must also support selection. The current selection must appear clearly as well on the screen as on the alternative display (braille). This is achieved by showing the current selection with a different background color. On the braille bar it is possible to underline the selection using dots 7 and 8 (section 3.1).

Researchers agree that the issue of mathematical notation is complex and crucial to opening the field up to people who are blind. Schweikhardt (2000) noted five requirements for the successful integration of students who are blind into mathematics environments: (1) the notation must be easy to read with fingers with a standard prefix notation only used as necessary; (2) to the extent possible, a one-to-one translation of print to tactile symbols, with operators as concise as possible; (3) intuitive characters like mirror images for each end of a parenthesis or less-than and greater-than signs, that simplify understanding; (4) computer-usable notation that supports use by both people who are blind and those who have vision; and (5) the notation must support joint education of students who are blind and those who are not. If the notation created by a student who is blind is converted into its corresponding printed symbol, a student with vision should be able to easily understand the mathematical meaning. This conversion simplifies the translation process and with the aid of computers, can allow for simultaneous work on a problem by a student who is blind and his/her teacher.

Technology and Advanced Mathematics Students

Many mathematicians, like Buteau, Marshall, Jarvis, and Lavicza (2010), now believe that to some degree, being proficient in advanced mathematics has become synonymous with being proficient in corresponding technology. Technology has allowed for an increase in demand of more applications of mathematical concepts from students. Because they have graphing calculators and computers to speed up their ability to create and interact with graphs, they are expected to have a broader understanding of graphs and how they are applied in modern day engineering, finance, and environmental science. In their literature review, Buteau et al. (2010) analyzed 204 papers about the use of Computer Algebra Systems (CAS) at the post-secondary school level. Some of the most common potential benefits of CAS usage identified in the review are noted here. First, they found that by taking the focus of solving mathematics problems away from the tediousness of calculations, students were more able to focus on the conceptual understanding and problem-solving strategies. Students also were able to enjoy working problems independently, often choosing to challenge themselves with more interesting problems when CAS usage was available to them to help with the computation portions. Students reported that they found this type of work more motivating, and more realistic and meaningful problems could be explored at earlier levels. These potential benefits are just as crucial for students who are blind. They too must be motivated to understand how to problem solve real-world problems and seek out tools to facilitate that process.

Technology and Advanced Mathematics for Students Who Are Blind

In 1963, the American Standard Code for Information Interchange (ASCII) was developed by a joint industry–government committee (Computer History Museum, n.d.). This was the first universal standard for computers, permitting machines from different manufacturers to exchange data. The 128 unique 7-bit strings represent letters of the alphabet, Arabic numbers, or an assortment of punctuation strings. For braille readers, it played a big role in the development of the braille translation software such as Duxbury Braille Translator (Sullivan, 1996). Text could not be translated into braille on a computer and transmitted through telephone lines to embossers. In the Duxbury Translator, ASCII characters are paired with a related English braille equivalent. For example, dot 1-2 is paired with the ASCII B.

Since then, a number of research projects proposed some partial solutions to problems of accessing and preparing mathematical material. Following is a sample of the products, first focusing on notation, and finally, products that allow students who are blind to work out mathematic problems. According to A. Karshmer, most of the projects are in various states of completion due to limited funding (personal communication, May 5, 2011)**.**

The original LaTeX was developed by Leslie Lamport at Digital Equipment

Corporation in the mid 1980s to enable authors to create electronic-publishing-ready works (Ziegler, 2000). Text, including formulas, is typed on a computer keyboard using characters of the 7-bit-ASCII. Then, the final translation, which can include mathematical formulas input linearly, could be shown on screen or printed, depicting linear mathematical expressions accurately. Because of the use of prefix notation instead of two-dimensional formatting, mathematics can be translated to Nemeth Code for embossing.

In Germany, using the LaTeX-to-braille converter called The Labradoor, a mathematically based LaTeX document can be converted to Marburg braille for embossing. Additionally, several projects have been developed to convert MathML (an application that makes mathematics in the World Wide Web accessible) into braille in several languages including French and Nemeth. Universal Math Conversion Library (UMCL), an ongoing project, is a programming library whose purpose is to contain various converters for different braille codes in a single library and simplify multilingual conversions. Input modules for LaTeX and Marburg braille are also under development (Stöger et al., 2007).

The Infty Project (Karshmer, Gupta, & Pontelli, 2009) is comprised of volunteer researchers from various universities who conduct research and development that focuses on computer systems that process scientific information including mathematical expressions. The organization has developed, among others, two products that accomplish functions relevant to students who are blind studying advanced mathematics.

First, the InftyReader (Karshmer et al., 2009) uses optical character recognition (OCR) to convert scanned print mathematical documents into extensible markup language (XML), which can then be converted into various formats including LaTeX and MathML. Second, ChattyInfty is another product that converts from the various language formats into audio presentation.

Aside from conversion of print material into accessible braille, advanced-mathematics students who are blind in academic classes need to be able to fully engage in the same calculations their classmates are making, at the same time, with their teachers' guidance. Numerous projects, like MathGenie and Lambda systems, focus on this synchronized aspect of learning. They incorporate other technologies, like MathML, MathType, and various audio and speech capabilities. These projects are in development around the world**.**

Research by Maneki (2010) surveyed current and former students about their experiences in learning advanced mathematics. Thirty-eight braille readers, five large-print readers, and nine auditory learners responded to the informal open-response survey. Respondents indicated that in order to participate in their mathematics classes, they used braille textbooks, electronic speech, live readers, and/or large print. Not all respondents had braille textbooks available to them. Recorded textbooks resulted in inconsistent presentation of material and ambiguous descriptions of graphic elements. Extra time was required in almost all aspects of learning, from accessing the material to submitting the work. Particularly difficult was getting enough independent practice to reach mastery because there was no efficient way to simultaneously solve and read multiline problems. Braille notetakers only display one line of text at a time. The survey (Maneki, 2010) concluded that there is a need for multi-line electronic braille displays and tools that support converting print to audio and back and print to Nemeth Code and back. Respondents suggested teaching LaTeX incrementally along with Nemeth. In addition, all software that is used in advanced mathematics classrooms must be accessible to all students.

Teachers, Technology, and Mathematics

Adopting available and accessible technology to support teaching and learning requires educators to change their teaching practices (Pierce & Ball, 2009) from being paper and pen based. In their Australian study, Pierce and Ball's (2009) Mathematics in Technology Perception Survey (MTPS), based on the Theory of Planned Behavior (TPB) framework, attempted to reveal mathematics teachers' perceptions of possible barriers and enablers to their intention to use technology in teaching. The TPB, which was proposed by Ajzen (1991), postulates that there are three antecedent factors that determine intent: 1) attitude towards behavior, 2) subjective norm, and 3) degree of perceived behavioral control. In general, if the attitude towards the behavior in question is favorable, and the subjective norm (i.e., perceived social pressure to perform the behavior) is positive, and it is perceived as a behavior that is relatively easy to achieve, then the person's expected intention to perform the behavior is stronger. The Pierce and Ball (2009) MTPS was e-mailed to approximately 200 secondary schools with the request that it be forwarded to the schools' mathematics teachers, and 92 anonymous volunteers participated. The 12-item survey (plus demographic questions) contained language common for teachers in the area. It was distilled from a 57-item pilot survey given to teachers from four different schools. Participants were asked to agree or disagree with six items that summarized perceptions likely to encourage adoption of technology, and six items that presented barriers to its adoption. Items were tagged according to which antecedent factors—attitude, subjective norm, or degree of behavioral control—they correlated.

Results regarding attitudes about using technology in mathematics classes indicated that teachers felt positive about its potential to motivate students, make math more enjoyable, and assist students in gaining deeper understanding and how to solve real-world problems. However, 23% of respondents believed that students would not understand the mathematics without doing it by hand before integrating technology. Responses to items related to the second antecedent factor—subjective norms or perceived social pressure from administrators, colleagues, parents, and other vested adults—indicated that most of the teachers clearly felt that their mathematics coordinator or principal expected them to use technology. However, most teachers did not feel pressure from students' parents, and 15% of the teachers still agreed that their colleagues would think students were not really learning math. Overall, items regarding social pressure indicated that social pressure was more likely to be perceived as an enabler than a barrier to integrating technology into teaching mathematics. However, teachers who did not feel that the school leadership expected them to use technology were less likely to believe that technology could be used to motivate students.

The final antecedent factor considered how difficult it is perceived to be to infuse technology into teaching. Barriers to making this change included concerns about costs to students and time. Teachers voicing those concerns believed that students must learn mathematics by hand first and were worried about the additional time necessary to teach students how to use the technology. In addition, teachers needed to allocate time to learn about it themselves. Once they and their students learned how to operate a device, teachers had to continue to plan for how it would be integrated into daily lessons, homework, and assessments. Once all of this was accomplished, cost to students and families must be considered for initial purchases, as well as for replacement, repair, and additional training. Implications of the results of this survey were that professional development cannot only focus on teaching technological skills. Professional development must also address the attitudes and perceptions of impacted staff members (Pierce & Ball, 2009). According to Pierce and Ball (2009), in short professional development needs to:

> capitalize on enablers and present strategies for dealing with barriers. For example, in the cultural context of the respondents to this survey, presenters should be mindful that females are almost three times more likely, than males, to be concerned by unexpected problems with technology. (p.315)

Teachers, Technology, and Students Who Are Blind

Reed and Curtis (2011) conducted a study in Canada that attempted to understand the issues teachers encountered when students with visual impairments transitioned to higher education. A total of 68 respondents, including classroom teachers (33%), teachers of students with visual impairments (53%), and other education professionals (14%), completed the confidential, voluntary survey. The survey was distributed online in both English and French and contained a total of 15 open-ended-opinion, multiple-choice, and yes-or-no questions about their experiences, perceived barriers to learning, professional development, and knowledge of accommodations. Results showed that most high schools provided equipment, such as computers and laptops and screen-reading software, and, depending on student needs, some had braille-translation software and braille devices.

Over 40% of respondents reported at least one difficulty in students' abilities to access accommodations (Reed & Curtis, 2011). Issues included getting accessible materials in time because classroom teachers had not submitted requests for transcription early enough and late arrival and poor quality of books transcribed into braille. In some cases, teachers indicated students with impairments did not have enough training in using technology efficiently and did not want to appear different from peers. Overall, there seemed to be inadequate support in providing accommodations as evidenced by few technologists available and their frequent inability to solve problems. Although over 65% of respondents reported that training in adaptive technology was offered, lack of time or funding for substitutes prevented them from attending.

In addition, Reed and Curtis (2011) found that most of the training was offered to TVIs and not the classroom teachers, impacting the classroom teachers' ability to support accommodations in their classrooms. Classroom teachers stated they needed more education about visual impairment. The study also found that respondents believed more teachers of students with visual impairments were needed because students needed further accommodations. One-quarter of respondents stated that classroom materials needed to be made accessible by mandating that textbooks be available in alternate formats.

Smith, Kelley, Maushak, Griffin-Shirley, and Lan (2009) conducted a Delphi study in order to define a set of appropriate assistive-technology competencies and corresponding levels of expertise that teachers of students with visual impairments should possess upon completion of a pre-service teacher certification program. Forty experts out of a group of 73 potential participants nominated by a group of 49 professional leaders agreed to participate as panelists in the study. They included 14 university faculty members, 14 itinerant teachers of students with visual impairments, eight residential teachers of students with visual impairments, 16 technology specialists, seven educational technology specialists, and 14 individuals with visual impairments. Many panelists were in more than one professional group (i.e., an itinerant teacher may have also been an individual with a visual impairment), explaining why there were not a total of 75 panelists.

After five extensive rounds of deliberations, an exhaustive list of 111 competencies emerged. Panelists commented that the combination of evolving technology and changing roles of teachers of students with visual impairments would necessitate continuous dialogue and updating of the list. Future research recommendations include having a focus group of experts examine the list and make it more comprehensive and conducting a large-scale study of teachers of students with visual impairments. Additionally, it was recommended that the established competencies be used by universities developing training programs and by professional organizations for professional development.

The 111 assistive-technology competencies generated in the Smith et al. study (2009) were divided into 10 domains, from which six domains, for a total of 74 competencies, were later included in the Zhou, Smith, Parker, and Griffin-Shirley (2011) study. In this study, competencies that were eliminated were in the four domains that were not directly related to student activities, such as professional collaboration. This study attempted to determine what level of expertise in each competency teachers of students with visual impairments perceived as necessary to perform their jobs and whether that was aligned with what the expert panelists perceived as optimal in the Delphi study (Smith et al., 2009). Also, the study compared the perceptions of the TVIs versus expert panelists in regard to levels of importance of the six assistive technology domains. Educational leaders of all 20 Regional Service Centers in Texas were contacted and asked to disseminate the link to the online survey via e-mail invitation. Teachers were not given the results from the 2009 study. Responses from 165 TVIs were analyzed.

In addition to basic demographic questions, the survey used a four-level Likert scale for participants to rate their opinions about necessary expertise in each competency within each domain. The panel experts and TVIs agreed to the priority of four out of the six domains. They differed in opinions regarding importance of proficiency in technology for “access to information” and “disability-related assistive technology.” As a whole, the “access to information” domain was rated lower by TVIs, with the competencies “ability to teach students how to deal with inaccessible materials” and “how to use the Internet” rating significantly lower (Zhou et al., 2011). The implication here is that experts think teachers of students with visual impairments would be spending a large portion of their work time helping students understand how to access materials and information on the Internet. In actuality, TVIs indicated that a larger portion of their job was working with students with multiple disabilities who needed switches and augmentative communication devices, and therefore, they ranked “disability-related assistive technology” as the most important domain.

Comments about the variety of needs they encounter as itinerant teachers point toward a wide range and continuous rotation of important assistive-technologies competencies. These comments may explain why TVIs gave a significantly higher rank to five of the competencies in the “professional development” domain than the field experts did. They just cannot attend to every technology available until they actually need it for a student. In addition, the continuous evolution of technology makes it inefficient to attempt to learn everything until it’s relevant. However, according to Zhou et al. (2011), when educators do find that they need professional development, it may not be easy to acquire.

Thus, the teachers of students with visual impairments thought it was more important for teachers to be able to get professional development resources for assistive technology. This finding is in concert with the results from other studies that it is difficult for teachers to find support for assistive technology and that the lack of adequate teacher training is one of the major obstacles to the wider use of assistive technology by students with visual impairments.

Teachers, Technology, and Advanced Mathematics for Students Who Are Blind

Research shows that a custom-built curriculum in one-on-one instruction for a single student who is blind can be successful without the use of any high-tech devices.

> Throughout the lessons, John helped me in learning the braille code. It was essential that while monitoring his work, I will be able to follow every step he does without interrupting. Moreover it was also necessary to use and learn braille for the preparation of the tasks used during the lessons. I made use of non-technological and low-technological tools to teach. Since the timeframe was very limited, it was difficult to find suitable software and to teach both the mathematical concepts and how to use the software at the same time. (Tanti,2006, section 4.4).

In the Tanti case study (2006), the student, John, was an adult with visual memory of standard print operators. In this case, the teacher and student agreed that taking time for him to learn Nemeth Code was not possible. Instead, they used large tactile print operators made by attaching thin wires to cardboard. This approach is an unusual one for teaching advanced mathematics to students who are blind. Abraham Nemeth developed the Nemeth Code when he found that braille alone was insufficient of notations in advanced mathematics. Student proficiency in Nemeth braille Code is considered critical to student success in advanced mathematics classes (Osterhaus, 2010).

Rosenblum and Amato (2004) conducted a study that examined the experiences of 135 teachers of students with visual impairments in regard to their learning Nemeth Code and using it to teach. Participants from 41 states, 92.5% female and 99.2% Caucasian, were asked how many academic students they had on their caseloads and how many of those students were using Nemeth Code. Surveys had been distributed via mail through the Council for Exceptional Children- Division on Visual Impairment (CEC-DVI), two divisions of the Association for Education and Rehabilitation of the Blind and Visually Impaired (AER), at the California Transcribers and Educators of Visually Handicapped (CTEVH) conference, and at the international convention of the CEC. The study intended to answer the following questions:

- What type of and how effective is preparation in the Nemeth Code for teachers of students who are visually impaired?
- How many students who use the Nemeth Code do teachers serve and what materials do they prepare for them?
- How do teachers prepare materials in the Nemeth Code?
- How do teachers support their students in learning mathematics by using the Nemeth Code?

Some key findings of the survey point to a need for university programs to provide separate intense preparation for teachers in Nemeth Code. Only 37 participants thought their university programs provided enough preparation in the Nemeth Code, with 18 reporting no instruction whatsoever. On average, teachers only had about seven academic students, and while 70 participants had either a transcriber or teaching assistant, there was rarely any preparation of advanced mathematics material. Researchers recommended that university programs provide their students with access and skills in using tools to produce materials in the Nemeth Code, such as Duxbury Braille Translation Software, MegaDots MegaMath Mathematics Translator, and Scientific Notebook/DBT. The most common text, *Learning the Nemeth Braille Code* (Craig, 1987), was found to provide inadequate information on higher-level mathematics (Kapperman & Sticken, 2003). Additional research is necessary to determine how to best support students and teachers learning the Nemeth Code, whether in campus settings or schools for the blind.

The main implication of this research is that as the technology that supports students who are blind improves, it is vital to make sure that TVIs have adequate training in state-of-the-art devices in order to communicate higher-level mathematics to these students. This result means training in both Nemeth Code—the mathematical language for the blind—and training in all the technologies and software their students may need so they can access, manipulate, solve, and demonstrate their understanding of math problems. Finally, a clear understanding of the roles of classroom teachers and TVIs as related to supporting students who are blind is critical. Classroom teachers must be willing to use creativity to make content accessible and TVIs must understand enough mathematics to prevent miscommunication in the conversion process (Maneki, 2011).

Summary

Literature thus far has clearly indicated that in addition to the unique challenges inherent in studying advanced mathematics, including formulation, translation, and multimodality, there are complex obstacles specific to students who are blind. These challenges are related to the linearization of mathematics, problem solving, communicating mathematically, and necessary teaching time. Additionally, while there is a wide array of technology available to facilitate studying advanced mathematics by students who are blind, there is confusion about its current state of development and purpose, and reluctance in integrating it into classroom teaching in general. Research has shown that teachers of students with visual impairments have indicated a need for professional development in assistive technology, but the range of needs is so vast, it is very difficult to time the training to the need.

