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Charting Success: The Experience of Teachers of Students with Visual Impairments in Promoting Student Use of Graphics

Kim T. Zebehazy and Adam P. Wilton

Structured abstract: *Introduction:* This study analyzed the qualitative responses of a survey of teachers of students with visual impairments in Canada and the United States about tactile and print graphic use by their students with visual impairments. Questions focused on barriers to students using graphics, strategies taught to tactile graphics users, and profiles of successful tactile and print graphics users. *Methods:* The researchers followed a thematic analysis approach to independently code and then reach consensus on themes and subthemes of the qualitative responses. *Results:* In general, the teachers cited a range of challenges under the main themes of quality and instruction. Subcategories included availability of time for both production and instruction, lack of standardization in material production, and student development of concepts through the use of graphics. Main characteristics of successful graphics users included motivation and an ability to apply skills across tasks. Variations in responses for tactile and print graphics users are highlighted. *Discussion:* Findings highlighted areas in which teachers of students with visual impairments can focus to promote effective graphics use by their students. Commonality in strategies used for teaching tactile graphics was apparent, as was a general belief that being intelligent contributed to success. *Implications for practitioners:* Frequent exposure and practice with graphics, whether tactile or print, is important. Developing an ability to analyze the features of a graphic and its impact on comprehension can inform strategies for and selection of instructional methods.

Graphics are everywhere, and, in the classroom, they are a prominent means for representing information. Graphical literacy is vital to students' success in areas of the curriculum that are related to science, technology, engineering, and mathematics (STEM) as well as in standardized assessments of the knowledge of students in these curricular areas. Most students will have straightforward access to visual representations of STEM-area content (for instance, graphs, diagrams), and evidence suggests that strategically used graphics facilitate cognitive processing

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and retention (Lewalter, 2003; Sung & Mayer, 2012). Graphical representations, however, are not inherently accessible for students with visual impairments. These students will require specialized tools and alternate formats in order to access the data displayed in visual graphics. Those students with visual access to print may require the use of a low vision device or enlargement, while those with visual impairments without visual access to print will require that the information be displayed in tactile format. These specialized requirements translate into a set of unique challenges for students with visual impairments when accessing information displayed in visual graphics (Beck-Winchatz & Riccobono, 2008).

In the kindergarten through 12th grade (K-12) education system, these challenges are addressed by teachers of students with visual impairments, who provide the tools and instruction needed to mitigate the impact of vision loss on students' access to graphical information (Rosenblum & Smith, 2012). These teachers are uniquely positioned to comment on the challenges faced by students, since they may be responsible for producing adapted graphical materials and alternate formats, as well as for instructing students in the use of these graphics (Sheppard & Aldrich, 2001). Existing research highlights several key challenges. Sheppard and Aldrich (2001) surveyed 24 teachers of students with visual impairments working in specialized or inclusive settings and noted that they faced a number of challenges in producing high-quality graphics, and in making those graphics meaningful to students via direct instruction. Interestingly, challenges related to instruction were not elicited by survey items, but were volunteered by the teachers of students with visual impairments. To support students' comprehension of graphical data, teachers related the graphic to authentic (that is, "real-life") materials, provided verbal descriptions, and involved students in the production of tactile graphics. Despite these initial findings, there has been little research addressing the instructional and environmental factors related to students' successful use of tactile graphics (Aldrich, 2008).

Zebehazy & Wilton (2014) conducted a survey to extend the work of Sheppard and Aldrich (2001) by examining teachers of students with visual impairments' perceptions of the quality and importance of graphical material used by students accessing print graphics as well as by those using tactile materials. Quantitative results of the 26 Likert scale questions included differences in the teachers' perceptions related to print versus tactile graphic use. The teachers indicated overall that general classroom instruction in the use of graphics was not sufficient, that their time was limited to directly teaching the use of graphics, and that many tactile graphics users were not able to use such graphics independently.

In addition to the demographic and Likert scale survey results reported in Zebehazy and Wilton (2014), five additional open-ended items were posed to the teachers of students with visual impairments in the present study. The use of

open-ended survey items is advantageous for a number of reasons. Since open-ended survey items do not require specific responses, these items impose fewer limits on the scope of participants' responses when compared with closed-ended items (Esses & Maio, 2002). When designed with intention within a questionnaire, open-ended questions can serve to add depth to the quantitative data, serve as verification to quantitative responses, or generate stories that add to the richness of interpretation (O'Cathain & Thomas, 2004). The study presented here reports the qualitative results of these five open-ended items. The items provided participants with the freedom to share diverse strategies and issues related to barriers faced by students when using graphics and to comment on factors that contribute to successful graphics use. The open-ended items allowed the teachers of students with visual impairments to enrich the survey dataset with insights from their practice as education professionals.

