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Pre-Algebra Students' Performance Locating and Interpreting Data in Graphs and Maps

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Abstract

Introduction: Developing graphicacy skills is important for students with visual impairments if they are to succeed in science, technology, engineering, and mathematics (STEM) content. Teachers of students with visual impairments report that they lack resources to use in teaching students graphicacy skills.

Methods: Forty-one students with visual impairments in grades 5–10 completed a pretest, intervention, and posttest designed to evaluate their skills locating and interpreting graphical data. Videos of the pre- and posttests were scored using a researcher developed instrument.

Results: Following intervention, there was a significant difference in students' ability to use descriptors and mathematical terms when exploring graphs and a map. Students answered significantly more questions correctly from pre- to posttest.

Discussion: Students who receive direct instruction in how to locate and interpret data in graphs and maps can improve their level of independence in STEM classes. Use of an intervention that targets the development of graphicacy skills has been found to be effective.

Implications for practitioners: More research is needed to determine effective hand strategies students should use when exploring different types of graphics.

Researchers have long recognized that understanding information presented in graphical formats is an important component of mathematical success (Aldrich, et al., 2003; Friel et al., 2001; Rosenblum & Herzberg, 2015). Students who have proficiency in mathematics are more likely to be successful in science, technology, engineering, and mathematics (STEM) careers. Success with graphics involves developing a set of skills which includes representing data in different ways (e.g., from line

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graph to bar graph), locating and interpreting information, and demonstrating extrapolation/ interpolation (Friel et al., 2001).

The National Council of Teachers of Mathematics (2000) recommended processes standards, which include interpreting and representing data throughout all content standards and grade levels. Smith and Smothers (2012) highlighted the representational skills of data at each grade band that students need in order to achieve graphicacy; that is the ability to use data to answer questions and to display data to represent information gathered. They noted, "… proficiency in data analysis is a critical and foundational skill that all students, including those with visual impairments, should have the opportunity to learn and use (p. 544). Fewer students with visual impairments (referred to as students for the remainder of the article) tend to choose STEM careers (McDonnall et al., 2009; National Science Foundation, Division of Science Resource Statistics, 2009), which may be an indication for improved accessibility and graphicacy skill development to spark interest in students about STEM fields.

Within instructional material, there are a wide array of graphical images. In their analysis of three mathematics textbooks (grades 5, 8, and 11), Wall Emerson and Anderson (2018) reported the most frequently used graphic categories were tables, scatter or line graphs, and equations. Bar graphs, pie (circle) graphs, maps, and question specific images were also included in the textbooks. While these images may be included in an accessible format, it does not guarantee that the student who is visually impaired will accurately and efficiently access the image to gather and interpret information needed to succeed with the content (Beal & Rosenblum, 2015, 2018; Rosenblum & Herzberg, 2015).

In fact, researchers have found that students are challenged to read and interpret information presented in different graphical formats (Authors 1, 2018; Rosenblum & Herzberg, 2015; Smith & Smothers, 2012; Wall Emerson & Anderson, 2018; Zebehazy & Wilton, 2014a, 2014c). The abilities of students in the area of mathematics has been the focus of work by Beal and Rosenblum (2015, 2018), initially in building pre-algebra level students' abilities to solve math word problems, and later in designing curriculum that supports students in increasing their graphics literacy skills. Beal and Rosenblum (2015) had a sample of 43 students in grades 4 to 10 and found that students required teacher assistance more often when solving math problems when information was in graphics. Only five of 23 students who read braille in the Beal and Rosenblum (2015) study correctly and independently answered all 16 problems that relied on a graphic. Assistance was needed from the teacher for at least one of the 16 problems for the other 18 students who read braille. Nine of the 28 print readers worked without teacher assistance on all 16 of the word problems that used graphics.

Zebehazy and Wilton (2014a) surveyed 306 teachers of students with visual impairments (referred to as teachers for the remainder of the article) and found that 80% believed their students lacked skills to use graphics independently. The most common reason cited for this challenge was lack of explicit instruction for the students in how to use graphics efficiently. This finding coincides with Zebehazy and Wilton's (2014c) finding that students reported that they were not able to keep up with sighted peers in the classroom when using graphics.