Research related to teaching and technology for students who are blind studying advanced mathematics centers mostly around the Nemeth Code and the need for extensive professional training and consistent teaching of it. It is not clear how teachers are functioning at this point in time with all these factors. Are there teachers out there who have created useful systems from the various high-tech tools available to enable students who are blind to fully engage in their advance math courses? As state-of-the art equipment continues to evolve, the trend in colleges of having digital textbooks is making its way to secondary schools. How do students who are blind handle these challenges at the college level, particularly in college level mathematics? It is important to evaluate the core devices that currently support their studies in order to make sure these students are properly prepared to meet the challenges of studying advanced mathematics in both secondary and post-secondary educational settings.

CHAPTER 3

METHODOLOGY

Purpose of Study

The purpose of this research was to obtain TVI perspectives on the current status of high-technology devices being used in advanced mathematics classes to support students who are blind. The study examined which of the devices that are being used in classrooms are best facilitating student learning, as perceived by TVIs. The technology boom of the last 10 years has fueled a surge in development of accessibility tools, many specifically alleging to support learning advanced mathematics by students who are blind. TVIs must sift through mass quantities of information and products, often through trial and error, to find a handful of tools that are actually useful, affordable, available, and designed for the specific subjects they will be supporting. This process is an arduous one for already overextended teachers who may have only one such student in their careers. This research attempted to appraise the educational value of these high-tech devices.

Research Questions

The following questions were developed to guide this study.

1. Which high-tech devices, according to TVI perspectives, are currently being used in secondary school advanced mathematics courses to support students who are blind?
2. Is there a core set of devices that is perceived by TVIs as beneficial for supporting advanced mathematics student who are blind, regardless of specific subject?

3. Are there variations of the core set of devices, as perceived by TVIs, depending on the particular advanced mathematics subject involved?
4. According to TVI perceptions, how effective are these tools in supporting learning throughout the following lesson-plan steps?
    - Preparation of materials
    - Accessing the lesson
    - Guided practice
    - Independent practice
    - Submission of work

It is important to note that value of the high-tech devices is not determined solely by student use. A device used by a teacher's assistant (TA) to transcribe printed notes into braille so the student can follow along with the class during demonstration is valuable. In essence, a device is considered potentially valuable if it is used to support a student who is blind in any advanced mathematics subject, regardless of who the actual user is.

5. Are there gaps between technologies being used and teaching activities? Are there lesson-plan steps that are not supported, either overall or in specific subjects?
6. Are themes emerging in TVIs' recommendations about high-tech devices that were not listed or used in ways not indicated?

The survey used a mixed-methods design, where the first five research questions were addressed via multiple rating matrixes and the last one via open-ended response questions.

Rationale

This study used a descriptive survey as discussed by Gay, Mills, and Airasian (2009). This survey is a type of quantitative research that collects data in order to test a hypothesis or answer questions about a subject. A cross-sectional survey was administered to a sample population to examine TVI perceptions at this point in time, when, due to the technology boom, there existed an assortment of tools that purport to facilitate learning advanced mathematics by students who are blind. The survey attempted to obtain a holistic approach to answering the questions, containing both structured and unstructured items. The quantitative items allowed investigations of relationships between dependent and independent variables, perceptions of use of devices and steps in lesson planning, and perceptions of the use of devices with the subject being taught. The two unstructured items were to encourage contributions of tools to the “toolbox of devices” that may for one reason or another, not have been included in the list of options in the matrix. Answers to these questions may also indicate areas where future research needs to be directed.

Population and Sample

The target population for this study was TVIs with experience in facilitating the study of advanced mathematics by students who are blind. TVIs work with students from birth though adulthood. It is possible—even likely in the case of itinerant workers—that a TVI may work for years and never encounter an academic student who is blind and taking advanced mathematics. There is no way to determine out of the estimated 6,700 registered TVIs in the United Stated (Mason, McNerney, Davidson, & McNear, 2000) which ones are in the target population based solely on certification.

Since residential schools for students who are blind typically teach academic subjects, it follows that they are likely to staff TVIs that teach advanced mathematics. Almost every state has a residential school for students who are blind for students who cannot be served in their home districts, usually because the districts are too small to have a TVI on staff, or the students' needs are not being met by the services offered. Residential schools also have outreach programs, where they send TVIs experienced with specific student populations out to school districts for consultation on particular issues. Therefore, teachers at residential schools often have more experience with students studying advanced mathematics than many itinerant teachers.

The United States Congress, in 1879, passed the *Act to Promote the Education of the Blind,* which delegated the American Printing House for the Blind (APH) as the national resource center for educational materials for individuals with visual impairments. Ex Officio Trustees are appointed professionals who are in charge of the administration of their respective Federal Quota accounts. To ensure equal distribution of funds for educational materials for persons with visual impairments, Ex Officio Trustees maintain databases of educators who place orders for materials for students with visual impairments. This data includes a list of TVIs who have ordered braille versions of advanced mathematics textbooks

APH also maintains a list of TVIs who have taught mathematics in order to conduct field-testing of mathematics products. APH offered to send the survey to the

100+ potential participants currently on the list. In addition, they ran an announcement about the survey, including participant criteria, in the APH News, an electronic monthly newsletter available free to anyone who subscribes. It contains the latest information on the products, services, and training opportunities from the American Printing House for the Blind. The announcement was placed in the January issue. These four sources—APH field-testers, APH News readers, state residential schools for students who are blind, and Ex Officio Trustees—provided a purposive convenience sample that met criteria. The note in the e-mail itself included respondent criteria and asked potential participants not to respond if they did not meet all of the criteria.

As stated earlier, it is difficult to calculate the population size. Out of an estimated 6,700 certified TVIs, only a small number would have worked with students who were exclusively braille readers and who were taking advanced mathematics. According to the APH's Annual Report (2010), there were a total of 1,467 braille students in the 9th through 12th grades in the United States in 2009. The National Plan for Training Personnel to Serve Children with Blindness and Low Vision (Mason et al., 2000) recommended a teacher–student ratio of 8:1, but they estimated actual caseloads to be closer to 14:1. The range of the number of TVIs that would have served those students in 2009 is between 104 and 183. Gay, Mills, and Airasian (2009) suggest that for a population of 100, the entire population should be surveyed. It is difficult to extrapolate how many TVIs have had experience in advanced math with braille students during the past 10 years. For this research, a response population of 100 participants was targeted.

Instrumentation

An instrument using SurveyMonkey was developed to answer the research questions above. The initial version contained several questions about teaching experience followed by a list of devices. Respondents were asked to check off those they had used for each of up to three advanced mathematics classes in which they had the most experience. The list of devices was generated during the literature review, but their appropriateness for this student population was unclear. Many tools were created for mathematics-related professionals who were blind or for individuals with limited vision. Two TVI experts in Austin, TX, reviewed this initial version of the survey. Their insight led to some significant changes in the list of devices included in the survey. Additional open-response space was also included in the survey.

The first three items queried participants about their age, geographic regions, and types of communities in which they work. The next two items asked participants to provide the number of years experience they had working with students who are blind in advanced mathematics and when the most recent experience occurred. These were followed by two items that asked about respondents' current positions and past experience as teachers of students with visual impairments. There may or may not be correlations between the types of teaching assignments, such as itinerant TVIs versus residential school TVIs, and experience with technology. Therefore, having a list of respondents who only had experience in one type of position may reveal relations between that position and use of technology.

Item 8 defined *proficiency in advanced mathematics technology level* (PAMTL) as participants' perceived proficiency level in managing the integration of technology for the purpose of supporting braille readers with no vision in advanced mathematics courses. Respondents were asked to rate their PAMTL in six secondary school subjects. This rating would let the researcher know how many participants did not complete the survey for all the subjects in which they indicated PAMTL. It also provided information about which courses TVIs were supporting braille readers in most frequently. The next three items had respondents determine their three highest PAMTL subjects.

The assumption was that respondents were likely to have the most meaningful input regarding subjects in which they have had the most experience supporting students who are blind. Using conditional branching (Alreck & Settle, 2004), answers to these questions were inserted into future questions about specific device usage in each course indicated. The subjects listed were algebra, algebra 2, geometry, trigonometry, precalculus, and calculus. Respondents could also check "other," requiring entry of a course name. The survey itself used logic to direct the flow of questions. Due to the variety of routes a respondent could take, item numbers were not visible to them. However, a percentage-completed bar was included on the bottom of each page so participants could determine approximately where the survey ended. Participants could exit the survey at any time, but their answers would not be saved. They would have to start over at a later date. This process was explained in the very beginning of the survey.

Unfortunately, responses to Item 8 yielded relative PAMTL for up to seven subjects but they could not be used in the logic that directed the rest of the survey. Therefore, a participant's response to Item 9 yielded his/her highest PAMTL subject. If this was the only advanced mathematics subject taught, Item 10 redirected the respondent to a page with a device matrix where the respondent was able rate the effectiveness of various high-tech devices for specific tasks in a lesson plan as used in the answer to Item 9. For detailed representation of the survey's branching, see Appendix A.

Otherwise, Item 10 requested participants' second highest PAMTL, and Item 11 yielded the third highest PAMTL. At this point, participants were sent to the device matrix page. Here, they rated devices they had experience in using, according to effectiveness for each step of the lesson plan. Following the matrix, there was an open-response area for notation of additional devices or purposes not listed in the matrix. Finally, another open-response space was included for participants to add any input regarding high-tech devices supporting mathematics students who are blind. Participants were then asked if they believed device ratings and usage would have been different for the next highest PAMTL subject indicated in Items 9 through 11. A "no" response led to the same question about the next highest PAMTL subject, if there was one. Did participants believe their ratings would be different for the next subject in which they indicated they had experience? A "yes" led to a new device matrix for the next highest PAMTL subject. After exhausting up to three subjects that participants indicated experience in, they were asked if they had experience in more than three subjects. If so, the next item queried whether they believed one of the other subjects might yield a different set of answers in the device matrix. A "yes" answer to this question generated another matrix for that subject. A participant with PAMTL in many mathematics subjects who believed there were purpose and subject-specific devices would take much longer to fill out the survey than a participant with PAMTL in only one subject.

As indicated earlier, the devices listed were modified to exclude any that were intended for student use where students had some vision and any that were still prototypes or integrated into other devices. Another major change to the survey after obtaining expert input was that instead of simply checking off which high-tech tools were used for different parts of the lesson plan in each subject, the devices were now rated in a Likert-scale system that used drop-down menus. Participants went down the list of devices until they got to one they had experience with. They then looked at the column headers to determine which part(s) of the lesson plan the device supported. Finally, they rated the device, 1 being the lowest and 5 the highest, for effectiveness in supporting the student in that subject for each part of the lesson plan. Participants did this first for the subject they previously indicated they had the highest perceived proficiency in supporting. If a TVI indicated multiple subjects taught, such as algebra 1, calculus, and geometry, a query determined if he/she believed devices used or their ratings would be different for the next subject.

Finally, the survey was piloted on two itinerant TVIs with many years experience teaching and supporting students who are blind in advanced mathematics classes. This pilot led to some rewording of the instructions, clarification of steps in the lesson plan, and a larger text box for the last open-response segment. They also suggested moving the item that asked about beliefs that ratings would be different for other subjects to after each device matrix. It was originally positioned after Items 9, 10, and 11, but the TVIs indicated that seeing the matrix triggered memories of using tools in other subjects. Two experts in the field of mathematics education for students who are blind reviewed the final version and determined that it would provide sufficient data to answer the research questions. A copy of the final instrument can found in Appendix B.

This instrument was presented to Texas Tech University to undergo the Institutional Review Board's (IRB) process for exempt review. The IRB requested some changes in wording of the directions in the instrument to make it clear that this was research and that participation was voluntary. Coercion was to be avoided, so the e-mails also needed to reassure anonymity, that participation was voluntary, and that completion was not mandatory. Settings in the instrument's web page prevented obtaining IP addresses. A $50 Amazon gift card was offered as incentive through SurveyMonkey. Researchers would not have access to contact information, and SurveyMonkey would not share survey results or participant contact information. A copy of the IRB letter of approval is in Appendix C.

Data Collection Methods/Procedure

Participants received the online survey via e-mail or by going to the link indicated in the APH News announcement. In order to participate in the online survey, teachers must be or have been Certified Teachers of Students with Visual Impairments and must have had experience with students who are blind and studying advanced mathematics as indicated by self-selection. At this time, contacts at APH were eager to contribute to the success of this research. They were a vested party. Also, TVIs are aware that some of their current elementary braille reading students may be heading towards advanced mathematics. They also have an interest in increasing high-tech efficiency in teaching these students.

APH forwarded the link via e-mail to its field-testing volunteers and Ex Officio Trustees on January 6th, 2012. In addition, they ran an announcement about the survey in the January issue of the APH Newsletter. The newsletter included a link to a web page that contained the survey on SurveyMonkey.

The president of the Council of Schools for the Blind (COSB) agreed to send the link to the survey to residential schools for the blind and asked that it be forwarded to their TVIs teaching advanced mathematics. The e-mail went out on January 16th, 2012. Participants were advised that they should not participate more than once in case they had already completed the survey via the link in APH News or any other emails. The link to the survey was e-mailed to the same groups on January 20th to remind potential participants to complete the survey. The survey was closed on January 31st. Copies of each of the e-mails as well as the APH News announcement can be found in Appendix D.

Data Analysis

The analysis of the interrelationship of the effectiveness of the high-tech tool, each subject, and each part of the lesson plan was done through visual examination of the results. Cross-tabulation analysis was not performed because the purpose of the research was to be inclusive of all devices, even those with very low relationships to the independent variables. This survey was a starting point and each device identified warranted further examination. Microsoft's Excel™ program was used to sort data, create graphs and tables, and calculate means and standard deviations. Following are the methods used to analyze the results.

1. Which high-tech devices are currently being used in secondary school advanced mathematics courses to support students who are blind?

This information was gathered from answers to the matrix questions. A list of all of the devices that were mentioned was generated. In addition, a graph of the number of participants who indicated using or supporting the use of each device was created.

2. Is there a core set of devices that is perceived by TVIs as beneficial for supporting advanced mathematics students who are blind, regardless of specific subject?

A device will be considered a core beneficial device if it was reported as being used by more than 50% of TVIs or the mean score is 3 or more in any lesson-plan tasks indicated. These criteria were devised through the collaboration of the researcher and the two field experts who reviewed the final instrument as well as the research questions.

3. Are there variations of the core set of devices, as perceived by TVIs, depending on the particular advanced mathematics subject involved?

A device will be considered a core beneficial device for a particular subject if it was reported as being used by more than 50% of TVIs who are teaching or have taught that subject, and the mean score is 3 or more in any lesson-plan tasks indicated. TVIs were queried to help them remember the mathematics subject in which they perceived themselves to have the highest proficiency in supporting braille readers with technology. The goal here was that participants would have their highest PAMTL experience in mind when responding to the device matrix. Ratings could then be compared for different subjects. These criteria were devised through the collaboration of the researcher and the two field experts who reviewed the final instrument as well as the research questions.

4. According to TVI perceptions, how effective are these tools, in supporting learning throughout the following lesson-plan steps?
   - Preparation of materials
   - Accessing the lesson
   - Guided practice
   - Independent practice
   - Submission of work

A device will be considered beneficial for a step if it is identified as being used by more than 50% of the participants and its mean score is 3 or more for that task. Researchers created and examined the charts of the means of the ratings of each device used and the number of participants who reported using the device. These criteria were devised through the collaboration of the researcher and the two field experts who reviewed the final instrument as well as the research questions.

5. Are there gaps between technologies being used and teaching activities? Are there lesson-plan steps that are not supported, either overall or in specific subjects?

Examination of graphs and charts generated in the preceding question led to conclusions regarding gaps between technology used and teaching activities.

6. Are themes emerging in TVIs' recommendations about high-tech devices that were not listed, or used in ways not indicated?

Researchers examined the responses to the open-response segments for repeated references to devices. High-tech tools that were suggested were listed in the results sections. Other tools, concerns, and/or suggestions that seem to repeat in several responses were presented in the conclusion.

Data Management Plan

Approval for this study was obtained from the Texas Tech University Protection of Human Subjects Committee using the standard Institutional Review Board exempt review process. A web-based-survey method was used to collect data anonymously. IP addresses were not collected. Participants did not provide contact information. The data were downloaded and will be maintained on the researcher's computer. A copy of entered parameters in SurveyMonkey is available in Appendix E.

Summary

This chapter described the methods that were used to collect and analyze data for this study. Information presented in the chapter included the purpose of this study, research questions, rationale, population and sample, instrumentation; data collection methods/procedure, data analysis, and data management plan. The four sources for potential participants were identified as APH field-testers, APH News readers, Ex Officio contacts, and state residential school mathematics TVIs. Criteria for participation were

TVIs experienced in teaching/supporting braille readers in advanced mathematics.

SurveyMonkey tools were used to collect and filter responses and create a database, from which preliminary graphs were generated. All the data was imported into Excel spreadsheets for sorting. Calculations of means and standard deviations were made using Excel. Data analysis included visual scanning of graphs and charts. The results obtained were sufficient to answer the research questions.

CHAPTER 4

RESULTS

Introduction

The purpose of this study was to determine the current state, as perceived by teachers of students with visual impairments, of high-technology devices being used in advanced mathematics classes to support students who are blind. The data for this study were collected via an online survey distributed to TVIs with experience teaching or supporting students who are braille readers in advanced mathematics classes. *Proficiency in advanced mathematics technology level* (PAMTL) was defined as participants' perceived proficiency level in managing the integration of technology for the purpose of supporting braille readers with no vision in advanced mathematics courses. The crux of the survey was the device matrix that asked teachers which tools they used for their highest PAMTL subject, and in what way they used them. Participants were also asked to rate each device that was used for effectiveness as related to the application indicated. Open-ended response areas provided space for addition of tools not included in the matrix as well as other feedback. While 157 surveys were returned, a total of 82 were completed through the device matrix question. This chapter presents a descriptive analysis of the data collected from the survey.