Method

Instrument

The researchers disseminated a survey to teachers of students with visual impairments about their practices and perceptions regarding the use of graphics, both tactile and print, by students with visual impairments. Instructional materials centers, specialized schools for students with visual impairments, and regional consultants sent the survey link to these teachers in their respective provinces and states in Canada and the United States. Along with a series of quantitative items (for detailed results, see Zebehazy & Wilton, 2014), the survey included the following five qualitative items that sought to provide further context to the main topics explored in the survey.

1. From your experience, what are some barriers to print-reading students with visual impairments effectively using visual graphics (pictures, graphs, maps, charts, and the like) in the classroom or on assessments? [Barriers for print graphic users]
2. From your experience, what are some barriers to braille-reading students with visual impairments using tactile materials for graphics (tactile pictures, maps, graphs, and charts)? [Barriers for tactile graphic users]
3. Please list some of the strategies that you teach students to use when engaging with tactile graphics. [Tactile graphic instructional strategies]
4. Think of one of your students with low vision who is successful in using graphical materials (charts, graphs, maps, and the like). What characteristics of that student or that student's environment or situation do you think contributed to his or her success? [Print graphic user success]
5. Think of a braille-reading student who is successful in using tactile materials for graphical information (charts, graphs, maps, and the like). What characteristics of that student or that student's environment or situation do you think contributed to their success? [Tactile graphic user success]

This article focuses on the results of the qualitative responses. The University of British Columbia ethics board approved this study.

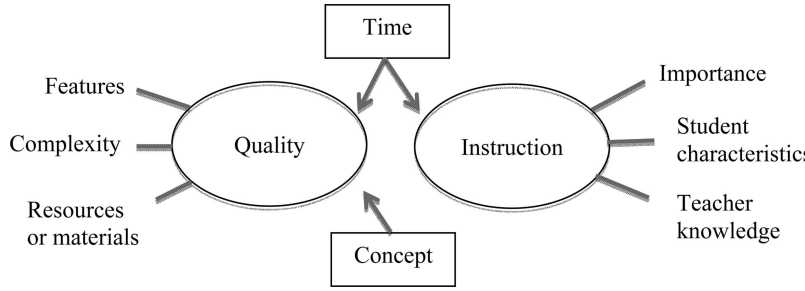

Figure 1. Thematic map of barriers for print graphic use.

Demographics and response rate

Three hundred and six teachers of students with visual impairments responded to the survey in whole or in part. Responses came from eight Canadian Provinces or Territories (15%; $n = 47$) and 37 U.S. states (81%; $n = 248$), and 11 respondents (4%) did not indicate their location. Ninety-four percent indicated that they have served at least one student who used tactile graphics in their career. The majority of respondents were itinerant teachers (66%, $n = 203$), followed by teachers at specialized schools (12%, $n = 38$), and resource room teachers (8%, $n = 25$). The remaining respondents indicated other settings or did not answer the question. Half of the respondents ($n = 152$) indicated that they worked exclusively in larger communities (that is, large cities, suburbs, or both). Thirty-four percent of the respondents ($n = 104$) indicated that they worked in smaller communities (that is, a town or village, rural or remote), and the remaining respondents said they worked in both smaller and larger communities. Of the 306 respondents, the response rate to each qualitative item ranged from 56% to 66%.

Analysis

The researchers conducted a thematic analysis of participants' responses to qualitative items in the online survey. Thematic analysis is a "method for identifying, analyzing and reporting patterns (themes) within data" (Braun & Clarke, 2006, p. 79). Patterns in the data were identified inductively following the phases for thematic analysis outlined by Braun and Clarke (2006). The process first included the researchers individually familiarizing themselves with the data and making initial notes on emerging patterns, applying codes to the participants' responses, and collating those codes into potential themes. Then, the researchers collectively reviewed the themes and checked the consistency of results, resolving any discrepancies in coding to achieve consensus. Each main theme was given structure by determining corresponding subthemes, which form the basis for the interpretation and discussion that follow.