Despite teachers recognizing a need for more explicit instruction for students to learn to read graphics, in the Zebehazy and Wilton (2014a, 2014b) survey, the teachers reported feeling under prepared to specifically teach graphic reading skills. They welcomed a curriculum to support them in building their students' graphics literacy skills. The *Guidelines and Standards for Tactile Graphics* (Braille Authority of North America, 2010) gives information to users on how to prepare tactile graphics for those who read braille. There does not currently exist guidelines or curricula that guide teachers in how to actually teach their students to locate and interpret information in graphics. The field also lacks guidelines on preparing graphics for print readers who have low vision. Students' development of graphicacy skills, which could provide richer access to STEM materials, cannot be left to chance.

This study examined the effectiveness of a new curriculum designed to build graphicacy skills of students with visual impairments at the pre-algebra level. The following research questions guided the study.

Following the intervention, do students:

(1). increase their ability to use descriptors and mathematical terms?
(2). increase their ability to locate data and to use two pieces of data to complete a basic computation question?
(3). improve in their efficiency and competence using graphics to obtain information?

Method

The University of Arizona Institutional Review Board approved the study. All participants provided informed consent.

Curriculum

A group of teachers of students with visual impairments, three of whom were nationally recognized experts in mathematics, and one an expert in building students' questioning skills, developed the curriculum. The curriculum contained a teacher notebook, student iPad app with 10 instructional units at the 6th–7th grade level, and an accessible book of graphics (print, braille) that were also presented in the units on the iPad. The teacher curriculum notebook provided print copies of all the iPad screens, correct answers to questions, graphics used in the units in both print and SimBraille, a list of vocabulary words and terms, and suggested extension activities. See Table 1 for a list of units. Units used environmental science content about endangered or invasive species and contained four graphics.

Each unit began with a brief introduction to the focus animal followed by instruction and practice opportunities. First, students used Graphic 1 to complete *Getting Started*, containing two open-ended questions in which they interpreted the targeted graphic. With Graphics 1 and 2, students completed the *Warm Up* consisting of 10 multiple choice questions with embedded instruction and suggested strategies. For example, in the coordinate plane unit (see Figure 1), on a question about finding a specific coordinate, the strategy component of the question stated: "On the key for GZ1, find the symbol for the lions' den. Find the lions' den on the coordinate plane. So that you don't miss it, begin at the top of the coordinate plane and use your hands or eyes to scan across the page, then move down and scan again…"

After the *Warm Up,* students completed *Set A* using Graphic 3 and *Set B* using Graphic 4. Four questions in each set required the student to locate a specific piece of data and the fifth question required the student to locate two pieces of data and complete a basic math computation. The final open-ended question required students to interpret the graphic or make a prediction. Following *Set B*, students rated their skills with the target graphic on a 3-point Likert scale and then answered two open-ended questions reflecting on their ability with the graphic and the strategies that worked best for them.

Intervention

Teachers completed a 1.5 hour online training to familiarize themselves with the project background, curricular materials, and intervention. The curriculum was the basis for the intervention. During the *Warm-Up,* teachers were allowed to assist students and provide additional instruction. For *Sets A* and *B*, teachers were asked to refrain from providing assistance unless the student requested it or missed several answers, indicating a need for re-teaching. Students worked through the units during the school year based on teacher/student schedules.

Test development

A pre- and posttest was developed to measure student skill level. Two parallel versions were

Table 1. Description of unit and test graphics.