The research questions addressed were:

1. Which high-tech devices, according to TVI perspectives, are currently being used in secondary school advanced mathematics courses to support students who are blind?

2. Is there a core set of devices that is perceived by TVIs as beneficial for supporting advanced mathematics student who are blind, regardless of specific subject?
3. Are there variations of the core set of devices, as perceived by TVIs, depending on the particular advanced mathematics subject involved?
4. According to TVI perceptions, how effective are these tools in supporting learning throughout the following lesson-plan steps?
    - Preparation of materials
    - Accessing the lesson
    - Guided practice
    - Independent practice
    - Submission of work
5. Are there gaps between technologies being used and teaching activities? Are there lesson-plan steps that are not supported, either overall or in specific subjects?
6. Are themes emerging in TVIs' recommendations about high-tech devices that were not listed or used in ways not indicated?

Number of Surveys Returned

A total of 157 surveys were returned: 131 from the link that went to Ex Officio Trustees, 14 from the link that went to TVIs on APH's list of field-testers, 12 from the link included in the APH Newsletter, and 0 from the link that went to state schools for students who are blind. Eighty-three surveys (53%) of the 157 were complete. Of these, the largest number (*n* = 68) were accessed using the link sent to Ex Officio Trustees. However, one of these participants revealed that she had not yet had experience supporting braille readers in advanced mathematics. The link sent to the list of TVIs used by APH as field-testers yielded nine completed surveys, and the link published in the APH Newsletter yielded another six completed surveys. The link sent to residential schools for students who are blind did not yield any surveys. This link was the last one to be disbursed. It is possible that TVIs in residential schools who were interested in completing the survey had already received the link through another source since each residential school also has an APH Ex Officio Trustee. The data reported in this research are from the 82 completed surveys, which is 82% of the100 targeted.

Descriptive Data

Participant Demographics

The population for the study was TVIs who have had experience teaching and supporting braille readers in advanced mathematics courses. Descriptive data of demographic characteristics of the participants can be found in Table 4.1. Thirty-nine (47.5%) of the 82 participants were between 53 and 60 years of age, while 13 (15.9%) were between 45 and 52, nine (11%) between ages 29 and 36, nine (11%) between 61 and 68, 8 (9.8%) between 37 and 44, and four (4.9%) were under 28. Most participants listed their current geographic regions as South or Midwest with 27 (32.9%) in each region. Fifteen participants (18.1%) listed the Northeast and 13 (15.7%) listed the West. More than half of the participants—48 (57.8%)—listed their current work community as suburban. Twenty-three participants (28%) selected rural, and 21 participants (25.3%)

said their community was urban.

In terms of teaching experience, the largest group of participants [31 (38.3%)] had more than 10 years experience. Twenty-four (29.2%) had between 1 and 3 years experience, 19 (23.5%) between 4 and 6 years experience, and six participants (7.4%) had between 7 and 10 years experience. Fifty four (65.9%) participants listed the current school year, 2011–2012 as their most recent year in supporting and teaching students who are blind in advanced mathematics. Most other responses indicated years between 2004 and 2011, with one response indicating before 1997 as the most recent year.

Sixty (73%) participants reported their current positions as itinerant TVIs. Another nine participants (11%) said they were teachers at residential schools for students who are blind, and eight (9.9%) said they were resource room or self-contained classroom teachers. The last three participants (3.7%) responded that they were currently working at a regional education service center or school district. None were working in rehabilitation centers or in supervisory roles. Responses for previous positions held were similar, with 66 (80.5%) indicating having worked as itinerant teachers, 18 (22%) as resource room or self-contained classroom teachers, and 14 (17.1%) as teachers at residential schools for students who are blind. Nine participants (11%) indicated they had previously worked in positions at regional education service centers or school districts, one (1.2%) indicated a rehabilitation center, and five (6.1%) responded that they had previously worked as independent consultants.

Table 4.1
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
Geographic region			
	Northeast	15	18.3
	Midwest	27	32.9
	South	27	32.9
	West	13	15.9
Type of community			
	Urban	21	25.6
	Suburban	48	58.5
	Rural	23	28.8
Years of experience[1]			
	1–3	24	29.2
	4–6	19	23.1
	7–10	6	7.3
	> 10	31	37.8
	NA	1	1.2
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
	2003–2004	0	0.0
	2002–2003	0	0.0
	2001–2002	0	0.0
	2000–2001	0	0.0
	1999–2000	0	0.0
	1998–1999	0	0.0
	1997–1998	0	0.0
	Before 1997	1	1.2

Table 4.1 *Continued* (*N* = 82)

Descriptive Data		*n*	%
Current position			
	a teacher at a residential school for the blind	9	11.1
	an itinerant TVI	60	73.1
	a resource room or self-contained classroom teacher	8	9.8
	working at a regional education service center or school district	3	3.7
	working at a rehabilitation center	0	0.0
	trained as a TVI and working in a supervisory or administrative role	0	0.0
	independent consultant	0	0.0
	Other	2	2.4
	NA	1	1.2
Previous positions			
	a teacher at a residential school for the blind	14	17.0
	an itinerant TVI	66	80.5
	a resource room or self-contained classroom teacher	18	22.0
	working at a regional education service center or school district	9	11.1
	working at a 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.

Participants' Perceived Proficiency

In the current study, participants were first asked to indicate their proficiency of integrating high-tech devices to support braille readers in various advanced mathematics courses (PAMTL). Many participants indicated proficiency in more than one subject. For the proficiency rating, algebra 1 received the highest rating with the mean of 3.02 on the PAMTL, followed by algebra 2, geometry, trigonometry, precalculus, and calculus. Means and number of participants who responded to the proficiency scale are shown in Table 4.2. Nine participants added "statistics" or "statistics and probability" to the "other" subject with an average rating of 2.11.

Table 4.2
Participants' Perceived Proficiency in Advanced Mathematics Technology Level (PAMTL)

Answer options	1	2	3	4	5	Rating average	Response count
Algebra 1	13	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
Other (please specify)							4

Once participants determined the relative PAMTL for the various subjects, they were asked which subject they perceived themselves to have the highest PAMTL—that is, to be the most proficient in supporting a student who was blind with high-tech devices in an advanced mathematics subject—as shown in Table 4.3. This perceived proficiency was in order to ensure that branching to the correct part of the questionnaire occurred.

Fifty-seven participants (69.5%) selected algebra 1 as the subject with the highest PAMTL. Eleven (13.3%) answered each algebra 2 and geometry, two (2.4%) indicated precalculus, and one (1.2%) indicated trigonometry. None of the participants selected calculus or “other.”

Teachers were then asked to determine in which subject they had the second highest PAMTL (see Table 4.4), or to indicate that they had only had experience in one subject. SurveyMonkey allows the use of branching to lead participants to different sections of the questionnaire depending on their responses to certain questions. Those who had experience with only one subject would bypass additional questions about PAMTL and go directly to the device matrix. In this case, 34 (41%) of participants selected algebra 2, 19 (22.9%) selected geometry, 17 (20.5%) selected algebra 1, two (2.4%) said trigonometry, and one (1.2%) said calculus. Precalculus and “other” were not selected by any participants. Ten teachers (12.0%) said that they had not supported students in more than one subject.

Finally, Table 4.5 shows responses when teachers were asked in which subject they had the third highest PAMTL. In this case, participants made the following selections: 25 (33.8%) chose geometry, 19 (25.7%) chose algebra 2, six (8.1%) chose trigonometry, three (4.1%) chose precalculus, and one (1.2%) chose each algebra 1 and calculus. No participants selected “other,” and 19 reported they did not have experience supporting students in more than two advanced mathematics subjects.

Table 4.3
Highest Perceived Proficiency in Advanced Mathematics Technology Level (PAMTL)

Subjects	Response percent	Response count
Algebra 1	69.9%	57
Algebra 2	13.3%	11
Geometry	13.3%	11
Trigonometry	1.2%	1
Precalculus	2.4%	2
Calculus	0.0%	0
Other (please specify)	0.0%	0

Table 4.4
Second Highest Perceived Proficiency in Advanced Mathematics Technology Level (PAMTL)

Subjects	Response percent	Response count
Algebra 1	20.5%	16
Algebra 2	41.0%	34
Geometry	22.9%	19
Trigonometry	2.4%	2
Precalculus	0.0%	0
Calculus	1.2%	1
Other (please specify)	0.0%	0

Table 4.5
Third Highest Perceived Proficiency in Advanced Mathematics Technology Level (PAMTL)

Answer Options	Response percent	Response count
Algebra 1	1.4%	1
Algebra 2	25.7%	19
Geometry	33.8%	25
Trigonometry	8.1%	6
Precalculus	4.1%	3
Calculus	1.4%	1
Other (please specify)	0.0%	0

Results Related to Question One

1. Which high-tech devices are currently being used in secondary school advanced mathematics courses to support students who are blind?

In order to answer this question, the data were examined in two ways. The first way of analyzing the data focused on how often a device was selected for lesson-plan tasks across all mathematics subjects (see Figure 4.1) rather than how many participants selected the tool. The Total Use Score (TUS) for each high-tech tool was calculated based on the total number of times the tool was selected for use in various subjects and lesson-plan tasks by all participants. For example, Participant A taught three math subjects: algebra 1, geometry, and calculus. When asked if she thought the devices used to support students who were blind in each of these subjects was different, her response was “yes.” In this case, Participant A would have been presented with the matrix of devices/lesson-plan tasks three times, once for each subject. If she checked off Device 26 as being used in algebra 1 for preparation of materials, submission of work, and independent practice, then Device 26 would receive 3 use-score points. The rating that Device 26 received for each of the three lesson-plan tasks is not considered. Participant A also selected Device 26 for geometry, in this case, for teacher/student-guided practice, adding 1 point to the score. Device 26 now has 4 use-score points. Finally, Participant A selected Device 26 four times for use in calculus during preparation of materials, teacher/student-guided practice, independent practice, and work submission. This rating adds another 4 points to the Total Use Score, bringing it up to 8 points. All the scores for all the participants for each device were added together to obtain a TUS for each device.

In this analysis, it seems that every single device was used and none received below 51 points. Total Use Scores are presented in Figure 4.1. According to this analysis, all the devices currently are used.

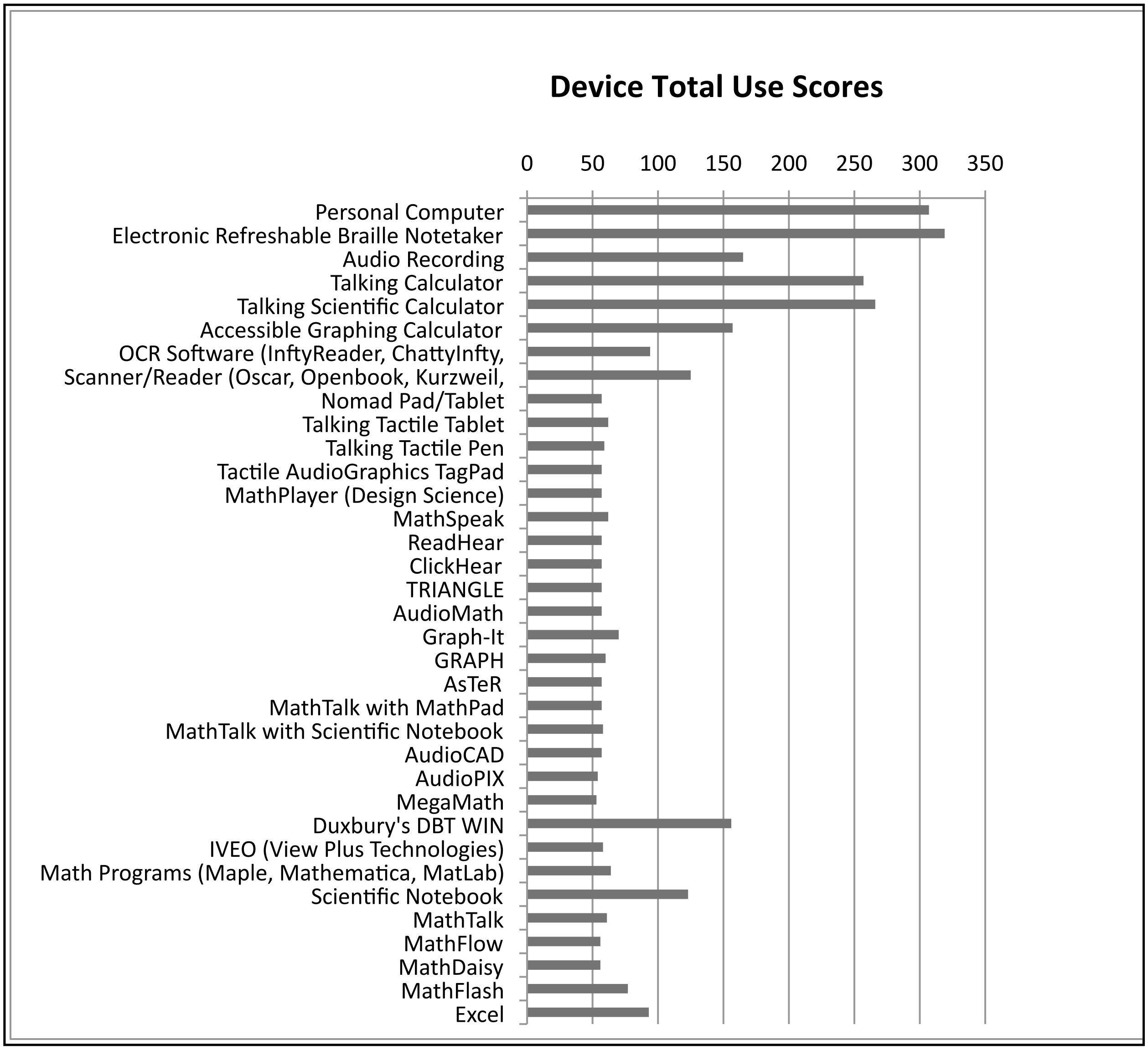

Figure 4.1. Total Use Scores (TUS) for Devices

In the second analysis, only the number of participants who selected a device was considered, not the number of relevant courses or lesson-plan tasks. For example, Participant A taught or supported three courses. She selected Device 26 for its use in preparation of materials, teacher/student-guided practice, and work submission, in algebra 1 and geometry, but not at all in calculus. Participant A counted as one respondent who used Device 26, regardless of how many courses or lesson-plan tasks it was used in or the rating it received for each of these tasks. If Participants A, B, and C selected Device 26 only for preparation of materials in algebra 1, Participants A, B, and C counted as three participants for Device 26 even though it was used for only one task in only one subject. Figure 4.2 shows the results of this method of determined devices used.

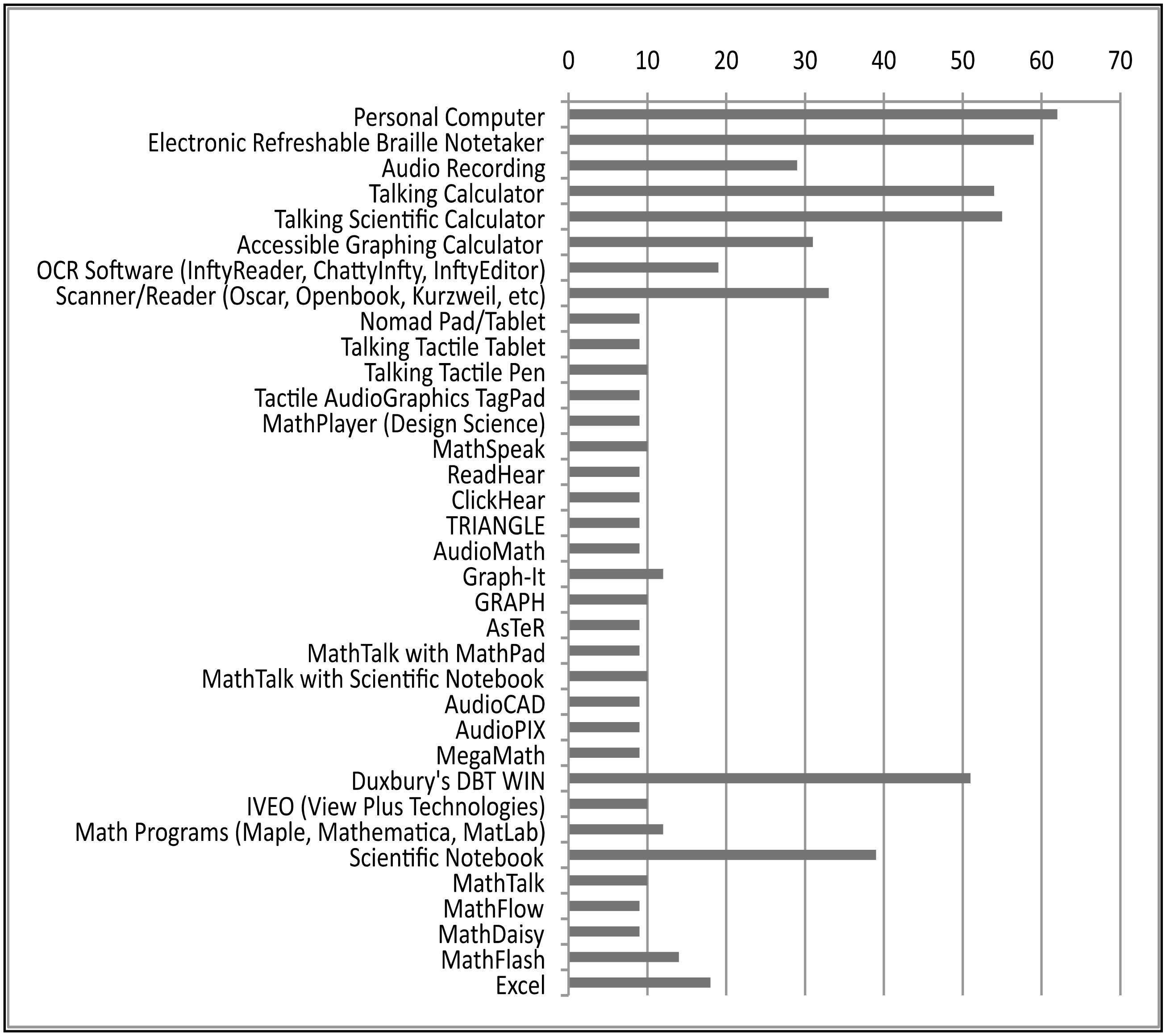

Figure 4.2. Number of Participants Who Used Each Device

In this analysis, results showed that every single device was used by at least nine teachers. Further examination of individual surveys revealed that nine participants entered a “1” in all of the Likert ratings for every part of the lesson plan in which they didn’t enter a higher rating. This may mean participants thought a rating was required for every device in every lesson plan task. Since some of the devices did rate higher than 1, it is impossible to determine which entries were not valid ratings. The fact that two participants entered a “1” for every device in their highest PAMTL subject but not in their second highest suggests that they realized a rating was not required for every device. This result suggests that some of the high-tech tools that were used by nine teachers may not have been used at all. Tools that are certainly being used by at least one teacher are:

- Personal Computer (PC)
- Electronic Refreshable Braille Notetaker
- Audio Recording
- Talking Calculator
- Talking Scientific Calculator
- Accessible Graphing Calculator
- OCR Software (InftyReader, ChattyInfty, InftyEditor)
- Scanner/Reader (Oscar, Openbook, Kurzweil, etc.)
- Talking Tactile Tablet
- Talking Tactile Pen
- MathSpeak
- Graph-It

- GRAPH
- MathTalk with Scientific Notebook
- Duxbury's DBT WIN
- IVEO (View Plus Technologies)
- Math Programs (Maple, Mathematica, MatLab)
- Scientific Notebook
- MathTalk
- MathFlash
- Excel

Results Related to Question Two

2. Is there a core set of devices that is perceived by TVIs as beneficial for supporting advanced mathematics students who are blind, regardless of specific subject?