Results

Barriers for print graphic and tactile graphic users

Figures 1 and 2 represent the thematic maps that emerged from the analysis of the responses to qualitative items 1 and 2, and form the basis of a comparison between the types of barriers cited by respondents for print versus tactile graphics users. For both types of graphics, two

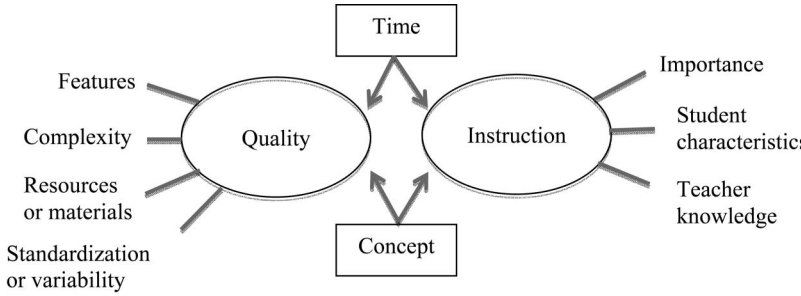

Figure 2. Thematic map of barriers for tactile graphic use.

global themes were evident: quality and instruction. Within those global themes, similar subthemes emerged, and one additional subtheme became evident for tactile graphics. Under quality, print and tactile graphic responses both referred to features that inhibit understanding or access (for instance, size of the graphics and texture quality), the issue of complexity or clutter (for instance, too many items on the page, density of information), and the availability or resources or materials (for instance, time to enlarge, access to tools). The additional subtheme for tactile graphics that was not evident for print graphics was standardization or variability (for instance, different production methods).

In instruction, common barriers for both print and tactile graphics were the subthemes of importance of instruction (for instance, previewing, direct instruction), characteristics of students (for instance, level of functional vision, motivation) and knowledge of teachers (for instance, awareness of classroom teachers, confidence of teachers of students with visual impairments). Time and concept were ideas that were linked under several subthemes for both modes of graphics and were therefore extracted in the thematic maps (see Figures 1 and 2) to better illustrate the interaction of these two themes. In other words, the interpretations of several subthemes were partially dependent on the ideas of time and concept. As noted in the figures, the interaction of concept with instruction (that is, students not having the conceptual background to understand graphics) for print graphics was not as evident as it was for tactile graphics.

Although the themes and subthemes mirrored each other, there were distinct differences in the details on which respondents focused under each of the subthemes for print and tactile graphics. For example, for importance of instruction respondents more often focused on the importance of previewing print graphics with students or allowing students time to preview graphics and less often on the need for providing direct instruction to students on how to interpret graphics. For tactile graphics, however, responses were more focused on the need to provide direct instruction. In the area of teacher knowledge, specific incidents for print graphics focused more on the classroom teacher and support staff members; whereas for tactile graphics there was also a focus on the level of knowledge in teaching graphics of teachers of students with visual impairments. Table 1 displays representative incidents that highlight the

Table 1
Representative incidents of subthemes for print graphic and tactile graphic barriers.

Subthemes	Print graphics	Tactile graphics
Quality Features	Key terms*: Size, color, contrast, concept* ● Poorly copied from color to black and white ● The graphic usually consumes multiple pages to get everything on it; the questions end up being on separate pages ● Even if the materials are enlarged, sometimes the detail is so small that it still can't be distinguished and is confusing to the student ● Modifications are not always appropriate or size causes misunderstanding of concept	Key terms*: Part to whole, raised line or symbol, texture, concept* ● Lines and symbols are either not clearly marked or not raised enough; lacks sufficient relief for easy distinguishing of features ● A braille reader has to skim the entire tactile graphic to get an overview and cannot always understand the meaning of different line widths, dots, etc., without some assistance from the instructor ● Takes a long time to process and feel out the graphic
Complexity or clutter	Key terms*: background*, *details*, *clutter*, *concept* ● Visual clutter in foreground or background is an added confusion ● Too much visual clutter—just making diagrams larger does not help a child who needs a simple, uncluttered environment ● At times the graphics are too complicated or detailed for the child to understand the concept	Key terms*: density*, *clutter*, *space*, *concept* ● Many tactile graphics are too cluttered and have too many different kinds of information to decipher; not enough space is given to adequately outline the graphic illustration ● Information may need to be broken down into smaller sections or multiple graphics to cover the same information presented in the print graphic ● Maps are usually too busy for braille-reading students
Resources or materials	Key terms*: time*, *access*, *tools*, *adaptation* ● The time it takes to create them and actually getting the materials ahead of time from classroom teachers so they can be adapted ● The student must have adequate magnification tools, large print, and lighting available ● There is no attention to or time to adapt materials used in the regular classroom ● Regular classroom teachers do not understand the importance of clear copies and enlargements	Key terms*: time*, *availability* ● Receiving materials on time (same time as their peers) ● Materials are presented too late for timely transcription or modification ● If they are missing or done poorly in a textbook, there may not be enough time to produce a good graphic when needed ● Prepared materials are not always available; unavailable except on statewide or national assessments
Standardization or variability	N/A	Key terms*: formats*, *rules*, *assessments* ● Tactile graphics try too hard to comply with the print version, which can be very confusing for tactile users ● Graphics can be transcribed in so many ways that it often takes a student a few minutes to figure out the setup of the tactile graphic before they can begin to process the concept ● There are no uniformity or specific formatting rules like there are with braille and Nemeth ● Everyone seems to make the graphics differently