Unit	Description	Associated pre- and posttest graphic
Single bar graph	Two had values on the y-axis and categories on the x-axis and two had values on the x-axis and categories on the y-axis.	NA
Double bar graph	Same as above. Each bar graph had a key.	Title, key with two categories, a y-axis with 8 values, and an x-axis with four categories
Line graph	One had a single line and three had two lines with a key.	Title, key with two categories, a y-axis with 14 values, and x-axis with four categories
Circle graph	Two had labels next to each section and two had keys that used color and texture to distinguish sections.	NA
Venn diagram	One had two circles, one had three circles, and two had four circles (one with a key using color and texture, one with a key using two letter abbreviations).	Title, three categories (distinguishable by both color and texture) containing numbers with labels outside the circles
Coordinate plane, quadrant I	All four had positive values on the x-axis and y-axis. Each had a key to identify the types of points.	NA
Coordinate plane, 4 quadrants	All four had positive and negative values on the x-axis and y-axis. Each had a key to identify points (all four) as well as regions (for three).	Four quadrants, 5 points with 1–2 points per quadrant. Values on the x-axis and y-axis ranged from −6 to 6.
Box plot	Two were horizontal and two were vertical, presented as a single box plot or two on one sheet.	Title, values ranged from 0 to 100 in increments of 10, visually and tactually distinct box, whiskers, and quartile points
Data table	Each contained an incomplete data table and one of four graphic types: bar, line, Venn, or four quadrant coordinate plane. The Venn diagram did not have a key. The other three graphics had a key.	NA
Map	Two maps were regions in Africa, one was a map of an island, and the other was a map of streets in a city. Each map contained a key.	Title, key in two columns with 6 items that included lines (e.g., bike path) and points (e.g., waterfall). Four towns, represented by a closed circle, were labeled on the map.

NA = not applicable

developed, each with six graphics (see Table 1). Both versions had the same layout of graphics but with variation in labels, numbers, titles, and keys. Questions mirrored those used in the curriculum.

Test administration

Each pre- and posttest was administered by the first author and video recorded using Zoom. Administration lasted from 20 to 40 minutes based on student performance and speed. Pretests occurred between October and February based on study enrollment. Posttests occurred between March and June. Prior to beginning the pretest, the student completed two warm-up activities to acquaint the student and researcher, ensure the teacher understood their role, and allow the researcher to check that the video was recording properly. In the first activity, the student was provided a 5×5 grid of shapes and asked to locate a specific shape and in the second the student followed a maze.

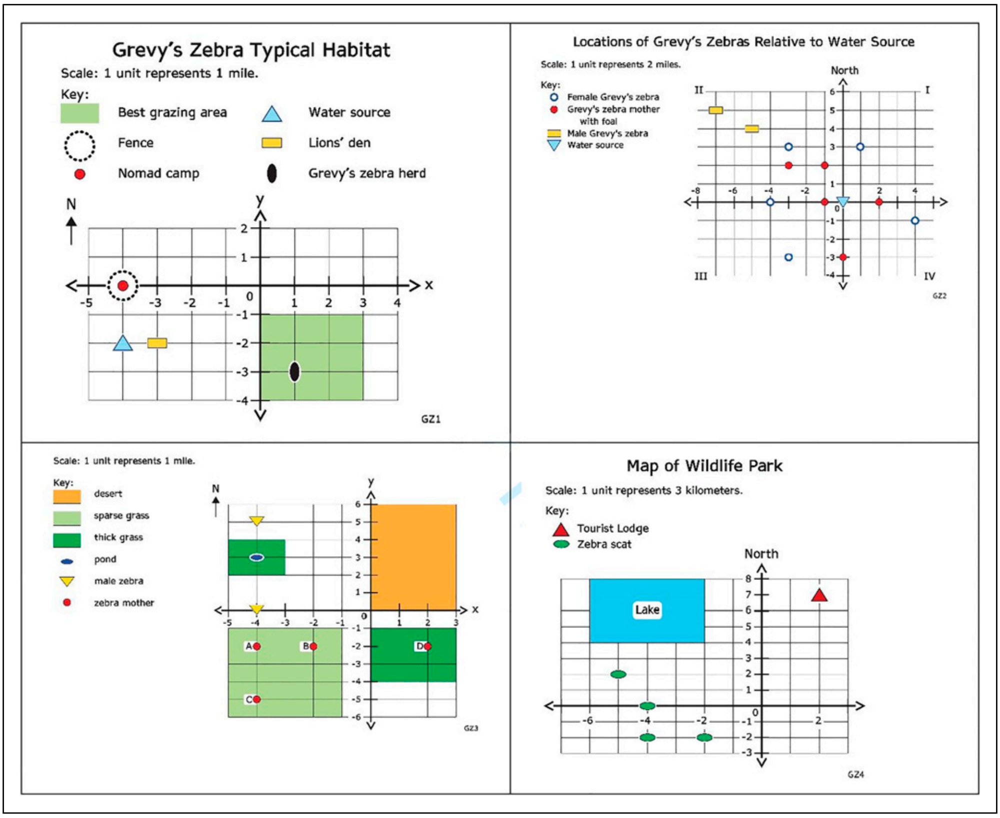

Figure 1. Sample graphic for coordinate plane 2: Grevy's Zebra.