A device is considered to be a core beneficial device if it was reported as being used by more than 50% of TVIs. Additionally, any device with a mean rating of 3 or more in any/all lesson-plan tasks indicated is considered a core beneficial device. These criteria were devised through the collaboration of the researcher and the two field experts who reviewed the final instrument as well as the research questions.

Since 82 participants completed the survey, any device selected by 41 or more participants was considered a core beneficial device (.50) x 82 = 41. Figure 4.2 indicates the number of participants who selected each device. There are five high-tech tools that meet the criteria: personal computers, electronic refreshable braille notetakers, talking calculators, talking scientific calculators, and Duxbury's DBT WIN.

In order to obtain information about use of high-tech devices in subjects in which teachers believed they were most proficient, means of the devices' ratings were calculated using participants' highest PAMTL. Also, responses for second and third highest PAMTL subjects were inconsistent. For example, many participants said they thought the list of devices would be different for subjects other than their highest PAMTL subject, yet most did not complete another matrix for their second highest PAMTL subject. Ten participants indicated that they had taught or supported one subject. Another 18 indicated they had taught or supported two subjects, eight of whom expected their answers to be different for their second highest PAMTL subject. Of these eight, only three actually answered the matrix question for both their highest and second highest PAMTL subjects. While 54 participants indicated teaching or supporting students in three or more subjects, only four completed the device matrix question three times. This may be due to survey fatigue, where respondents have gotten tired (Alreck and Settle, 2004).

Device ratings assigned by the 10 teachers who taught or supported braille readers in one advanced mathematics course are presented in Table 4.6. The high-tech tools that received a mean rating of 3 or more include all five of those listed as "used by most participants," as well as the Accessible Graphing Calculator, scanner/reader, Scientific Notebook, MathFlash, and Excel. Table 4.7 presents ratings of teachers who taught or supported two subjects. This group adds audio recording, OCR software, and Graph-It to the list of core devices. Examining the responses of teachers who taught or supported three or more subjects yielded no additional high-tech tools (Table 4.8). Results indicated that the core set of devices that is perceived by TVIs as beneficial for supporting advanced mathematics students who are blind, regardless of specific subject consists of:

- Personal Computers
- Electronic Refreshable Braille Notetakers
- Talking Calculators
- Talking Scientific Calculators
- Duxbury's DBT WIN
- Scientific Notebook
- Accessible Graphing Calculator
- Scanner/Reader
- MathFlash
- Excel
- Audio Recording
- OCR Software
- Graph-It.

Table 4.6
Ratings of Participants Who Taught/Supported One Subject (N = 10)

	Preparation of materials			**Student lesson access**			**Teacher/student-guided practice**			**Student independent practice**			**Student work submission**		
Device	***n***	**Mean**	***SD***	***n***	**Mean**	***SD***	***n***	**Mean**	***SD***	***n***	**Mean**	***SD***	***n***	**Mean**	***SD***
Personal Computer	4	4.0	2.0	4	2.3	1.3	4	2.0	0.8	4	1.3	0.5	4	1.8	0.5
Electronic Refreshable Braille Notetaker	3	2.0	1.0	4	3.3	1.5	3	3.3	2.1	3	3.3	2.1	2	4.5	0.7
Audio Recording	2	2.5	2.1	2	2.0	1.4	1	1.0	0	2	2.0	1.4	1	1.0	0
Talking Calculator	3	2.3	2.3	4	4.5	1.0	5	4.6	0.9	5	4.6	0.9	3	5.0	0
Talking Scientific Calculator	2	1.0	0	2	4.5	0.7	2	4.5	0.7	2	4.5	0.7	2	4.5	0.7
Accessible Graphing Calculator	2	3.0	1.4	3	4.0	1.0	4	4.0	1.2	3	3.7	1.2	2	4.0	1.4
OCR Software (InftyReader, ChattyInfty, InftyEditor)															
Scanner/Reader (Oscar, Openbook, Kurzweil, etc.)	2	5.0	0	2	4.5	0.7	2	5.0	0	2	4.0	1.4	2	2.0	1.4
Nomad Pad/Tablet															
Talking Tactile Tablet															
Talking Tactile Pen															
Tactile AudioGraphics TagPad															
MathPlayer (Design Science)															
MathSpeak															
ReadHear															
ClickHear															
TRIANGLE															
AudioMath															
Graph-It															
GRAPH															
AsTeR															

Table 4.6 *Continued*

	Preparation of materials			**Student lesson access**			**Teacher/student-guided practice**			**Student independent practice**			**Student work submission**		
Device	***n***	**Mean**	***SD***	***n***	**Mean**	***SD***	***n***	**Mean**	***SD***	***n***	**Mean**	***SD***	***n***	**Mean**	***SD***
MathTalk with MathPad															
MathTalk with Scientific Notebook															
AudioCAD															
AudioPIX															
MegaMath															
Duxbury's DBT WIN	3	5	0	2	4	0	2	1	0	2	1	0	2	1	0
IVEO (View Plus Technologies)															
Math Program (Maple, Mathematica, MathLab)															
Scientific Notebook	3	5.0	0	3	3.3	2.1			0	3	2.3	2.3	3	1.0	0
MathTalk															
MathFlow															
MathDaisy															
MathFlash	2	2	1.4	2	2.5	2.12	2	3.0	1.4	1	2.0	0	1	1.0	0
Excel													1	5.0	0

Note: Shaded cells indicate mean ratings ≥ 3 for at least one lesson-plan task.

Table 4.7
Ratings of Participants Who Taught/Supported Two Subjects–Highest PAMTL Subject (N = 18)

	Preparation of materials			**Student lesson access**			**Teacher/student-guided practice**			**Student independent practice**			**Student work submission**		
Device	***n***	**Mean**	***SD***	***n***	**Mean**	***SD***	***n***	**Mean**	***SD***	***n***	**Mean**	***SD***	***n***	**Mean**	***SD***
Personal Computer	11	4.5	1.3	6	3 3	1.6	5	3	1.9	6	2.7	2.0	7	3.3	1.5
Electronic Refreshable Braille Notetaker	4	2.5	1.7	10	3.4	1.5	8	3.9	1.4	10	4.1	1.3	8	3.8	1.3
Audio Recording	4	3.3	1.7	4	3	1.6	4	2.5	1.3	4	3.5	1.3	2	2.5	0.7
Talking Calculator	5	3.6	1.7	11	3.9	1.6	9	4.1	1.4	9	4.1	1.4	3	3.0	2.0
Talking Scientific Calculator	4	3.8	1.9	11	4.1	0.8	9	4.3	0.7	9	4.4	0.9	4	4.5	0.6
Accessible Graphing Calculator	3	2.3	2.3	8	2.6	1.8	7	2.4	1.8	4	2.0	2.0	3	2.3	2.3
OCR Software (InftyReader, ChattyInfty, InftyEditor)	4	3.5	1.7	1	1.0	0	1	1.0	0	3	2.7	2.1	3	2.7	2.1
Scanner/Reader (Oscar, Openbook, Kurzweil, etc.)	5	4.6	0.5	3	3	2.0	3	3.0	2.0	2	2.5	2.1	2	2.5	2.1
Nomad Pad/Tablet	1	1.0	0	1	1	0	1	1.0	0	1	1.0	0	1	1.0	0
Talking Tactile Tablet	1	1.0	0	1	1	0	1	1.0	0	1	1.0	0	1	1.0	0
Talking Tactile Pen	1	1.0	0	1	1	0	1	1.0	0	1	1.0	0	1	1.0	0
Tactile AudioGraphics TagPad	1	1.0	0	1	1	0	1	1.0	0	1	1.0	0	1	1.0	0
MathPlayer (Design Science)	1	1.0	0	1	1	0	1	1.0	0	1	1.0	0	1	1.0	0
MathSpeak	1	1.0	0	1	1	0	1	1.0	0	1	1.0	0	1	1.0	0
ReadHear	1	1.0	0	1	1	0	1	1.0	0	1	1.0	0	1	1.0	0
ClickHear	1	1.0	0	1	1	0	1	1.0	0	1	1.0	0	1	1.0	0
TRIANGLE	1	1.0	0	1	1	0	1	1.0	0	1	1.0	0	1	1.0	0
AudioMath	1	1.0	0	1	1	0	1	1.0	0	1	1.0	0	1	1.0	0
Graph-It	2	3.0	2.8	2	3	2.8	2	3.0	2.8	2	3.0	2.8	1	1.0	0
GRAPH	1	1.0	0	2	2	1.4	1	1.0	0	1	1.0	0	1	1.0	0
AsTeR	1	1.0	0	1	1	0	1	1.0	0	1	1.0	0	1	1.0	0
MathTalk with MathPad	1	1.0	0	1	1	0	1	1.0	0	1	1.0	0	1	1.0	0
MathTalk with Scientific Notebook	2	2.5	2.1	1	1	0	1	1.0	0	1	1.0	0	1	1.0	0
AudioCAD	1	1.0	0	1	1	0	1	1.0	0	1	1.0	0	1	1.0	0

Table 4.7 *Continued*

	Preparation of materials			Student lesson access			Teacher/student-guided practice			Student independent practice			Student work submission		
Device	***n***	**Mean**	***SD***	***n***	**Mean**	***SD***	***n***	**Mean**	***SD***	***n***	**Mean**	***SD***	***n***	**Mean**	***SD***
AudioPIX	1	1.0	0	1	1	0	1	1.0	0	1	1.0	0	1	1.0	0
MegaMath	1	1.0	0	1	1	0	1	1.0	0	1	1.0	0	1	1.0	0
Duxbury's DBT0WIN	12	4.9	0.3	3	3.7	2.3	3	3.7	2.3	3	3.3	2.1	2	3.0	2.8
IVEO (View Plus Technologies)	1	1.0	0	1	1	0	1	1.0	0	1	1.0	0	1	1.0	0
Math Programs (Maple, Mathematica, MatLab)	1	1.0	0	1	1	0	1	1.0	0	1	1.0	0	1	1.0	0
Scientific Notebook	12	4.3	1.5	2	2.5	2.1	3	3.3	2.1	2	2.5	2.1	2	2.5	2.1
MathTalk	1	1.0	0	1	1	0	1	1.0	0	1	1.0	0	1	1.0	0
MathFlow	1	1.0	0	1	1	0	1	1.0	0	1	1.0	0	1	1.0	0
MathDaisy	1	1.0	0	1	1	0	1	1.0	0	1	1.0	0	1	1.0	0
MathFlash	1	1.0	0	2	2.5	2.1	2	2.5	2.1	2	2.5	2.1	1	1.0	0
Excel	2	3.0	2.8	3	3.3	2.1	2	3.0	2.8	2	2.0	1.4	3	3.3	2.1

Note: Shaded cells indicate mean ratings ≥ 3 for at least one lesson-plan task.

Table 4.8
Ratings of Participants Who Taught/Supported Three Subjects–Highest PAMTL Subject
(N = 54)

	Preparation of materials			Student lesson access			Teacher/student-guided practice			Student independent practice			Student work submission		
Device	***n***	**Mean**	***SD***	***n***	**Mean**	***SD***	***n***	**Mean**	***SD***	***n***	**Mean**	***SD***	***n***	**Mean**	***SD***
Personal Computer	47	4.1	1.3	33	2.8	1.8	33	2.9	1.6	32	2.75	1.8	36	2.9	1.8
Electronic Refreshable Braille Notetaker	27	2.0	1.5	38	3.4	1.7	36	3.2	1.5	45	3.7	1.5	41	3.5	1.6
Audio Recording	23	1.7	1.2	23	1.9	1.4	22	1.8	1.2	23	1.9	1.3	20	1.7	1.3
Talking Calculator	23	2.2	1.7	33	3.5	1.8	31	3.9	1.5	38	4	1.5	24	3.4	1.8
Talking Scientific Calculator	24	2.3	1.8	37	3.8	1.5	36	4.1	1.2	42	4.2	1.3	24	3.6	1.7
Accessible Graphing Calculator	17	2.2	1.5	20	2.6	1.6	20	2.7	1.3	19	2.9	1.5	14	2.1	1.3
OCR Software (InftyReader, ChattyInfty, InftyEditor)	15	2.8	1.8	13	1.8	1.0	11	1.5	0.8	11	1.4	0.8	12	1.8	1.3
Scanner/Reader (Oscar, Openbook, Kurzweil, etc.)	24	3.5	1.7	14	2	1.5	12	1.8	1.5	12	1.75	1.5	13	1.9	1.8
Nomad Pad/Tablet	8	1.3	0.7	8	1.3	0.7	7	1.3	0.8	7	1.6	1.	7	1.3	0.8
Talking Tactile Tablet	8	1.8	1.5	8	1.8	1.5	7	1.9	1.6	7	1.9	1.6	7	1.9	1.6
Talking Tactile Pen	9	1.3	0.7	8	1.3	0.7	8	1.5	0.9	7	1.3	0.6	7	1.3	0.8
Tactile AudioGraphics TagPad	8	1.1	0.4	8	1.1	0.4	7	1.1	0.4	7	1.1	0.4	7	1.1	0.4
MathPlayer (Design Science)	8	1.3	0.5	8	1.1	0.4	7	1.1	0.4	7	1.1	0.4	7	1.1	0.4
MathSpeak	9	1.9	1.8	9	1.9	1.8	8	2.0	1.9	8	2.0	1.9	8	2.0	1.9
ReadHear	8	1.0	0	8	1.0	0	7	1.0	0	7	1.0	0	7	1.0	0
ClickHear	8	1.0	0	8	1.0	0	7	1.0	0	7	1.0	0	7	1.0	0
TRIANGLE	8	1.5	1.4	8	1.5	1.4	7	1.6	1.5	7	1.6	1.5	7	1.6	1.5
AudioMath	8	1.0	0	8	1.0	0	7	1.6	1.5	7	1.6	1.5	7	1.6	1.5
Graph-It	9	1.9	1.8	9	2.0	1.7	9	2.3	1.8	9	2.0	1.7	10	2.3	1.9
GRAPH	8	1.9	1.5	8	1.5	1.4	7	1.6	1.5	8	2.0	1.9	8	2.0	1.9
AsTeR	8	1.0	0	8	1.0	0	7	1.0	0	7	1.0	0	7	1.0	0

Table 4.8 *Continued*

	Preparation of materials			Student lesson access			Teacher/student-guided practice			Student independent practice			Student work submission		
Device	***n***	**Mean**	***SD***	***n***	**Mean**	***SD***	***n***	**Mean**	***SD***	***n***	**Mean**	***SD***	***n***	**Mean**	***SD***
MathTalk with MathPad	8	1.0	0	8	1.0	0	7	1.0	0	7	1.0	0	7	1.0	0
MathTalk with Scientific Notebook	8	1.8	1.5	8	1.5	1.4	7	1.6	1.5	7	1.6	1.5	7	1.6	1.5
AudioCAD	8	1.0	0	8	1.0	0	7	1.0	0	7	1.0	0	7	1.0	0
AudioPIX	8	1.0	0	8	1.0	0	6	1.0	0	6	1.0	0	6	1.0	0
MegaMath	8	1.75	1.5	8	1.25	0.7	6	1.3	0.8	5	1.4	0.9	6	1.3	0.8
Duxbury's DBT0WIN	36	4.3	1.4	15	2.8	1.9	15	3.0	1.9	12	2.8	2.0	12	2.1	1.8
IVEO (View Plus Technologies)	9	1. 6	1.3	8	1.1	0.4	7	1.1	0.4	7	1.1	0.4	7	1.1	0.4
Math Programs (Maple, Mathematica, MathLab)	11	2.3	1.8	9	1.8	1.6	8	2	1.9	8	1.8	1.6	8	1.9	1.6
Scientific Notebook	24	3.9	1.7	11	2.7	1.9	10	2.5	2.0	9	2.0	1.7	11	2.6	2.0
MathTalk	9	1.9	1.8	8	2.0	1.9	8	2.0	1.9	8	2.0	1.9	8	2.0	1.9
MathFlow	8	1.5	1.4	7	1.6	1.5	7	1.6	1.5	7	1.6	1.5	7	1.6	1.5
MathDaisy	8	1.5	1.4	7	1.6	1.5	7	1.6	1.5	7	1.6	1.5	7	1.6	1.5
MathFlash	8	2.0	1.9	9	2.0	1.7	9	2.2	1.9	10	2.1	1.7	9	2.0	1.7
Excel	14	2.9	1.9	11	2.5	1.9	11	2.6	1.8	11	2.6	1.8	11	2.6	1.8

Note: Shaded cells indicate mean ratings ≥ 3 for at least one lesson-plan task.