(cont.)

Table 1
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Subthemes	Print graphics	Tactile graphics
Instruction		
Importance	Key terms*: preview, preteach*, *time*, *learning* ● Adequate classroom time to view ● Need to practice with students before they have to use them in the classroom or on assessments ● Students don't have enough time during the day to learn how to use visual graphics	Key terms*: direct instruction*, *early exposure or intervention*, *teacher of students with visual impairments*, *concept*, *time* ● When students have not been exposed to tactile graphics at an early age they have a tough time using the graphics; it tends to be a step-by-step process to teach them how to interpret the graphics ● Students may not get the amount of direct teaching time to allow them to become proficient ● Students with limited access to direct instruction from a qualified teacher of students with visual impairments may be deficient in instruction and use of tactile graphics.
Student characteristics	Key terms*: low vision aids*, *willingness*, *functional vision*, *time* ● People make the assumption that because they can see it, they can understand it in the same way as a person without a visual impairment ● Students with impaired color vision find it difficult to interpret graphics; severely restricted field of vision makes it difficult ● Students get discouraged if visual graphics aren't large enough to read comfortably ● Students' preferred low vision aid works well for text but not for graphics; some students refuse to use low vision aids ● Can't use graphics quickly and easily	Key terms*: conceptual development*, *additional disabilities*, *time* ● Student has to have excellent concept development to follow tactile graphics ● Many blind students have other disabilities, such as learning disabilities, which hinder reading charts and graphs because they confuse right and left and sometimes even up and down ● Congenitally blind students need to have conceptual and positional knowledge before they can begin to understand a tactile graphic ● A blind student sees from the parts to the whole; it takes a long time to mentally integrate the details into something meaningful
Teacher knowledge	Key terms*: classroom teacher*, *assumptions*, *training* ● Support staff in the classroom do not always remember or understand how to present the information to the student, or feel rushed in keeping up ● Often a new form of visual graphic is used by classroom teachers without preteaching the format ● If the student is a visual learner, regular education teachers assume they are accessing everything presented visually	Key terms*: comfort*, *training*, *value*, *teacher of students with visual impairments*, *classroom teacher* ● Some teachers of students with visual impairments believe that if they don't have O&M training they are not responsible for this skill or they don't feel comfortable enough with their knowledge base ● Lots of emphasis on braille instruction but not tactile instruction in M.Ed. teachers' programs ● Teacher of the visually impaired doesn't know how to teach it ● Teachers who do not understand the value or importance of tactile graphics in understanding content and concepts ● Classroom teachers being unable to interpret the graphic was a huge difficulty

meaning of the themes and subthemes, as well as the differences in how respondents focused on each of the subthemes between print and tactile graphics.

Instructional strategies for tactile graphics

Responses to open-ended item 3 could be grouped into four main themes: materials, organized exploration, procedure, and supportive techniques. For organized exploration, although teachers suggested variations in exploration techniques depending on the type of graphic, a common attribute of the responses was the necessity to use both hands while exploring. For procedure, most respondents indicated a general analytic progression moving from textual information to exploring the whole scope of the graphic to focusing on the details. Table 2 lists specific examples of the strategy suggestions provided by the respondents under each theme.