Order of presentation for the pretest was (a) bar graph, (b) line graph, (c) Venn diagram, (d) coordinate plane, (e) box plot, and (f) map. For the posttest the order was (a) line graph, (b) Venn diagram, (c) coordinate plane, (d) map, (e) box plot, and (f) bar graph. The version of the test each student received for pre and post was randomly assigned across all participants.

The researcher used the same process for each graphic, the researcher: (1) had the teacher place the sheet containing the graphic in front of the student; (2) asked the student to describe the graphic and name the type (e.g., bar graph); (3) asked if there was anything else the student wanted to share about the graphic; and (4) asked four questions about the graphic. If the student did not answer the first two questions correctly, the researcher moved to the next graphic. Students did not receive feedback about their answers and were assured the purpose of the test was for research, and their responses were not affecting their school performance.

Scoring development

The first and second authors, the three project consultants, and two raters developed the scoring instrument for the pre- and posttests. All were certified teachers of students with visual impairments with extensive knowledge in the area of braille literacy and STEM. Over 6 months, they developed and refined the scoring instrument. After each iteration, each used the instrument to score a graphic with video clips from student pretests. They then met and discussed their experiences, compared ratings, and refined the questions on the scoring instrument until the final version was completed. A copy is available from the first author upon request. Pretest videos used for development were officially scored once the instrument was finalized.

To ensure that the first author and two raters had inter-rater reliability, two videos were prepared of an adult completing the test. Together the three raters scored one video and then each scored the second independently. Inter-rater reliability was .95. The three raters discussed the items for which agreement was not reached and came to consensus prior to scoring student videos.

Scoring of tests

For each student, one rater scored the pretest and the other the posttest. The first author scored 20% of the tests as a reliability check. Inter-rater reliability was determined using percentage agreement for each score by summing the total number of agreements for each scale (e.g., total items correct, graphics efficiency) and dividing by the total number of agreements and disagreements. The average agreement for items correctly identified was 97.7%. Across the six graph types, the average agreement for efficiency was 71.5%, ranging from 52% for bar graph to 95.7% for line graph.

To score a video, the rater indicated if the student named the graphic correctly, what descriptors on the checklist the student stated (e.g., there is a dashed line), and what mathematical terms the student used (e.g., key, x-axis). The rater then answered the question, "Did the student interpret any of the information on the graphic (e.g., The lines intersect in 2015)?" describing any interpretation provided.

For each of the four questions for the graphic, the rater recorded if the student (a) gave the correct answer; (b) went back and changed the answer; and (c) the level of efficiency demonstrated in obtaining the answer. Raters judged the student's level of efficiency based on four levels, the student: (a) did not understand the questions, (b) had no or very little systematic process to get information, (c) had a systematic method to get information, but answered incorrectly, and (d) had a systematic method to get information and answered correctly. Systematic method was defined as purposeful and organized use of hands, eyes, or hand-eye movements to locate information.

After the fourth question, the rater made a subjective judgment of the student's overall skill level: (a) little if any skill, (b) beginning (i.e., understands basic components of graphic but does not get correct information quickly, efficiently, accurately, or consistently), (c) intermediate (i.e., understands basic components of graphic and somewhat quickly, efficiently, accurately, or consistently gets the correct information most of the time. The student may or may not have done an overall viewing of the graphic), and (d) high (i.e., understands the basic components of the graphic, did an overall viewing of the graphic, and obtained information quickly, efficiently, accurately, and consistently).