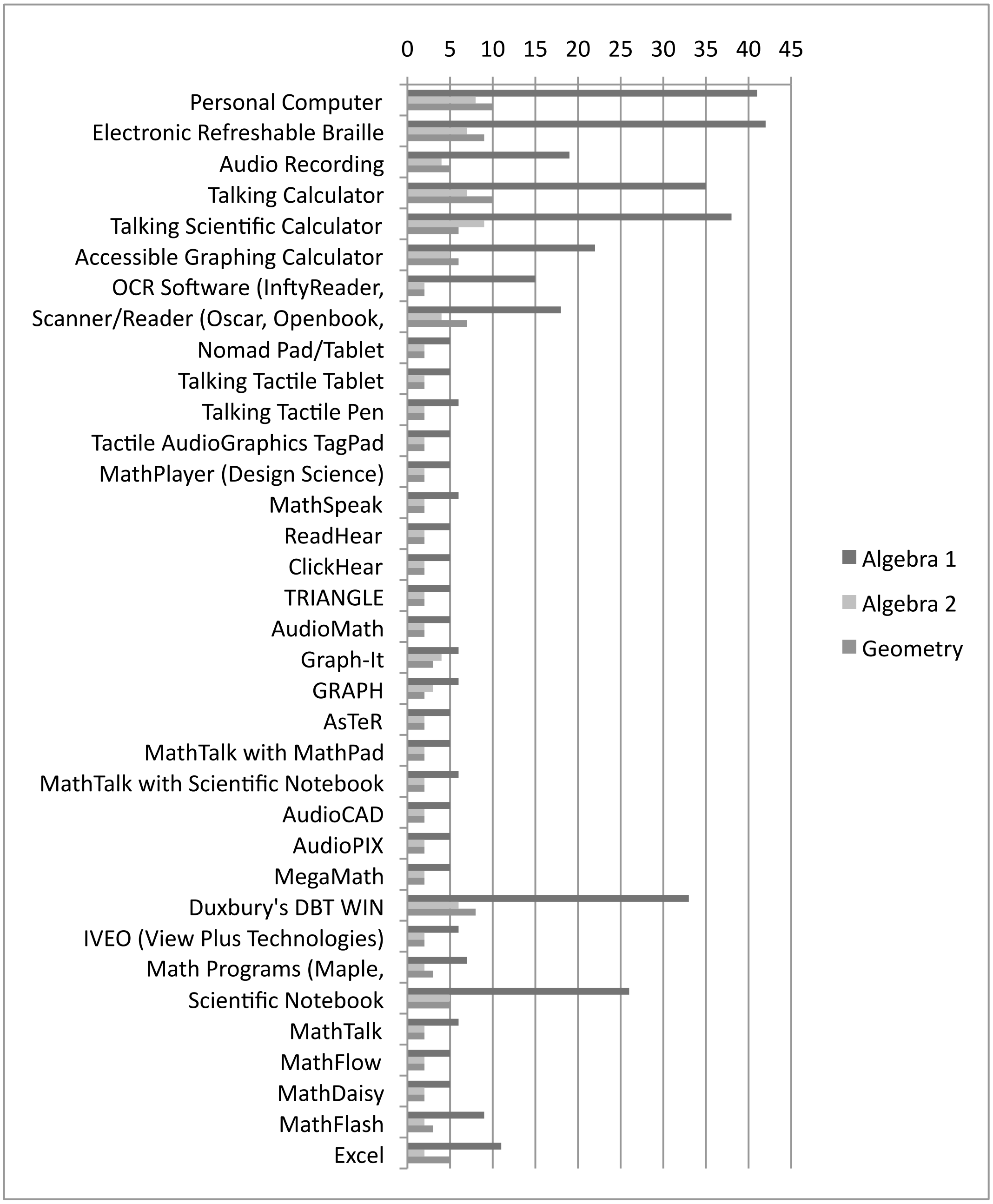

Figure 4.3. Participants Who Used Each Device for Different Courses.

Results Related to Question Three

3. Are there variations of the core set of devices, as perceived by TVIs, depending on the particular advanced mathematics subject involved?

A device is considered a core beneficial device for a particular subject if it was reported as being used by more than 50% of TVIs for that subject. Additionally, any device with a mean rating of 3 or more in any/all lesson plan tasks indicated is considered a core beneficial device. These criteria were devised through the collaboration of the researcher and the two field experts who reviewed the final instrument as well as the research questions.

The number of participants who selected each of the six subjects as their highest PAMTL subject is represented in Figure 4.3. In order for a device to be considered a core high-tech device for algebra 1, more than half of the participants (28) teachers must have selected it in their survey. Of the 57 teachers who said algebra 1 was their highest PAMTL subject, 41 said the personal computer was used. Table 4.9 shows all the responses for all the subjects in which teachers had proficiency supporting. Shaded cells indicate those in which more than half of participants selected the tool. According to the results, there are five core tools for both algebra 1 and algebra 2: personal computer, electronic refreshable braille notetaker, talking calculator, talking scientific calculator, and the Duxbury's DBT WIN.

The same tools met the criteria for core devices in geometry with the additions of the Accessible Graphing Calculator and the scanners/readers. There was only one participant who listed trigonometry as his/her highest PAMTL subject. The core set of devices here included the personal computer, electronic refreshable braille notetaker, scanners/readers, Graph-It, Duxbury's DBT WIN, and Scientific Notebook. The two participants in precalculus yielded a core set of devices, including the personal computer, electronic refreshable braille notetaker, audio recording, talking calculator, talking scientific calculator, Accessible Graphing Calculator, scanners/readers, Duxbury's DBT WIN, and Scientific Notebook.

Table 4.9
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
OCR Software (InftyReader, ChattyInfty, InftyEditor)	15	2	2	0	0
Scanner/Reader (Oscar, Openbook, Kurzweil, etc.)	18	4	7	1	1
Nomad Pad/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's DBT WIN	33	6	8	1	2
IVEO (View Plus Technologies)	6	2	2	0	0
Math Program (Maple, Mathematica, MathLab)	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 with ratings greater than or equal to 3 in any lesson-plan steps also met criteria for being in the core set of devices. Ratings in algebra 1, algebra 2, and geometry are displayed in Tables 4.10, 4.11, and 4.12 respectively.

Table 4.10
Ratings of Participants Who Taught/Supported Algebra 1 (*N* = 57)

	Preparation of materials			**Student lesson access**			**Teacher/student-guided practice**			**Student independent practice**			**Student work submission**		
Device	***n***	**Mean**	***SD***	***n***	**Mean**	***SD***	***n***	**Mean**	***SD***	***n***	**Mean**	***SD***	***n***	**Mean**	***SD***
Personal Computer	41	4.5	1.2	28	2.8	1.7	27	2.7	1.5	29	2.4	1.6	32	3.0	2.0
Electronic Refreshable Braille Notetaker	24	.02	1.5	38	3.3	1.6	32	3.2	1.6	41	3.7	1.5	34	3.6	1.5
Audio Recording	19	1.8	1.1	19	1.9	1.4	18	1.5		19	2	1.3	15	1.3	0.69
Talking Calculator	20	1.9	1.6	32	3.625	1.7	30	3.9	1.5	34	4.2	1.4	20	3.3	1.6
Talking Scientific Calculator	18	2	1.6	34	4	1.3	32	4.2	1.1	36	4.4	1.0	20	3.6	1.6
Accessible Graphing Calculator	13	1.8	1.2	20	2.7	1.5	20	2.7	1.3	17	2.6	1.2	13	1.9	0.8
OCR Software (InftyReader, ChattyInfty, InftyEditor)	15	3.1	1.8	10	2.5	1.3	9	1.3	.7	11	1.6	1.1	11	3.1	1.8
Scanner/Reader (Oscar, Openbook, Kurzweil, etc.)	18	3.7	1.3	13	2.5	1.3	12	2.3	1.2	11	2	1.3	12	1.83	1.3
Nomad Pad/Tablet	5	1.0	0	5	1.0	0	5	1.0	0	5	1.0	0	5	1.0	0
Talking Tactile Tablet	5	1.0	0	5	1.0	0	5	1.0	0	5	1.0	0	5	1.0	0
Talking Tactile Pen	6	1.0	0	5	1.0	0	6	1.0	0	5	1.0	0	5	1.0	0
Tactile AudioGraphics TagPad	5	1.0	0	5	1.0	0	5	1.0	0	5	1.0	0	5	1.0	0

Table 4.10 *Continued*

	Preparation of materials			**Student lesson access**			**Teacher/student-guided practice**			**Student independent practice**			**Student work submission**		
Device	***n***	**Mean**	***SD***	***n***	**Mean**	***SD***	***n***	**Mean**	***SD***	***n***	**Mean**	***SD***	***n***	**Mean**	***SD***
MathPlayer (Design Science)	5	1.0	0	5	1.0	0	5	1.0	0	5	1.0	0	5	1.0	0
MathSpeak	6	1.0	0	6	1.0	0	6	1.0	0	6	1.0	0	6	1.0	0
ReadHear	5	1.0	0	5	1.0	0	5	1.0	0	5	1.0	0	5	1.0	0
ClickHear	5	1.0	0	5	1.0	0	5	1.0	0	5	1.0	0	5	1.0	0
TRIANGLE	5	1.0	0	5	1.0	0	5	1.0	0	5	1.0	0	5	1.0	0
AudioMath	5	1.0	0	5	1.0	0	5	1.0	0	5	1.0	0	5	1.0	0
Graph-It	6	1.0	0	6	1.0	0	6	1.0	0	6	1.0	0	6	1.0	0
GRAPH	5	1.0	0	6	1.0	0	5	1.0	0	5	1.0	0	5	1.0	0
AsTeR	5	1.0	0	5	1.0	0	5	1.0	0	5	1.0	0	5	1.0	0
MathTalk with MathPad	5	1.0	0	5	1.0	0	5	1.0	0	5	1.0	0	5	1.0	0
MathTalk with Scientific Notebook	6	1.0	0	5	1.0	0	5	1.0	0	5	1.0	0	5	1.0	0
AudioCAD	5	1.0	0	5	1.0	0	5	1.0	0	5	1.0	0	5	1.0	0
AudioPIX	5	1.0	0	5	1.0	0	5	1.0	0	5	1.0	0	5	1.0	0
MegaMath	5	1.0	0	5	1.0	0	5	1.0	0	4	1.0	0	5	1.0	0
Duxbury's DBT WIN	33	4.3	1.0	13	3.2	1.8	12	2.7	1.9	11	2.5	1.9	10	1.4	1.1
IVEO (View Plus Technologies)	6	1.0	0	5	1.0	0	5	1.0	0	5	1.0	0	5	1.0	0
Math Programs (Maple, Mathematica, MathLab)	7	1.0	0	6	1.0	0	6	1.0	0	6	1.0	0	6	1.0	0
Scientific Notebook	26	3.8	1.6	11	2.6	1.8	11	2.5	2.3	9	1.9	1.0	9	1.4	1.0
MathTalk	6	1.0	0	6	1.0	0	6	1.0	0	6	1.0	0	6	1.0	0
MathFlow	5	1.0	0	5	1.0	0	5	1.0	0	5	1.0	0	5	1.0	0
MathDaisy	5	1.0	0	5	1.0	0	5	1.0	0	5	1.0	0	5	1.0	0
MathFlash	6	1.3	.5	9	1.8	1.2	9	2.1	1.5	8	1.75	1.2	6	1	0.0
Excel	9	2.8	2.1	10	2.8	2.0	9	2.8	2.1	8	2.6	1.9	11	3.1	1.8

Note: Shaded devices indicated mean ratings ≥ 3 for at least one lesson plan task.

Table 4.11
Ratings of Participants Who Taught/Supported Algebra 2 (N = 11)

	Preparation of materials			**Student lesson access**			**Teacher/student-guided practice**			**Student independent practice**			**Student work submission**		
Device	***n***	**Mean**	***SD***	***n***	**Mean**	***SD***	***n***	**Mean**	***SD***	***n***	**Mean**	***SD***	***n***	**Mean**	***SD***
Personal Computer	8	4.6	1.1	6	2.5	2.0	5	3.2	1.8	4	3.2	2.1	5	3.4	2.2
Electronic Refreshable Braille Notetaker	3	1	0	4	4.8	2.4	6	4.0	1.7	7	4	1.3	5	3.4	2.2
Audio Recording	4	2.0	1.2	4	2.0	1.2	3	2.3	1.2	4	2.0	0.8	2	2.0	1.4
Talking Calculator	4	1.75	1.5	7	3.3	1.7	5	3.6	1.7	7	3.3	1.7	2	2.5	2.1
Talking Scientific Calculator	5	1.8	1.0	8	4.0	1.3	8	4.125	1.1	9	3.9	1.5	3	4.7	0.6
Accessible Graphing Calculator	3	3.3	2.0	5	3.2	2.0	4	3.0	1.8	3	4.7	0.6	1	5.0	
OCR Software (InftyReader, ChattyInfty, InftyEditor)	2	3.0	2.8	2	1.0	0	1	1.0	0	1	1.0	0	2	2.5	2.1
Scanner/Reader (Oscar, Openbook, Kurzweil, etc.)	4	2.5	1.9	2	1.0	0	1	1.0	0	1	1.0	0	1	1.0	0
Nomad Pad/Tablet	2	1.0	0	2	1.0	0	1	1.0	0	1	1.0	0	1	1.0	0
Talking Tactile Tablet	2	3.0	2.8	2	3.0	2.8	1	5.0	0	1	5.0	0	1	5.0	0
Talking Tactile Pen	2	1.0	0	2	1.0	0	1	1.0	0	1	1.0	0	1	1.0	0
Tactile AudioGraphics TagPad	2	1.0	0	2	1.0	0	1	1.0	0	1	1.0	0	1	1.0	0
MathPlayer (Design Science)	2	1.0	0	2	1.0	0	1	1.0	0	1	1.0	0	1	1.0	0
MathSpeak	2	1.0	0	2	1.0	0	1	1.0	0	1	1.0	0	1	1.0	0
ReadHear	2	1.0	0	2	1.0	0	1	1.0	0	1	1.0	0	1	1.0	0
ClickHear	2	1.0	0	2	1.0	0	1	1.0	0	1	1.0	0	1	1.0	0
TRIANGLE	2	1.0	0	2	1.0	0	1	1.0	0	1	1.0	0	1	1.0	0
AudioMath	2	1.0	0	2	1.0	0	1	1.0	0	1	1.0	0	1	1.0	0

Table 4.11 *Continued*

	Preparation of materials			**Student lesson access**			**Teacher/student-guided practice**			**Student independent practice**			**Student work submission**		
Device	***n***	**Mean**	***SD***	***n***	**Mean**	***SD***	***n***	**Mean**	***SD***	***n***	**Mean**	***SD***	***n***	**Mean**	***SD***
Graph-It	2	2.3	2.3	2	1.0	0	2	3.0	2.8	3	2.7	2.1	1	1.0	0
GRAPH	2	2.5	2.2	3	2.3	2.3	1	1.0	0	2	3.0	2.8	2	3.0	2.8
AsTeR	2	1.0	0	2	1.0	0	1	1.0	0	1	1.0	0	1	1.0	0
MathTalk with MathPad	2	1.0	0	2	1.0	0	1	1.0	0	1	1.0	0	1	1.0	0
MathTalk with Scientific Notebook	2	1.0	0	2	1.0	0	1	1.0	0	1	1.0	0	1	1.0	0
AudioCAD	2	1.0	0	2	1.0	0	1	1.0	0	1	1.0	0	1	1.0	0
AudioPIX	2	1.0	0	2	1.0	0	1	1.0	0	1	1.0	0	1	1.0	0
MegaMath	2	1.0	0	2	1.0	0	1	1.0	0	1	1.0	0	1	1.0	0
Duxbury's DBT WIN	6	4.5	1.2	2	1.0	0	2	2.0	1.4	1	1.0	0	1	1.0	0
IVEO (View Plus Technologies)	2	1.0	0	2	1.0	0	1	1.0	0	1	1.0	0	1	1.0	0
Math Programs (Maple, Mathematica, MathLab)	2	1.0	0	2	1.0	0	1	1.0	0	1	1.0	0	1	1.0	0
Scientific Notebook	5	5.0	0	1	1.0	0	1	1.0	0	1	1.0	0	2	3.0	2.8
MathTalk	2	1.0	0	1	1.0	0	1	1.0	0	1	1.0	0	1	1.0	0
MathFlow	2	1.0	0	1	1.0	0	1	1.0	0	1	1.0	0	1	1.0	0
MathDaisy	2	1.0	0	1	1.0	0	1	1.0	0	1	1.0	0	1	1.0	0
MathFlash	2	1.0	0	1	1.0	0	1	1.0	0	2	1.5	0.7	2	1.5	0.7
Excel	2	1.0	0	1	1.0	0	1	1.0	0	2	1.5	0.7	1	1.0	0

Note: Shaded devices indicated mean ratings ≥ 3 for at least one lesson plan task.