Success of print graphic and tactile graphic users

Qualitative response items 4 and 5 focused on the factors that respondents felt contributed to their students being successful print or tactile graphic readers. It is interesting to note that for the question on the success of tactile graphic users, several respondents indicated that they did not have a student who was able to use tactile graphics well or had not had a successful student in a long time. For both graphic modes, characteristics of the individual, the team, the materials, and the level of experience and exposure were highlighted as important and emerged as the main themes for success. The following profiles describe the successful student based on the most prevalent subthemes discovered under each of these main themes. The profiles are not meant to purport that students who do not have all of these factors cannot be successful, but should be used as a model for determining areas in which additional support can help increase students' successes with graphics.

Profile of a successful print graphic user

The successful print graphic user is self-motivated and curious, is able to communicate and ask questions, and is a good self-advocate. She or he has the cognitive ability to generalize and has well-developed prior knowledge, basic concepts, and spatial abilities. The student has had early intervention and early exposure to graphics, and tends to have more functional vision or uses residual vision well. The student is proficient in using a variety of low vision devices (for instance, magnifiers, and CCTV) and has had opportunities for repeated practice. She or he has the skills to analyze and break down graphics into their parts and can scan systematically. The student's team is supportive, follows through with the instructions of the teacher of students with visual impairments, and is committed to inclusive practices. Parents are engaged. The classroom teacher's style is effective, and the teacher is willing to adapt and take responsibility for the student's learning. Time is given to explore, and materials are of good quality (for instance, in terms of contrast, color, and appropriate size). Carefully worded descriptions are provided when needed. The teacher of students with visual impairments has enough

Table 2
Strategies for teaching tactile graphics: themes and examples.

Themes	Examples
Materials	• Use manipulatives
	• Pair with 3-D models or real objects
	• Wikki Sticks to create or highlight lines
	• American Printing House for the Blind (APH) quick-draw paper
	• Games
	• APH *Squid Tactile Activities* magazine series
	• APH tactile graphics book
	• Cookie sheet with magnets to mark points on a graphic
	• APH tactile stickers to make own graphic
	• Make graphs on brailler
Organized exploration	• Use both hands to explore
	• Open hands, not just fingers
	• Use hands independently
	• Use one hand to anchor a point and the other to follow a line
	• Establish a starting point that makes sense for the graphic
	• Systematically explore: horizontally or vertically, perimeter first
	• Scan clockwise
	• Use quadrants
Procedure	• Teach a procedure to follow
	• Read the related questions first
	• Read description and titles or captions first, then explore key or legend, then scan whole graphic for the "big picture" and size and scope, then analyze details
	• Determine axes and type of graph first
Supportive techniques	• Begin early
	• Use prior knowledge
	• Work from simple to complex; start large scale and move to smaller scale; real object to 3-D model to 2-D representation
	• Teach questioning strategies; discuss and question
	• Have student think out loud while exploring the graphic and match language to what student is explaining
	• Work on problem-solving skills
	• Teach types of graphs and common features
	• Teach to look for patterns; use prediction skills
	• Compare new graphic to known graphic types; verbalize similarities and differences between graphics; sort or categorize by attributes
	• Become familiar with typical symbols; work on texture and line discrimination
	• Teach following and tracing skills
	• Make own graphics or take part in production
	• Provide verbal explanation of layout and features
	• Relate compass directions to the graphic
	• Hand-over and under-hand modeling
	• Repeated practice
	• Work on tactile graphics as a warm-up activity
	• Use ruler to help line up bars with numbers
	• Ask for help
	• Go over with a black marker if student has residual vision

time to provide appropriate and sufficient direct instruction.

Profile of a successful tactile graphic user

The successful tactile graphic user is an active learner. She or he is intelligent, determined, and curious, wants to be independent, and asks questions. The student has good braille literacy and tactile discrimination; and good O&M, spatial, visualization, and problem-solving skills. The student has had early intervention, early and consistent exposure to graphics, and opportunities to make his or her own graphics. The student also has the basic concepts and background knowledge needed to understand graphics. The student's educational team is flexible, supportive, and encouraging, and has high expectations. A paraprofessional, if present, has been trained in how best to support the student. The classroom teacher is willing to assist and is committed to inclusive practices. The student's parents are involved, and the teacher of students with visual impairments has been able to provide appropriate and sufficient direct instruction. The student is given enough time to explore, analyze, and process graphics. Materials are of a high quality, have consistency in presentation, are simple enough to understand, and contain effective keys. Descriptions are provided either verbally when needed or in written format.