Recruitment

Recruitment occurred between April 2018 and January 2019. Advertisement of the study occurred on listservs and social media pages in the field of visual impairment. Announcements were made at conferences. Eligible students, based on teacher report, had to: (1) be working at the 6^{th}-7th grade math level, (2) have access to and be proficient using an iPad (e.g., use VoiceOver, swipe between screens), and (3) receive services from a teacher once a week minimum. Teachers had to be willing to complete all study activities.

Results

The pretest, 8–10 instructional units, and posttest were completed by 41 students. One student's pretest and another student's posttest were not recorded. These two students were excluded from some analyses. Thirty-three (80%) students completed 10 instructional units, 6 (15%) completed 9 units, and 2 (5%) completed 8 units.

Participants

Demographic data for the students is in Table 2. Four of the students attended specialized schools and the remainder received itinerant

Table 2. Student demographic data.

Variable	N	Percent
Gender (*n* = 41)		
Female	21	51.2
Male	20	48.8
Grade (*n* = 41)		
Fifth	11	26.8
Sixth	8	19.5
Seventh	13	31.7
Eighth	4	9.8
Ninth	2	4.9
Tenth	3	7.3
Reading medium (*n* = 41)		
Braille	33	80.5
Print	8	19.5
Ethnicity (*n* = 40)		
African American	3	7.5
Asian	1	2.5
Caucasian	24	60
Hispanic/Latino	4	10
Multi-Racial	3	7.5
Other	5	12.5
Number of units completed (*n* = 41)		
8	2	4.9
9	6	14.6
10	33	80.5

services. Students were assigned to a grade group: (a) Group 1, 5th grade; (b) Group 2, 6th and 7th grade; and (c) Group 3, 8th, 9th, and 10th grades. As content was at the 6th and 7th grade level, the grade groups acknowledged students below, on, and above grade level. The mean time in the intervention was 4.5 months with the range being 3–7 months.

Descriptors and mathematical terms

For each graphic, the rater had checklists of possible descriptors and specific mathematical terms the student might say. Descriptors had no mathematical meaning and mathematical terms were terms used in pre-algebra math instruction. An example of a descriptor for the line graph was if the student said, "There's a line at the bottom." An example of a mathematical term was if the student said "x-axis or horizontal axis" when touching or pointing to the x-axis.

Table 3 reports the means, *SD*s, and range for the descriptors and mathematical terms used by the students in the pre- and posttests. For descriptors, significant differences were found for five of the six graphics and the total from pre- to posttest. Students used significantly more mathematical terms for all six of the graphics and the total from pre- to posttest.

Correct answers

There were five possible correct answers for each graphic: (1) name the type of graphic (1 question), (2) locate an item on the graphic (3 questions), (3) use simple computation to compute an answer using two pieces of data from the graphic (1 question). The mean number of correct answers, *SD*s, and ranges for the pre- and posttest are presented in Table 3. Statistically significant differences were found for four of the six graphic types and total when comparing students' correct answers from pre- to posttest. There were no significant differences in student performance from pre- to posttest for Venn diagrams and box plots.

Efficiency

After scoring each question, raters assigned an efficiency rating based on how systematic the student was in locating the information based on a 4-point Likert scale (see Scoring section). For each graphic type, significant changes were observed from pre- to posttest (see Table 4). The negative Z scores indicated that posttest efficiency ratings were higher than pretest efficiency ratings.

Efficiency ratings were examined by grade group. For Groups 1 and 3 there were no significant differences for student efficiency for any of the graphics from pre- to posttest. For Group 2 significant differences between pre- and posttest were found for bar graphs and box plots.

Level of skill

Following the scoring of the student's performance for each graphic type, the raters

Table 3. Means, *SD*, range, and paired sample *t*-tests for descriptors, mathematical terms, and correct answers.