Table 4.12
Ratings of Participants Who Taught/Supported Geometry (*N* = 11)

	Preparation of materials			**Student lesson access**			**Teacher/student-guided practice**			**Student independent practice**			**Student work submission**		
Device	***n***	**Mean**	***SD***	***n***	**Mean**	***SD***	***n***	**Mean**	***SD***	***n***	**Mean**	***SD***	***n***	**Mean**	***SD***
Personal Computer	9	3.8	1.7	8	3.0	1.6	9	2.9	1.7	8	2.5	1.7	8	2	1.5
Electronic Refreshable Braille Notetaker	6	2.3	1.6	8	3.25	1.9	8	3.3	1.5	9	3.9	1.5	9	3.6	1.5
Audio Recording	5	2.8	1.8	5	2.6	2.2	5	2.8	1.8	5	2.4	1.9	5	2.8	2.0
Talking Calculator	6	3.8	1.8	7	3.9	2.0	9	4.6	.9	10	4.4	1.3	7	4.7	.8
Talking Scientific Calculator	6	3.3	2.0	6	3	1.8	6	4	1.3	6	3.7	1.8	6	3.8	1.5
Accessible Graphing Calculator	5	2.2	1.3	4	1.75	1.5	6	2.5	1.2	4	2.25	1.5	4	2.25	1.5
OCR Software (InftyReader, ChattyInfty, InftyEditor)	2	2.0	1.4	2	2.0	1.4	2	2.0	1.4	2	2.0	1.4	2	2.0	1.4
Scanner/Reader (Oscar, Openbook, Kurzweil, etc.)	7	4.3	1.1	3	2.3	2.3	3	2.7	2.1	3	2.3	2.3	3	2.3	2.3
Nomad Pad/Tablet	2	2.0	1.4	2	2.0	1.4	2	2.0	1.4	2	2.0	1.4	2	2.0	1.4
Talking Tactile Tablet	2	2.0	1.4	2	2.0	1.4	2	2.0	1.4	2	2.0	1.4	2	2.0	1.4
Talking Tactile Pen	2	2.0	1.4	2	2.0	1.4	2	2.0	1.4	2	2.0	1.4	2	2.0	1.4
Tactile AudioGraphics TagPad	2	1.5	.7	2	1.5	.7	2	1.5	.7	2	1.5	.7	2	1.5	.7
MathPlayer (Design Science)	2	1.5	.7	2	1.5	.7	2	1.5	.7	2	1.5	.7	2	1.5	.7
MathSpeak	2	3.0	2.8	2	3.0	2.8	2	3.0	2.8	2	3.0	2.8	2	3.0	2.8
ReadHear	2	1.0	0	2	1.0	0	2	1.0	0	2	1.0	0	2	1.0	0
ClickHear	2	1.0	0	2	1.0	0	2	1.0	0	2	1.0	0	2	1.0	0
TRIANGLE	2	3.0	2.8	2	3.0	2.8	2	3.0	2.8	2	3.0	2.8	2	3.0	2.8
AudioMath	2	1.0	0	2	1.0	0	2	3.0	2.8	2	3.0	2.8	2	3.0	2.8

Table 4.12 *Continued*

	Preparation of materials			Student lesson access			Teacher/student-guided practice			Student independent practice			Student work submission		
Device	***n***	**Mean**	***SD***	***n***	**Mean**	***SD***	***n***	**Mean**	***SD***	***n***	**Mean**	***SD***	***n***	**Mean**	***SD***
Graph-It	2	3.0	2.8	2	3.0	2.8	3	3.3	2.1	2	3.0	2.8	3	3.7	2.3
GRAPH	2	3.0	2.8	2	3.0	2.8	2	3.0	2.8	2	3.0	2.8	2	3.0	2.8
AsTeR	2	1.0	0	2	1.0	0	2	1.0	0	2	1.0	0	2	1.0	0
MathTalk with MathPad	2	1.0	0	2	1.0	0	2	1.0	0	2	1.0	0	2	1.0	0
MathTalk with Scientific Notebook	2	3.0	2.8	2	3.0	2.8	2	3.0	2.8	2	3.0	2.8	2	3.0	2.8
AudioCAD	2	1.0	0	2	1.0	0	2	1.0	0	2	1.0	0	2	1.0	0
AudioPIX	2	1.0	0	2	1.0	0	1	1.0	0	1	1.0	0	1	1.0	0
MegaMath	2	2.0	1.4	2	2.0	1.4	1	3.0	0	1	3.0	0	1	3.0	0
Duxbury's DBT WIN	8	4.6	1.1	4	3.3	2.1	5	3.4	1.8	4	3.5	1.9	4	3.3	2.1
IVEO (View Plus Technologies)	2	1.5	.7	2	1.5	.7	2	1.5	.7	2	1.5	.7	2	1.5	.7
Math Programs (Maple, Mathematica, MathLab)	3	3.3	2.1	2	3.0	2.8	2	3.0	2.8	2	3.0	2.8	2	3.0	2.8
Scientific Notebook	5	4.2	1.8	3	3.3	2.1	3	3.3	2.1	3	2.7	2.1	3	2.7	2.1
MathTalk	2	3.0	2.8	2	3.0	2.8	2	3.0	2.8	2	3.0	2.8	2	3.0	2.8
MathFlow	2	3.0	2.8	2	3.0	2.8	2	3.0	2.8	2	3.0	2.8	2	3.0	2.8
MathDaisy	2	3.0	2.8	2	3.0	2.8	2	3.0	2.8	2	3.0	2.8	2	3.0	2.8
MathFlash	3	3.7	2.3	3	3.7	2.3	3	3.7	2.3	3	3.7	2.3	3	3.7	2.3
Excel	5	3.8	1.8	3	3.0	2.0	3	3.0	2.0	3	3.0	2.0	3	3.0	2.0

Note: Shaded devices indicated mean ratings ≥ 3 for at least one lesson plan task.

The one participant who listed trigonometry as his/her highest PAMTL subject gave the personal computer a rating of 5 for preparation of materials and a 3 to the PC for student work submission. Participants who selected precalculus as their highest PAMTL subject assigned a 3 or greater rating to the personal computer, Duxbury's DBT WIN, the talking scientific calculator, and the Scientific Notebook.

Results Related to Question Four

4. According to TVI perceptions, how effective are these tools in supporting learning throughout the following lesson-plan steps?
   - Preparation of materials
   - Accessing the lesson
   - Guided practice
   - Independent practice
   - Submission of work

A device is considered beneficial for a step if it was identified as being used by at least 50% of the participants for that step, or its mean score is 3 or more for that task. With *N* = 82 participants, any device that was used in a lesson-plan task by at least 41 participants met the criteria as a core device for that task. Table 4.13 summarized these results yielding at least two core devices for each task.

Table 4.13
Devices Selected by More Than Half of Participants as Being Useful for Each Lesson-Plan Task

Preparation of materials			**Student lesson plan access**			**Teacher/student guided practice**			**Student independent practice**			**Student work submission**		
Device	***n***	**%**	**Device**	**n**	**%**	**Device**	***n***	**%**	**Device**	***n***	**%**	**Device**	***n***	**%**
Personal computer	62	76	Personal computer	43	52	Personal computer	42	51	Personal computer	42	51	Personal Computer	47	57
Duxbury's DBT WIN	51	62	Electronic refreshable braille notetaker	52	63	Electronic refreshable braille notetaker	47	57	Electronic refreshable braille notetaker	58	71	Electronic refreshable braille notetaker	51	62
			Talking calculator	48	58	Talking calculator	45	53	Talking calculator	51	62			
			Talking scientific calculator	50	61	Talking scientific calculator	47	57	Talking scientific calculator	53	64			

Examination of Tables 4.6, 4.7, and 4.8, produced five lists of core devices, one for each of the lesson plan tasks, based on the mean ratings calculated. These lists are represented in Table 4.14.

Table 4.14
Devices With Mean ≥ 3 in at Least One Lesson-Plan Task.

Preparation of materials	Student lesson plan access	Teacher/student-guided practice	Student independent practice	Student work submission
Personal computer	Personal computer	Personal computer	Electronic refreshable braille notetaker	Personal computer
Audio recording	Electronic refreshable braille notetaker	Electronic refreshable braille notetaker	Talking calculator	Electronic refreshable braille notetaker
Talking calculator	Audio recording	Talking calculator	Talking scientific calculator	Talking calculator
Talking scientific calculator	Talking calculator	Talking scientific calculator	Accessible Graphing Calculator	Talking scientific calculator
Accessible Graphing Calculator	Talking scientific calculator	Accessible Graphing Calculator	Scanner/reader	Accessible Graphing Calculator
OCR Software	Accessible Graphing Calculator	Duxbury's DBT WIN	Graph-It	Duxbury's DBT WIN
Scanner/reader	Scanner/reader	Scientific Notebook	Duxbury's DBT WIN	Excel
Graph-It	Duxbury's DBT WIN	MathFlash		
Duxbury's DBT WIN	Scientific Notebook	Excel		
Scientific Notebook	Excel			
Excel				

Results Related to Questions Five

5. Are there gaps between the technologies being used and teaching activities? Are there lesson-plan steps that are not supported, either overall or in specific subjects?

Examination of Tables 4.13 indicated that according to teacher perspectives, three lesson-plan tasks—student lesson plan access, teacher/student-guided practice, and student independent practice—were supported by the same four high-tech devices: the personal computer, electronic refreshable braille notetaker, talking calculator, and talking scientific calculator. There were only two devices selected by more than half of the participants for each of the other two lesson plan tasks. The personal computer was selected by 76% of participants as being used for preparation of materials and Duxbury's DBT WIN by 62% of participants. For student work submission, the personal computer was again selected by more than half of the teachers; in this case, 57% used it, and 62% selected the electronic refreshable braille notetaker. There were no lesson-plan steps that were not supported by high-tech tools.

Examination of the ratings assigned to each device for effectiveness in each lesson-plan step, Table 4.14, revealed different results. Eleven high-tech devices received an average rating of greater than 3 for perceived effectiveness in preparation of materials; 10 devices for student lesson plan access; nine for teacher/student-guided practice; and seven each for student independent practice and student work submission. In this case, four high-tech tools received high effectiveness ratings in all five lesson-plan tasks. These tools were the talking calculator, talking scientific calculator, accessible graphing calculator, and Duxbury's DBT WIN. There were no lesson-plan tasks in which no high-tech tools were perceived as effective.

Results Related to Questions Six

6. Are themes emerging in TVIs' recommendations about high-tech devices that were not listed or used in ways not indicated?

The open-response segment of the survey was examined for repeated references to devices that were not included in the device matrix, or to devices that were included but used in ways not captured by the matrix. There was no single device named by at least 10% of participants. Many participants listed low-tech devices as beneficial for specific tasks. In all, seven tools that met the definition of high-technology devices were revealed. Table 4.15 shows the answers to this question.

Table 4.15
Open-Ended Responses to Technologies That Facilitate Study of Advanced Mathematics.

Device	n	High-Tech?
Software		
MathType	3	Y
MathTrax	1	Y
Notetakers		
Refreshable braille notetaker with display	1	Y
Perkins braillewriter	7	N
Embossers/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
Other manipulatives		
Math Window® Braille Basic Math Kit	2	N
Geometric manipulatives	5	N
Other		
Abacus	2	N
Digital cameras	3	Y

Summary

This research was conducted in order to determine the current state, as perceived by TVIs, of the usage and effectiveness of high-technology devices in the study of advanced mathematics courses by students who are blind. By administering a descriptive survey with both structured and unstructured items to a sample population, the questionnaire attempted to obtain a holistic set of responses. Initial demographic information was collected, followed by items addressing participants' proficiency in advanced mathematics technology level (PAMTL). These questions were intended to focus participants' answers to the device matrix ratings questions on the subjects in which they felt they had the highest PAMTL. These quantitative items allowed investigations of use and effectiveness of a given set of high-tech tools. They were followed by two qualitative items designed to illicit additional information about tools not included in this questionnaire or about general perceptions about technology in mathematics.

The sample used for this survey was a convenience sample. There was no way to determine how many TVIs had experience teaching advanced mathematics subjects to students who were braille readers. Therefore, links to the target population were disseminated via a notice in the APH Newsletter, e-mails to state residential schools for students who are blind, Ex Officio Trustees in each state, and TVIs who voluntarily participated in field research for APH. A $50 gift card to Amazon was offered as incentive for participation. All participation was voluntary, and responses were anonymous. SurveyMonkey was used to collect responses and data analysis was conducted using spreadsheet software (Excel). While 157 surveys were returned, a total of 82 were completed through the device matrix question. This chapter presents a descriptive analysis of the data collected from the survey.

Results indicated that 21 of the 35 devices included on the survey were, in fact, used by TVIs. In addition, there was a core set of 13 devices used by TVIs regardless of specific subject. When looking at specific subjects, the core set did not vary much from subject to subject. More than half of the TVIs listing algebra 1, algebra 2, or geometry as their highest PAMTL subject stated they used these five devices: personal computer, electronic refreshable braille notetaker, talking calculator, talking scientific calculator, and Duxbury's DBT WIN. More than half of the participants who listed geometry as their highest PAMTL subject also selected the accessible graphing calculator and the scanner/reader. Two participants who listed precalculus as their highest PAMTL subject had a core list that matched that of geometry with the addition of audio recording and Scientific Notebook. The one TVI who stated trigonometry was his/her highest PAMTL subject selected the personal computer, electronic refreshable braille notetaker, scanner/reader, Graph-It, Duxbury's DBT WIN, and Scientific Notebook.

In terms of the effectiveness of the devices in supporting specific lesson-plan steps, results indicated that while many devices rated greater than or equal to 3, only a few were being used by more than half of participants. More than half of the participants listed the same four devices—the PC, electronic refreshable braille notetaker, talking calculator, and talking scientific calculator—for three of the five tasks. For preparation of materials, only the PC and Duxbury's DBT WIN were selected by more than half of participants, and for student work submission, only the PC and refreshable braille notetaker were selected. However, 11 devices received mean ratings of 3 or greater for for preparation of materials and 7 devices for student work submission. Overall, there were no lesson-plan tasks for which no high-tech devices were selected. Participants recommended another seven high-tech devices, two software packages, the refreshable braille notetaker with display, three types of 3D printers/embossers, and digital cameras for supporting students who are blind in advanced mathematics subjects. All of these tools except the digital camera, are designed specifically to support students who are blind. The digital camera was used by a TA, parent, or TVI in order to photograph a solution that would be dismantled, or that was too cumbersome to carry to class. Participants suggested solutions that were created on various tactile boards, like graphs on the graph board, geometric shapes on the magnetic board, or computations on the abacus, could be photographed for submission to the classroom teacher.

CHAPTER 5

CONCLUSIONS, RECOMMENDATIONS, AND SUMMARY

The purpose of this study was to determine the current state of high-technology devices being used in advanced mathematics classes to support students who are blind as perceived by teachers of students with visual impairments. Teachers of students with visual impairments (TVIs) must sift through mass quantities of information and products, often using trial and error, to find a handful of tools that are actually useful, affordable, available, and designed for the specific subjects they will be supporting. This chapter examines the results of the research in an attempt to appraise the educational value of high-tech tools for practical application in various mathematics subjects.

The research questions addressed were:

1. Which high-tech devices, according to TVI perspectives, are currently being used in secondary school advanced mathematics courses to support students who are blind?
2. Is there a core set of devices that is perceived by TVIs as beneficial for supporting advanced mathematics for students who are blind, regardless of specific subject?
3. Are there variations of the core set of devices, as perceived by TVIs, depending on the particular advanced mathematics subject involved?
4. According to TVI perceptions, how effective are these tools in supporting learning throughout the following lesson plan steps?
    - Preparation of materials

- Accessing the lesson
- Guided practice
- Independent practice
- Submission of work

5. Are there gaps between technologies being used and teaching activities? Are there lesson-plan steps that are not supported, either overall or in specific subjects?
6. Are themes emerging in TVIs' recommendations about high-tech devices that were not listed or used in ways not indicated?

Conclusions Related to Question One

The first research question was intended to simply tally which of the high-tech devices promoted for use with students who are blind in advanced mathematics subjects were actually being used. In order to answer this question, the data were analyzed in two ways. In the first analysis, each device received a Total Use Score (TUS) based on the total number of times the tool was selected for use in various subjects and the lesson-plan tasks, regardless of the number of participants who selected it. Scores ranged from 53 for MegaMath to 319 for the electronic refreshable braille notetaker. According to this analysis, all of the devices currently available were used by at least one teacher, in one subject, for one lesson-plan task. It is interesting that despite the extreme obscurity of some of the tools, not a single tool was entirely unused. Closer examination of the data revealed that 60% of the tools (21) scored within the 10-point range of 53 and 62. In fact, if the range of scores is divided into 50-point intervals, over 71% (25) of the tools fall into the 50–100 point interval. The only other intervals with any scores contain only two or three devices. In essence, although a very large portion of the devices was used very infrequently, as was expected, there were not any devices not used at all. Analyzing the data with the alternative method of comparing the number of participants who used each device would either support or contradict these results.

The second analysis employed to answer the first research question counted how many participants said they used each device, regardless of how many subjects or lesson-plan tasks were involved. This analysis corroborates the first in terms of which tools were used most. Here, it seems that every single device was used by at least nine teachers, which was higher than expected**.** Because the population of students—that is, students who are braille readers and studying advanced mathematics—is so small, the use of a device, even by one teacher, warrants further investigation of the tool's benefits. It is possible for one teacher to discover a high-tech solution with one student that can benefit others working with similar students (Maneki, 2010). Therefore, it was important to examine the completed surveys for evidence of bias.

The device matrix consisted of a long list of devices, potentially leading to order bias through routine answering strategies or respondent fatigue (Alreck and Settle, 2004). Individual examination of the completed surveys revealed that nine participants entered a "1" in all of the Likert ratings for every part of the lesson plan in which they didn't enter a higher rating. While this rating may have initially been assumed to be due to respondent fatigue, the fact that they did not enter a rating in just one lesson-plan task, a much easier shortcut, suggests there was misunderstanding of the instructions. The fact that two participants entered a 1 for every device in their highest PAMTL subject, but not in their second highest, suggests that they realized a rating was not required for every device. This finding suggests that some of the high-tech tools that were used by nine teachers may in fact, not have been used by any teachers. Since some of the devices did rate higher than 1, it is impossible to eliminate entire surveys. It can be concluded that 21 of the high-tech devices, the number of devices selected by at least 10 participants, were used by between 1 and 62 teachers.

Conclusions Related to Question Two

This research query attempted to appraise the educational value of high-tech tools that are being used to facilitate the study of advanced mathematics by students who are blind. The goal was to determine the contents of the high-tech portion of a core set of tools to provide TVIs working with these students. Whether any of the 21 devices identified as being used by TVIs should belong to this core set depends on the device meeting the criteria established for “beneficial” through the collaboration of three field experts. The device must either have been reported being used by more than 50% of TVIs participating in the study, or it must have had a mean rating of 3 or more in any of the lesson-plan tasks involved. Mean scores were calculated in TVIs highest PAMTL subjects. The reason there were two separate criteria is, again, a single teacher providing a single device that significantly increases the effectiveness of any part of the study of mathematics justifies its potential inclusion in the core set. If the device is truly rated 3 or more on the rating scale, and it is obtainable and affordable, other students will very likely benefit as well. While quantity matters, often, the most frequently listed tools are those that are already available and known.