Discussion

This study analyzed teachers' qualitative responses to survey items about the barriers, strategies, and characteristics for success in using print and tactile graphics. Main themes that emerged from the answers included focus on instruction, materials and their quality, individual characteristics, and team dynamics. The themes of time and concept emerged as ideas that interacted broadly with other themes and subthemes.

Interaction of time

Time emerged as a significant determining factor related to whether a student would be successful or would encounter difficulties in accessing and effectively using graphics. This concept of time was also identified in the quantitative results (Zebehazy & Wilton, 2014), with teachers indicating a lack of time to teach graphics and to produce quality materials. In the qualitative results about success, time emerges as an important condition for access. For example, teachers indicated that the successful tactile graphic user had opportunities to make their own graphics and also identified making graphics as a teaching strategy. Yet, in the quantitative data, which reports the actuality of teachers of students with visual impairments' situations, few indicated that students made their own graphics. This discrepancy between reality and the ideal has implications for service delivery as it relates to graphics instruction. And as seen in the profiles of successful graphics users, positive dynamics of the educational team can mitigate the impact of time.

Interaction of concept

Similar to time, concept emerged as an interacting theme in several areas. Most notable was the consistent indication by teachers of students with visual impairments that students needed the basic concepts and

background knowledge to be able to approach and use graphics effectively. Respondents related the development of concepts with the necessity of early intervention and early exposure. The importance of early exposure was also a result in the quantitative data (Zebehazy & Wilton, 2014). The idea of promoting concepts is further seen in the profiles of the successful student in terms of the various areas of the expanded core curriculum (ECC) that were identified as characteristics for success. Although the profiles do not represent any one student but rather a composite of the most prevalent student and environmental characteristics, the importance of ECC skills in promoting conceptual understanding of graphics is evident. Distinct ECC skills were associated with a particular graphic mode. For example, the ability of print graphic students to use a variety of low vision devices was commonly associated with success; whereas, for tactile graphic users, good braille literacy, tactual discrimination, and orientation and mobility skills were highlighted by the respondents. Given these specific skills, one common ECC domain for both print graphic and tactile graphic users is sensory efficiency skills. This finding serves as an important example of how adequate instruction in domains of the ECC connects directly to students' access to the academic curriculum.

Implications for practitioners and future research

The results from this study highlight several implications for practitioners, personnel preparation programs, and future research.

1. Because graphics are such an integral part of the general education environment, both print graphic and tactile graphic users need to be assessed for their current skill level in using such graphics, and the amount of direct instruction required needs to be considered.
2. Teachers of students with visual impairments need to continue to advocate for service levels that are based on students' needs, so that adequate instruction can be provided in the area of graphic literacy.
3. Student access to early intervention is important, and exposure to skills that will lead to understanding graphics encountered in the academic curriculum should start early.
4. Development of collaborative educational teams with whom the teacher of students with visual impairments works can be key to successful integration of graphics use in the classroom.
5. Personnel preparation programs should consider additional instruction for preservice teachers of students with visual impairments in the area of teaching the use of tactile and print graphics.
6. As a field, production of tactile graphics should continue to strive toward meeting standards for quality graphics such as through the use of the Braille Authority of North America (2010) guidelines.
7. Future research should investigate the graphic reading skills that students who are successful are using for different types of graphical information.

Limitations of the study

As with all qualitative research, the researchers recognize that their own points of view affect the interpretation of the data. In this case, it is important for the

reader to know that both researchers are teachers of students with visual impairments and therefore have approached interpretation of the results through that lens. Also, although the geographic sampling of teachers of students with visual impairments was comprehensive, it is still important to acknowledge that the results do not represent all areas and regions.

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Kim T. Zebehazy, Ph.D., *assistant professor, Department of Educational and Counseling Psychology, and Special Education, University of British Columbia, 2125 Main Mall, Vancouver, BC, V6T 1Z4, Canada; e-mail: <kim.zebehazy@ubc.ca>.*
Adam P. Wilton, M.A., *doctoral candidate, Department of Educational and Counseling Psychology, and Special Education, University of British Columbia, Vancouver, BC, Canada; e-mail: <awilton@interchange.ubc.ca>.*