Variable		Number of items	Pretest *M*	Pretest *SD*	Pretest Range	Posttest *M*	Posttest *SD*	Posttest Range	*t*[a]	*p*
Descriptors	Bar graph	9	3.62	2.00	0–8	5.10	1.94	0–9	3.47	.001
	Line graph	9	3.50	2.25	0–9	4.95	1.56	2–8	3.71	.001
	Venn diagram	5	1.87	1.05	0–3	2.82	1.06	1–5	4.37	.000
	Coordinate plane	9	2.03	1.56	0–6	2.23	1.68	0–6	5.78	.566
	Box plot	7	2.05	1.41	0–5	3.08	1.35	0–5	3.59	.001
	Map	9	2.36	1.48	0–5	3.21	1.47	0–6	2.82	.008
	Total	49	15.41	7.54	2–27	21.38	6.71	7–33	4.17	.000
Terms	Bar graph	7	0.38	0.59	0–2	1.54	1.07	0–5	5.78	.000
	Line graph	11	0.62	0.88	0–3	1.64	1.31	0–5	4.23	.000
	Venn diagram	4	0.59	0.64	0–2	0.90	0.82	0–3	2.80	0.44
	Coordinate planes	11	0.82	1.17	0–4	2.05	1.43	0–5	4.31	.000
	Box plot	10	0.41	0.88	0–5	1.10	1.33	0–5	3.38	.002
	Map	6	0.64	0.71	0–2	1.03	0.78	0–3	2.31	0.27
	Total	49	3.46	2.43	0–8	8.26	3.13	3–22	8.24	.000
Correct answers	Bar graph	5	2.23	1.65	0–4	3.21	1.34	0–5	3.63	.001
	Line graph	5	1.79	1.47	0–4	2.74	1.33	0–5	3.77	.001
	Venn diagram	5	2.05	1.30	0–4	2.44	1.05	0–4	1.96	.058
	Coordinate plane	5	1.26	1.29	0–4	2.44	1.57	0–5	5.29	.000
	Box plot	5	1.41	0.99	0–4	1.69	1.15	0–4	1.54	.133
	Map	5	2.74	1.25	0–4	3.21	0.95	1–4	2.47	0.18
	Total	30	11.49	5.86	1–22	15.72	5.22	5–23	6.07	.000

[a]t-tests are for 39 students.

selected the student's overall level of skill using a 4-point Likert scale (see Scoring section). For each of the graphic types there was a significant difference between pre- and posttest scores in students' skill (see Table 4). The ratings for overall skill were examined by grade group. For Group 1 significant change were found for all graphic types. For Group 2 significant change were found for bar graph, coordinate plane, and box plots. For Group 3 significant change were found for box plots and maps.

Discussion

Descriptors and mathematical terms

Students increased their use of descriptors and mathematical terms following intervention. The results represent a spontaneous, unprompted increased use of students' descriptions and mathematical terms. While few students used more than half of the possible descriptors or mathematical terms listed on the checklists, this may be a result of students not being asked explicitly to do so. An increase in the use of mathematical terms, in particular, is a promising outcome of the intervention. Researchers and teachers need to examine carefully the way they word questions in order to ensure students have an optimal opportunity to demonstrate their knowledge. In addition, the need for special and general educators to collaborate in sharing information is recognized as important, especially as more special education students receive instruction in general education classrooms (Blanton et al., 2017). When a teacher of students with visual impairments lacks a math or science background, working with the general education teachers to learn terms, understand

Table 4. Wilcoxon signed ranks for changes in efficiency and skills by graphic type.

Graphic	Number of students	Z*	p
Bar graph			
Efficiency	28	−3.482	.000
Skills	38	−4.097	.000
Line graph			
Efficiency	17	−2.528	.011
Skills	39	−3.249	.001
Venn diagram			
Efficiency	27	−2.027	.004
Skills	39	−2.984	.003
Coordinate plane			
Efficiency	14	−1.996	.046
Skills	39	−4.468	.000
Box plot			
Efficiency	30	−2.035	.004
Skills	37	−4.361	.000
Map			
Efficiency	30	−2.035	.004
Skills	39	−3.720	.000

Note: Z-score is based on negative ranks.

explanations, and recognize the scope of instruction is imperative.