Results showed that 13 of the 21 devices listed as used by TVIs were actually considered beneficial. Therefore, the core set of devices that is perceived by TVIs as beneficial for supporting advanced mathematics for students who are blind, regardless of specific subject, consists of:

- Personal Computers
- Electronic Refreshable Braille Notetakers
- Talking Calculators
- Talking Scientific Calculators
- Duxbury's DBT WIN
- Scientific Notebook
- Accessible Graphing Calculator
- Scanner/Reader
- MathFlash
- Excel
- Audio Recording
- OCR Software
- Graph-It.

Practical Implications

The results led to the conclusion that teachers have found these 13 devices beneficial in the facilitation of learning advanced mathematics by students who are blind. Implications for practice are that each of these devices should be seriously considered to be part of the high-tech contents of a "tool kit" that supports braille readers in advanced mathematics. Due to the small sample and inability to accurately determine the size of the total target population, additional research is recommended to determine whether the entire TVI population would consider this set of devices beneficial. TVIs will need information on where to obtain this core set, as well as the training necessary to implement its use.

Conclusions Related to Question Three

The third research question looked more intensely at the application of the devices. Due to expenses and fast evolution in high-tech products, it makes sense to understand whether this complete set is beneficial for every subject, or if subsets make more sense for students in specific advanced mathematics courses. Devices were considered to be core beneficial devices for particular subjects if they were reported as being used by more than 50% of TVIs for that subject. Additionally, any devices with a mean rating of 3 or more in any lesson-plan task indicated they were considered to be core beneficial devices. These criteria were devised through the collaboration of the researcher and the two field experts who reviewed the final instrument as well as the research questions.

Algebra 1 was selected by 57 teachers as their highest PAMTL subject. According to the results, there were five core beneficial devices for both algebra 1 and algebra 2: personal computer, electronic refreshable braille notetaker, talking calculator, talking scientific calculator, and the Duxbury's DBT WIN. The same tools met the criteria for core devices in geometry with the additions of the Accessible Graphing Calculator and the scanner/reader. There was only one participant who listed trigonometry as his/her highest PAMTL subject. The core set of devices here included the personal computer, electronic refreshable braille notetaker, scanners/readers, Graph-It, Duxbury's DBT WIN, and Scientific Notebook. The two participants in precalculus yielded a core set of devices that included the personal computer, electronic refreshable braille notetaker, audio recording, talking calculator, talking scientific calculator, Accessible Graphing Calculator, scanner/reader, Duxbury's DBT WIN, and Scientific Notebook.

Practical Implications

Based on these results, the conclusion is that the core set of beneficial tools varies to some degree depending on the subject. Practical implications are that school districts or regions can maintain a core set with all of the devices and check out those relevant to each subject as students advance to that level. It also makes sense to maintain more than one of each of the five devices that were considered to be beneficial in four out of the five subjects in which participants answered questions. Because blindness is considered a low-incidence disability and a small portion of these students are at academic functional levels, it is feasible that school districts could track in what year a student would take each advanced mathematics subject and need the corresponding tool kit.

Conclusions Related to Questions Four and Five

Breaking down the typical lesson plan into component parts endeavored to understand not only which high-tech tools were used, but also how they were used and who used them. Determining what, if any, gaps existed in technology available, and where specific lesson-plan tasks were unsupported by high-tech tools, provided additional information. These answers provide insight into what types of training are necessary, who should receive the training, and what lesson-plan steps can benefit from high-tech innovations.

Again, data were analyzed with two methods. Results from using the number-of-participants criteria identified four devices as perceived as beneficial in three out of the five lesson-plan tasks: the personal computer, electronic refreshable braille notetaker, talking calculator, and talking scientific calculator. While there were not gaps in technology used, more tools were identified as beneficial to all of the five lesson-plan tasks when the criteria used was the mean score rather than the number of teachers who used them. This finding may simply mean that to apply a parameter requiring that half of the participants use a device in order for it to be considered as beneficial may have been too high. For example, only two devices met the criteria of being used by at least half of participants to be considered beneficial for the steps of preparation of materials and submission of work —the personal computer (n = 62) and Duxbury's DBT WIN (n = 51) for preparation of materials, and the PC (n = 47) and the electronic refreshable braille notetaker (n = 51) for submission of work. Yet, 11 high-tech devices received an average rating of ≥ 3 for perceived effectiveness in preparation of materials, 7 for student independent practice, and 7 for student work submission. Also, using the mean criteria, four high-tech tools received high effectiveness ratings in all five lesson-plan tasks. These were the talking calculator, talking scientific calculator, Accessible Graphing Calculator, and Duxbury's DBT WIN.

Preparation of materials lesson-plan task has the most tools with 11. This result makes sense since classroom teachers, braillists, TAs, and TVIs may all have a hand in preparing materials for a lesson, and will use technology that is familiar and available. Student work submission has the fewest devices (7) with a mean of greater than or equal to 3. This finding also makes sense because there is a shortage of technology to allow for back translation from braille and Nemeth into print (Karshmer, Gupta, & Pontelli, 2009).

Practical Implications

In terms of a beneficial core set, the use of tools only in certain lesson-plan steps would not change the presence of the device in the tool kit. It would impact the training for use of the device. Training to the point of becoming proficient at the use of a high-tech device and its continuous integration into a curriculum requires a significant investment of TVIs' time (Pierce & Ball, 2009). With continuously evolving technology and changing needs of a TVI's caseload, obtaining the training in technology becomes a low priority (Zhou, Smith, Parker, & Griffin-Shirley, 2011). Also, the length of the list of tools is too long to be practical. Teachers would benefit from tools that are capable of performing more than one task efficiently and reliably. The Accessible Graphing Calculator, for example, was rated as beneficial for each lesson-plan step based on mean scores, yet it was only used by a total of 21 participants. Because it is a software package, both teachers and students for all lesson-plan tasks can theoretically use it. Open-ended comments provided insight into why some tools may not be used by more teachers:

> We have found so many glitches with AGC, can't save graphs to print out later in resource room, too many times errors come up and can't print, this week couldn't print out the matrix problems although they appear on the screens and she can hear the correct answer, not computing the inverses although we can enter them. It wastes so much time with inconsistent

product.

Conclusions Related to Question Six

Themes emerging from this research are that there is a definite core set of high-tech devices that needs to be examined for inclusion in the tool kit that will support advanced mathematics students who are blind. Participants offered additional information in the open-ended responses, which implied strong commitment to a core set of low-tech devices as well. The Perkins Braillewriter, manipulatives, and various tactile boards, mentioned by at least seven participants, were accompanied by comments, such as that they were "very effective" and:

> The braillewriter and abacus are not high-tech but are essential for braille students to understand Algebra!

Several participants, however, described either using low-tech devices and wanting to learn about high-tech, or somehow, using both. One participant said:

> We mainly use a braillewriter because it is the easiest for the student at the time. However, I would like to learn more about other technologies that would be easier to use.

Another participant wrote:

> I used more Low Tech devices in this level and continue to use Low Tech for instruction and concept development. Then use the High Tech after concepts are solid. Eventually they become integrated, Low and High tech being used together.

Many TVIs indicated they are open to training and would like to integrate more high-tech tools. The question remains, what has been preventing this? Again, answers from some of the open-response items provided some insight. The most common theme involved availability of devices. In some cases, devices are not available because technology evolves so quickly and school districts cannot keep up with what the latest potentially beneficial devices are. This response ties in directly with lack of training. Teachers, TVIs, and TAs cannot keep up with the latest trainings when the need is so intermittent and the technology so rapidly changing. In other cases, there are budgetary constraints that prevent acquisition of expensive equipment for use with a single student. In some cases, the equipment may be purchased and impossible to use in any practical way in a classroom setting. One participant wrote:

> The problem with the high tech options is school districts have no monies to pay for them or the training needed in order to use them correctly.

Another theme revolved around the complexity of advanced mathematics itself being further complicated by the challenge of access by students who are blind. Teachers suggested that increasing student interest in mathematics in general continues to be challenging. Another respondent commented that the difference between the high-tech tools developed for students who are blind and those who are not made it difficult for a braille reader to follow along with his/her peers. Translation between Nemeth and print continues to hinder many parts of the learning process. This situation will become more challenging as students progress to college where there is less support and often, no textbook. 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.

Recommendations for Future Researchers

This research suggests continuous in-depth interviewing of TVIs as they are identified as working with students who are blind in advanced mathematics for information regarding the integration of high-tech tools into teaching. Identification of such TVIs would have to be standardized throughout school districts. It is also suggested that TVIs identified should be equipped with the prototype technology tool kit. Training on use of each device should be provided to all key persons and qualitative data collected regarding practical applications and effectiveness. Formal training programs need to be developed, standardized, and tested as new students are identified who need this support. In addition, protocols will need to be developed for tool kit requisition, participating in trainings, and obtaining feedback regarding successes and problems that arise.

It is critical that research into development of cutting-edge high-tech products designed for supporting braille readers in advanced mathematics as they become market-ready is continuous. Vision impairment professionals need to know where to find up-to-date information on the existence of potentially effective devices in case they do get a braille-reading student in advanced mathematics. To this end, it is important that a standard procedure for the maintenance, review, and updating of the items in the tool kit be designed, and that responsible parties be included in that design. The results of this study provide a starting point for the development of a plan that ensures that students who are blind obtain the maximum benefits from our high-tech world.

Summary and Conclusion

This descriptive survey explored the current status of high-tech device usage in support of students who are blind in advanced mathematics classes. The theoretical framework proposed that the issues involved are complex and multilayered. The intrinsic complexity of advanced mathematics presents enough difficulty on its own, and when adding several other factors, including the evolution of technology, perceptions and training of teachers, and barriers caused by blindness, the layer of challenges increases exponentially.

The literature led to the conclusion that there is a vast array of technology that can, at least in theory, be used to support this group of students. However, there is still no multipurpose high-tech device or system that translates print to braille and Nemeth, allows for simultaneous visual and tactile viewing, mathematical manipulation, and back translation of Nemeth into print. The literature also showed that there are university programs researching the best ways to train and equip TVIs to best support students who are blind. There are still gaps in the research as evidenced by the disagreement between experts and teachers on essential core competencies in technology (Zhou, et al., 2011). Finally, TVIs as well as classroom teachers share the challenges inherent in teaching mathematics to and motivating all students.

This survey revealed that TVIs are using a certain set of high-tech tools for different functions. A core set of 13 devices perceived as beneficial emerged as well as different subsets for specific lesson plan tasks and different subjects. At the same time, the research revealed that many TVIs are enthusiastic about the use of high-tech tools, often coming up with their own solutions by combining various devices to achieve their goals. One TVI described using a four-step process to create graphics for her student.

> Used the Drawing Toolbar in MS Word to create geometry graphics, inserted braille font, copied to Swell Touch Paper, and raised graphic using a PIAF tactile imaging machine.

This research provides a foundation for additional work in how to best equip teachers of students with visual impairments so that they can support their students in advanced mathematics. Mathematics is considered the universal language and should, therefore, be accessible to all. As President Bill Clinton said, “Technology for everyone. If math is the great equalizer, it needs to be for everyone.”

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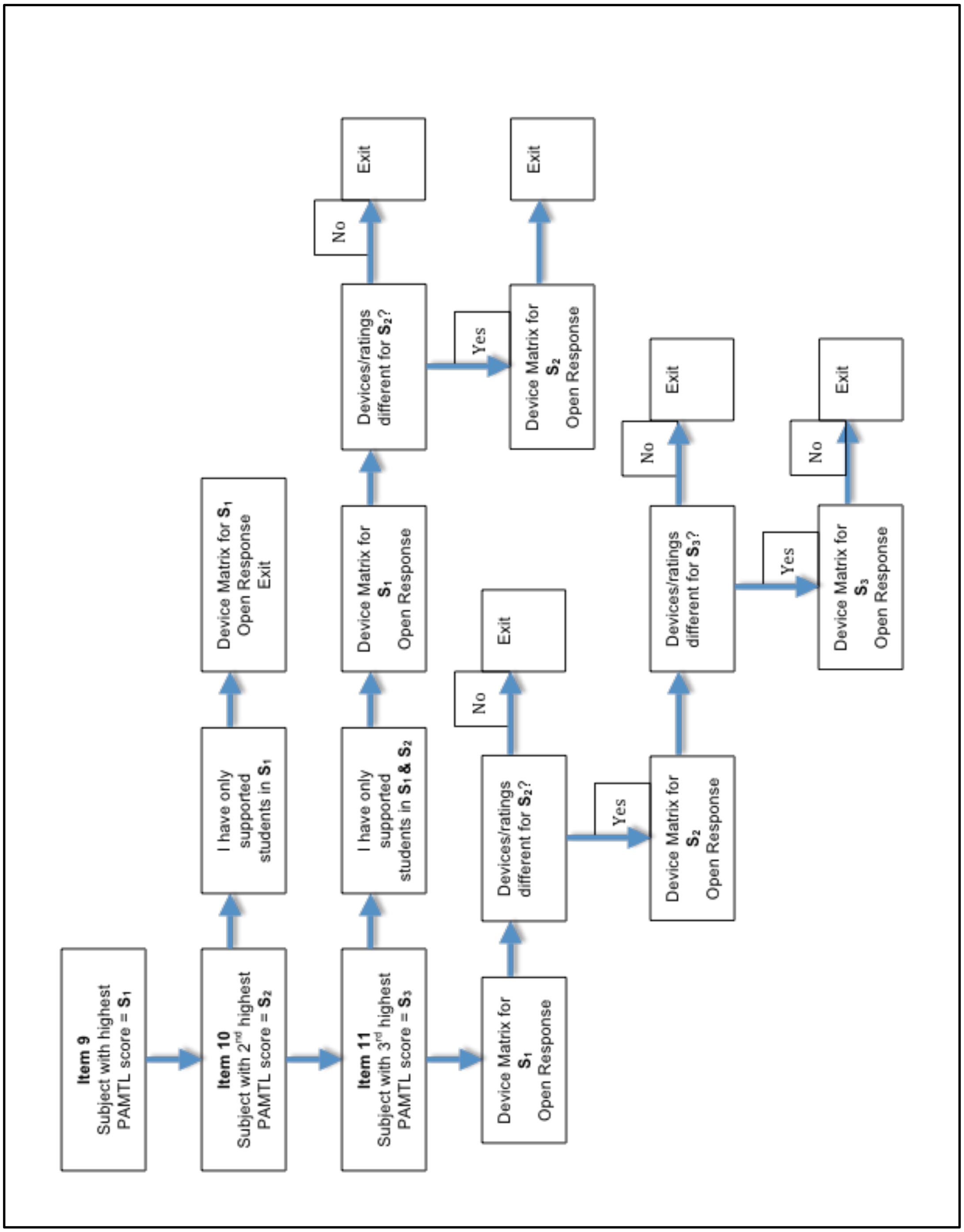
APPENDIX A

SURVEY BRANCHING



APPENDIX B

SURVEY INSTRUMENT

Technologies that Facilitate the Study of Advanced Mathematics by Students ...

Participation in this survey is entirely voluntary and confidential. No names will be collected. Questions may be skipped or left blank. The survey may be exited by closing the browser window or clicking the Exit Survey button on the top right. Answers will not be saved.

Please respond only if you have had experience teaching/supporting students with no functional vision (braille readers), in advanced mathematics classes. If you do not have any such experience, please exit the survey.

The purpose of this study is to sift through the wide array of technology that allegedly facilitates the study of advanced mathematics by students who are blind. It attempts to determine which tools are the most useful, how they are used, and whether or not the same set of tools is useful for the various advanced mathematics subjects taught in typical secondary school by examining the perspectives of teachers of students with visual impairments (TVIs).

The survey will take 10 - 30 minutes depending on how many mathematics subjects you have taught or supported. If you exit the survey, your information will not be saved, but you may return and start it over at another time. At the end of the survey, you will be given instructions for entering a drawing for a $50 Amazon Gift Card. Chances of winning are estimated to be 1 in 300. Drawing will be held on March 31st. All answers will remain confidential.

Definitions:
Students who are blind: students who cannot benefit from the use of low vision devices and are braille readers.

Technology: focus on high-tech devices, those that incorporate electronic and/or computer technology. The devices may be used by the student and/or others including various teachers and transcribers, who, through it's availability, facilitate the student's ability to perform tasks necessary to learn the subject.

Advanced Mathematics: Algebra 1 and beyond (secondary school level).

Your current age:

- ☐ < 28
- ☐ 29 - 36
- ☐ 37 - 44
- ☐ 45 - 52
- ☐ 53 - 60
- ☐ 61 - 68
- ☐ > 68

Your current geographic region:

- ☐ Northeast
- ☐ Midwest
- ☐ South
- ☐ West

Type of community in which you currently work:

- ☐ Urban
- ☐ Suburban
- ☐ Rural

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

- ☐ 1 - 3
- ☐ 4 - 6
- ☐ 7 - 10
- ☐ > 10

What was the most recent school year in which you taught/supported a student who was blind in an advanced mathematics subject?

- ○ 2011 - 2012
- ○ 2010 - 2011
- ○ 2009 - 2010
- ○ 2008 - 2009
- ○ 2007 - 2008
- ○ 2006 - 2007
- ○ 2005 - 2006
- ○ 2004 - 2005
- ○ 2003 - 2004
- ○ 2002 - 2003
- ○ 2001 - 2002
- ○ 2000 - 2001
- ○ 1999 - 2000
- ○ 1998 - 1999
- ○ 1997 - 1998
- ○ Before 1997

What is your current position?

- a teacher at a residential school for the blind
- an itinerant TVI
- a resource room or self-contained classroom teacher
- working at a regional education service center or school district
- working at a rehabilitation center
- trained as a TVI and working in a supervisory or administrative role
- independent consultant

Other (please specify)

Please check all positions in which you have ever worked directly with students who are blind on learning advanced mathematics.

- a teacher at a residential school for the blind
- an itinerant TVI
- a resource room or self-contained classroom teacher
- working at a regional education service center or school district
- working at a rehabilitation center
- independent consultant

Other (please specify)

Proficiency in advanced mathematics technology level (PAMTL) is defined as your perceived proficiency level in integrating technology to support braille readers in advanced mathematics subjects.

What is your PAMTL for each of the following subjects?
1 = novice; 3 = competent; 5 = expert.

	1	2	3	4	5
Algebra 1					
Algebra 2					
Geometry					
Trigonometry					
Precalculus					
Calculus					
Other					

Other (please specify)

In which of the following subjects is your PAMTL highest? If more than one subject got the same score in the preceding question, please use your judgment to select the subject with the highest PAMTL score.

- Algebra 1
- Algebra 2
- Geometry
- Trigonometry
- PreCalculus
- Calculus
- Other (please specify)

In which of the following subjects is your PAMTL the second highest?

- ○ Algebra 1
- ○ Algebra 2
- ○ Geometry
- ○ Trigonometry
- ○ PreCalculus
- ○ Calculus
- ○ I have only supported students in [q9]
- ○ Other (please specify)

In which of the following subjects is your PAMTL the third highest?

- Algebra 1
- Algebra 2
- Geometry
- Trigonometry
- PreCalculus
- Calculus
- I have only supported students in [q9] and [q10]
- Other (please specify)

Technologies

Each column head in the matrix below indicates a task in a typical lesson plan. Each row contains a high- tech device along with 5 drop down menus. If a device was used to support a student who was blind in [q9], determine which tasks it supported (column headers). Then, for each of those tasks, rate the device on effectiveness by selecting 1 to 5 in the drop-down menu, with 1 being slightly effective and 5 being extremely effective.

If a device was used for more than one task, make a rating choice in as many columns as are relevant. If a device was not used at all, leave the row blank. If a device was tried and found ineffective, and its use was terminated, leave the row blank. If you used a device in a way not indicated by the column headers, please explain in the next question.

Use the following descriptions to guide you:
Preparation of Lesson: the device was used by a classroom teacher, TVI, transcriber, TA, or other staff member to prepare the mathematics lesson, notes, and/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 lesson, in order to access the notes or demonstration his or her peers were accessing visually.

Teacher/Student Guided Practice: the device was used by the student and classroom teacher or TVI, so that they could simultaneously study, discuss, or work the relevant mathematics problems.

Student Independent Practice: the device was used by the student in or outside the classroom to work problems independently. This task corresponds to the paper and pencil students with vision use to solve mathematics homework problems.

Student Work Submission: the device was used by the student, teacher, transcriber, other staff member, to create a print document that could be read by the classroom teacher for assessment.

Make a selection in each drop-down menu using a scale of 1 to 5 where 1 = slightly effective and 5 = extremely effective.
Subject: [Q9]

	Preparation of Materials	Student Lesson Access	Teacher/Student Guided Practice	Student Independent Practice	Student Work Submission
Personal Computer					

Electronic Refreshable Braille Notetaker					
Audio Recording					
Talking Calculator					
Talking Scientific Calculator					
Accessible Graphing Calculator					
OCR Software (InftyReader, ChattyInfty, InftyEditor)					
Scanner/Reader (Oscar, Openbook, Kurzweil, etc)					
Nomad Pad/Tablet					
Talking Tactile Tablet					
Talking Tactile Pen					
Tactile AudioGraphics TagPad					
MathPlayer (Design Science)					
MathSpeak					
ReadHear					
ClickHear					
TRIANGLE					
AudioMath					
Graph-It					
GRAPH					
AsTeR					
MathTalk with MathPad					
MathTalk with Scientific Notebook					
AudioCAD					
AudioPIX					
MegaMath					
Duxbury's DBT WIN					
IVEO (View Plus Technologies)					
Math Programs (Maple, Mathematica, MatLab)					
Scientific Notebook					
MathTalk					
MathFlow					
MathDaisy					

MathDaisy					
MathFlash					
Excel					

Indicate any technologies that in your experience, facilitated the study of [q9] by students who are blind, that were not in the previous list, or need clarification in regards to their use. Include a brief description on how the technologies were used.

Device 1

Device 2

Device 3

Device 4

Device 5

Device 6

Please use this space to provide any additional information regarding high-tech tools in [q9] classes that, based on your experience, you believe is important to educating students who are blind.

In your professional opinion, would the devices used, and/or your ratings of them, and/or their role in facilitating steps of a lesson plan, be different for students taking [q10] versus [q9]?

Yes - devices and/or ratings would be different

No - devices and/or ratings would not be different

Technologies

Note: These instructions are the same as those for [q9].
Each column head in the matrix below indicates a task in a typical lesson plan. Each row contains a high- tech device along with 5 drop down menus. If a device was used to support a student who was blind in [q10], determine which tasks it supported (column headers). Then, for each of those tasks, rate the device on effectiveness by selecting 1 to 5 in the drop-down menu, with 1 being slightly effective and 5 being extremely effective.

If a device was used for more than one task, make a rating choice in as many columns as are relevant. If a device was not used at all, leave the row blank. If a device was tried and found ineffective, and its use was terminated, leave the row blank. If you used a device in a way not indicated by the column headers, please explain in the next question.

Use the following descriptions to guide you:
Preparation of Lesson: the device was used by a classroom teacher, TVI, transcriber, TA, or other staff member to prepare the mathematics lesson, notes, and/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 lesson, in order to access the notes or demonstration his or her peers were accessing visually.

Teacher/Student Guided Practice: the device was used by the student and classroom teacher or TVI, so that they could simultaneously study, discuss, or work the relevant mathematics problems.

Student Independent Practice: the device was used by the student in or outside the classroom to work problems independently. This task corresponds to the paper and pencil students with vision use to solve mathematics homework problems.

Student Work Submission: the device was used by the student, teacher, transcriber, other staff member, to create a print document that could be read by the classroom teacher for assessment.

Make a selection in each drop-down menu using a scale of 1 to 5 where 1 = slightly effective and 5 = extremely effective.

Subject: [Q10]

	Preparation of Materials	Student Lesson Access	Teacher/Student Guided Practice	Student Independent Practice	Student Work Submission
Personal Computer					
Electronic Refreshable Braille Notetaker					
Audio Recording					
Talking Calculator					
Talking Scientific Calculator					
Accessible Graphing Calculator					
OCR Software (InftyReader, ChattyInfty, InftyEditor)					
Scanner/Reader (Oscar, Openbook, Kurzweil, etc)					
Nomad Pad/Tablet					
Talking Tactile Tablet					
Talking Tactile Pen					
Tactile AudioGraphics TagPad					
MathPlayer (Design Science)					
MathSpeak					
ReadHear					
ClickHear					
TRIANGLE					
AudioMath					
Graph-It					
GRAPH					
AsTeR					
MathTalk with MathPad					
MathTalk with Scientific Notebook					
AudioCAD					
AudioPIX					
MegaMath					
Duxbury's DBT WIN					
IVEO (View Plus Technologies)					
Math Programs (Maple, Mathematica, MatLab)					
Scientific Notebook					
MathTalk					

MathFlow					
MathDaisy					
MathFlash					
Excel					

Indicate any technologies that in your experience, facilitated the study of [q10] by students who are blind, that were not in the previous list, or need clarification in regards to their use. Include a brief description on how the technologies were used.

Device 1

Device 2

Device 3

Device 4

Device 5

Device 6

Please use this space to provide any additional information regarding high-tech tools in [q10] classes that, based on your experience, you believe is important to educating students who are blind.

In your professional opinion, would the devices used, and/or your ratings of them, and/or their role in facilitating steps of a lesson plan, be different for students taking [q11] versus [q10] versus [q9]?

○ Yes - devices and/or ratings would be different ○ No - devices and/or ratings would not be different

APPENDIX C

IRB LETTER OF APPROVAL

TEXAS TECH UNIVERSITY
Vice President *for* Research

January 9, 2012

Dr. Rona Pogrund
Ed Psychology & Leadership
Mail Stop: 1071

Regarding: 503201 Study of Advanced Mathematics: Students Who Are Blind

Dr. Rona Pogrund:

The Texas Tech University Protection of Human Subjects Committee approved your claim for an exemption for the proposal referenced above on January 5, 2012.

Exempt research is not subject to continuing review. However, any modifications that (a) change the research in a substantial way, (b) might change the basis for exemption, or (c) might introduce any additional risk to subjects must be reported to the IRB before they are implemented.

To report such changes, you must send a new claim for exemption or a proposal for expedited or full board review to the IRB. Extension of exempt status for exempt projects that have not changed is automatic.

The IRB will send annual reminders that ask you to update the status of your research project. Once you have completed your research, you must inform the Coordinator of the Committee either by responding to the annual reminder or by notifying the Coordinator by memo or e-mail (donna.peters@ttu.edu) so that the file for your project can be closed.

Sincerely,

Rosemary Cogan

Rosemary Cogan, Ph.D., ABPP
Protection of Human Subjects Committee

Box 41075 | Lubbock, Texas 79409-1075 | T 806.742.3905 | F 806.742.3947 | www.vpr.ttu.edu
An EEO/Affirmative Action Institution

APPENDIX D

APH NEWS ANNOUNCEMENT AND LETTERS TO TVIS

TVIs Who Teach or Support Advanced Mathematics* Are Needed for a Survey

Teachers of students with visual impairments are needed to participate in a research study regarding experience in use of technology to teach advanced mathematics to students who are blind (no functional vision/braille readers). The research is being conducted by the Special Education Program of the College of Education at Texas Tech University as part of a doctoral dissertation.

This survey takes 10-30 minutes to complete and allows for skipping questions and exiting at any time. Participation is voluntary and anonymous.

Participants ***must*** have experience as:

- A TVI teaching advanced mathematics in a residential school **or**
- An itinerant TVI who has supported a student in an advanced class in a public school.

***Advanced mathematics is defined as algebra 1 or beyond at the secondary school level.**

Please complete the online survey by January 15th, 2012 by going to:

https://www.surveymonkey.com/s/58ND7MQ

Your time and willingness to share your expertise in efforts to best support the study of mathematics by students who are blind is greatly appreciated.

Thank you,

Vicki DePountis, M.Ed., TVI, COMS
Texas Tech University, Doctoral Candidate
512-297-0300
Vicki.depountis@ttu.edu

Rona Pogrund, Ph.D.
Texas Tech University
(512) 206-9213 (TSBVI)

Dear TVIs,

Teachers of students with visual impairments are needed to participate in a research study regarding experience in use of technology to teach advanced mathematics to students who are blind. The research is being conducted by the Special Education Program of the College of Education at Texas Tech University as part of a doctoral dissertation.

If you have taught or supported students who are blind (no functional vision/braille readers) in an advanced mathematics subject in secondary school, your input is valuable in determining which high-tech devices are beneficial. This online survey (see link below) takes 10-30 minutes to complete, depending on the number of different subjects you have taught or supported. It allows for skipping questions and exiting at any time. Participation is voluntary and anonymous.

Participants ***must*** have experience as:

- A TVI teaching advanced mathematics in a residential school **or**
- An itinerant TVI who has supported a student in an advanced class in a public school.

***Advanced mathematics is defined as algebra 1 or beyond at the secondary school level.**

Please complete the online survey by January 20th, 2012 by going to:

https://www.surveymonkey.com/s/CSQGDLF

Your time and willingness to share your expertise in efforts to best support the study of mathematics by students who are blind is greatly appreciated. All responses will remain strictly confidential. You may choose to enter a drawing for a $50 Amazon Gift Card. If you do so, an email address will be required. Chances of winning are estimated at 1 in 300. Winner will be notified by March 31st, 2012.

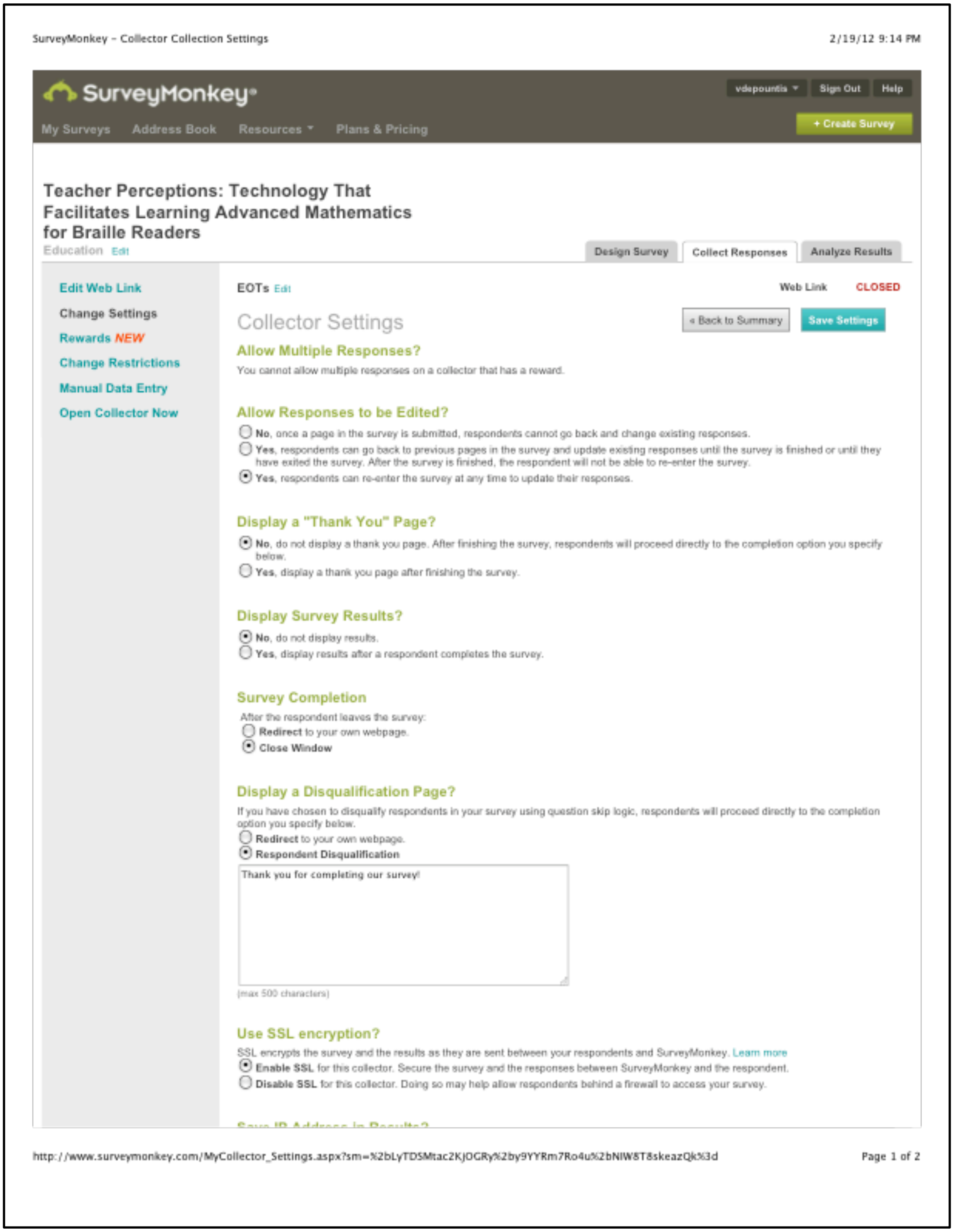
Thank you,

Vicki DePountis, M.Ed., TVI, COMS
Texas Tech University, Doctoral Candidate
512-297-0300
Vicki.depountis@ttu.edu

Rona Pogrund, Ph.D.
Texas Tech University
(512) 206-9213 (TSBVI)
RONA.POGRUND@TTU.EDU

APPENDIX E

SURVEYMONKEY PARAMETERS



SurveyMonkey - Collector Collection Settings 2/19/12 9:14 PM

SurveyMonkey

vdepountis | Sign Out | Help

My Surveys | Address Book | Resources | Plans & Pricing

+ Create Survey

Teacher Perceptions: Technology That Facilitates Learning Advanced Mathematics for Braille Readers

Education Edit

Design Survey | Collect Responses | Analyze Results

Edit Web Link

Change Settings

Rewards NEW

Change Restrictions

Manual Data Entry

Open Collector Now

EOTs Edit

Web Link CLOSED

Collector Settings

« Back to Summary | Save Settings

Allow Multiple Responses?

You cannot allow multiple responses on a collector that has a reward.

Allow Responses to be Edited?

- **No**, once a page in the survey is submitted, respondents cannot go back and change existing responses.
- **Yes**, respondents can go back to previous pages in the survey and update existing responses until the survey is finished or until they have exited the survey. After the survey is finished, the respondent will not be able to re-enter the survey.
- (selected) **Yes**, respondents can re-enter the survey at any time to update their responses.

Display a "Thank You" Page?

- (selected) **No**, do not display a thank you page. After finishing the survey, respondents will proceed directly to the completion option you specify below.
- **Yes**, display a thank you page after finishing the survey.

Display Survey Results?

- (selected) **No**, do not display results.
- **Yes**, display results after a respondent completes the survey.

Survey Completion

After the respondent leaves the survey:

- **Redirect** to your own webpage.
- (selected) **Close Window**

Display a Disqualification Page?

If you have chosen to disqualify respondents in your survey using question skip logic, respondents will proceed directly to the completion option you specify below.

- **Redirect** to your own webpage.
- (selected) **Respondent Disqualification**

Thank you for completing our survey!

(max 500 characters)

Use SSL encryption?

SSL encrypts the survey and the results as they are sent between your respondents and SurveyMonkey. Learn more

- (selected) **Enable SSL** for this collector. Secure the survey and the responses between SurveyMonkey and the respondent.
- **Disable SSL** for this collector. Doing so may help allow respondents behind a firewall to access your survey.

http://www.surveymonkey.com/MyCollector_Settings.aspx?sm=%2bLyTDSMtac2KjOGRy%2by9YYRm7Ro4u%2bNIW8T8skeazQk%3d Page 1 of 2

Save IP Address in Results?

- **No**, the respondent's IP address will **not** be stored in the survey results.
- **Yes**, the respondent's IP address will be stored in the survey results.