Correct answer

From pre- to posttest, students made significant gains in questions answered correctly. Though statistically significant, the actual changes in the number of questions students answered correctly were not as large as the researchers expected from the intervention. The largest change by any one student was an increase of seven questions answered correctly from pre- to posttest. One possible explanation for the smaller than expected change in the number of questions answered correctly is that the intervention did not provide enough practice for students to internalize the skills they were learning to demonstrate later. Teachers of students with visual impairments have cited frequency of engaging with graphics as an important aspect for students developing graphicacy (Zebehazy & Wilton, 2014b). Teachers of students with visual impairments' rating of how frequently students engage with graphics has also been recently found to be related to students' ability to answer questions about graphics (Zebehazy & Wilton, 2021). Since an average 4.5 months elapsed between the pre- and posttest students may not have recalled the skills they learned. Prior to the posttest, there was no review or practice of content introduced in the intervention. Posttests were also administered to more than half of the students within the last month of school, a time that is often busy and stressful for all.

Changes in efficiency and skills

Students who completed the intervention increased their efficiency and skills on most graphic types. For the three grade groups there was more variability in student skills for the different graphic types, potentially due to small numbers of students, especially for Groups 1 and 3. For Group 1 there was change in skills from the pre- to posttest for all graphic types which is to be expected since the math content was above their grade level. Therefore, they were less likely to have prior experience with the graphic types. Further, absence of statistical significance for most of the graphs by grade group appears to be an artifact of the small sample sizes by group. When all students were combined, the change was significant, suggesting that the grade groups were not adequately powered to identify significant change, even when change was present. Similar to performance efficiency, students' skill level should continue to improve as they use the skills learned during the intervention in the general education curriculum. It should be noted that while efficiency improved for students, this was a subjective rating with more variability in reliability between scorers than desired by the authors. This study is one of the first to evaluate student efficiency and future studies need to examine how to better operationalize student behaviors.

Limitations

This study had limitations. Though the study was open to teachers and students in the United States and Canada, there were districts that did not grant permission to the researchers. The 41 students whose data were included may not be representative of the population of students with visual impairments. If a student completed 8, 9, or 10 instructional units, the student was considered to have completed the intervention. Some students who had only completed 8 or 9 units may have scored higher on the posttest had they completed 10 units. Some of the video or audio quality was poor which may have affected the raters' abilities to score the tests.

Efficiency ratings involved a subjective decision on the part of the rater and had low inter-rater reliability for bar graph, so should be interpreted with caution. Poor video quality may have contributed to the variability in efficiency ratings. The two raters were included in the development of the scoring instrument. Though only one graphic per student was used in the development process and scores were not kept, it is possible the raters were biased having seen some videos in the development of the scoring instrument. Further, had the students been specifically requested to use mathematical terms in their descriptions of the six graphics it is possible they would have used more mathematical terms. Ordering effect between the pre- and posttests results may have been present. We controlled against ordering confounds by using two different versions of the test. Further, upon review of change by graphic type, the growth was consistent for all but coordinate plane, with an average change of 28.2% (Min = 26.5, Max 37.2). With regards to the coordinate plane, the lack of change does not appear to be related to ordering as it was presented third in pre and fourth in post. Finally, the study was a within-subject, pre–post design. Although we identified effects, the design does not control against all potential confounds, particularly maturation. Therefore, although promising, the study needs to be replicated, ideally with a comparison group, to confirm the efficacy of the intervention.

Implications for practitioners

Students need ongoing opportunities beginning at a young age to build their graphicacy skills. Teachers need to be systematic in their approach to introducing and reinforcing graphicacy skills and should establish a method to monitor improvement in efficiency. Within instruction, students would benefit from opportunities to compare different layouts of graphic types, apply their knowledge of a graphic type to a new or novel layout, make predictions, and work on problem-solving. Use of a curriculum, such as the one used in this intervention, can support teachers to provide direct instruction and on-going opportunities.

Future research

There is research documenting efficient hand use of students reading braille (Wright et al., 2009), there is no body of literature related to student efficient hand use for reading braille graphics. Research is needed to examine if students need different skills for hand use efficiency when using different types of graphics. Students begin their exposure to graphics in early elementary school, therefore development of curricular materials for younger students can be used by teachers to begin to build their graphicacy skills.

Dr. Carole Beal, University of Florida (retired), was the primary investigator for the AnimalWatch Vi: Building Graphics Literacy project. She died on July 28, 2021. Her strong intellect and commitment to increase the number of children who enter the STEM professions is commendable. Her passion lives on through her work.

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