Teaching Geometry to Visually Impaired Students

Teaching a visual subject to a visually challenged student inspires strategies that benefit all students in a class.

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From Euclid’s *Elements* to NCTM’s *Focus in High School Mathematics: Reasoning and Sense Making in Geometry* (McCrone et al. 2010), geometry teachers know the important geometric elements that high school students should master, those that enable us to understand the world around us. NCTM (2000) described geometry as “a means of describing, analyzing, and understanding the world and seeing beauty in its structures” (p. 309). Dossey et al. (2002) captured the essence of this aspect of visualization by stating that geometry fosters in students an ability to “visualize and mentally manipulate geometric objects.” (p. 200). Clearly, visualization is imperative in understanding geometry.

However, not all students have an inherent or physical ability to look at a figure or drawing and make conjectures on the basis of what they see or visualize the figure’s properties. One mathematics teacher was challenged by a cognitively able student who did not have the visual capability to fully “see” the beauty of geometry using her eyes. The teacher’s experience follows. (Note: The experiences of the primary author are conveyed in first person, and pseudonyms are used throughout.)

**THE NEW STUDENT**

The greatest challenge of my teaching career occurred when Jessie joined my geometry class. I had taught geometry for sixteen years and considered myself a fairly competent instructor. I knew my subject and was confident in my ability to help any student make the connections from one geometry topic to another. By the end of each academic year, I had rolled the entire geometry curriculum into a neat bundle ready for each student to carry with him or her to whatever mathematics class or life situation they would encounter next.

Most important, as a geometry teacher, I embraced the necessity of visualizing the subject and emphasized the importance of pictorially representing problem situations. My first question to a befuddled student was always, “Have you drawn a diagram to represent this problem?”

One morning in early August, as I was preparing for the new school year, my school district’s teacher for the visually impaired, Mrs. Jones, stopped by my room. She informed me that Jessie, who is completely blind, was going to be in my geometry class.

Teaching the visually impaired was not a completely new experience for me. I had taught many students who required large-print text, and I had even taught entry-level algebra to a blind student several years earlier. But I was completely unprepared to teach a subject so dependent on visual cues to someone who could not see. Almost every problem that my students solve involves making a diagram of some sort and gathering information from that diagram to help find solution strategies. Jessie was in a pre-Advanced Placement class designed to be taught as a college prep class; it consisted of about thirty ninth-grade students. Jessie had a high aptitude in mathematics; however, I was skeptical about her chance for success in this primarily visual subject.

I had only one day to prepare for Jessie. There was no time for me to investigate strategies for teaching geometry to the blind. I simply jumped in and hoped for the best.

As I worked feverishly to set up my room for the arrival of my students the next day, Mrs. Jones dropped off some supplies that Jessie would need for my class. These supplies included a Braille ruler and protractor, a geoboard for graphing, and an audicaculator. Also included was a board with Mylar® polyester film on it; scratching this board with a plastic “pencil” would raise lines, allowing one to draw crude diagrams.
Thus, I began learning new ways to teach this one student and improve instruction for all the other students.

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literals and that required an understanding of all the properties of both types of figures and how their angles are related. The drawings often took up a whole sheet of standard typewritten paper; using the drawings, students had to find numerous angle measures to solve a given problem. Typically, students wrote each measurement on the drawing as they calculated each one. This scratch work could then be used to find other measurements in the drawing.

This activity presented a huge challenge to Jessie. She could not take the brailled diagram, place it in her braillewriter, and record the measurements in the drawings when she found them and then use them to find other measurements. I began by breaking the problems into smaller pieces and having her work through them a few at a time, but this approach defeated the purpose of her being able to assimilate all the properties of the different shapes and understanding how they fit together.

The solution that we finally came up with made use of the simple thumbtack. Braille paper is more like card stock than regular paper, and the thumbtack worked well for punching small holes in the card stock from the back, thus raising bumps on the front. Mrs. Jones, who often accompanied Jessie to my class, would write the measurements Jessie calculated in the diagram in Braille using the thumbtack, and Jessie could then read the numbers and move forward through the problem. This was a tedious and time-consuming process, but Jessie successfully completed the unit on quadrilaterals.

**Symbols**

As the mathematics became more complicated, I realized that Jessie was getting lost. The new braillewriter and the hole punching helped her take notes and record scratch work, but much of the language of geometry consists of symbols that allow students to memorize the vocabulary and aid in note taking. Symbols are used to represent lines (↔), segments (→), and rays (→) as well as triangles (△). Symbols are also used to represent relationships: parallel (∥), perpendicular (⊥), and congruent (∼). The list of symbols is extensive.

Sighted students become accustomed to the symbols as visual clues to use when creating a diagram, labeling parts, or drawing conclusions. Such symbols help students bridge the gap between terminology and concrete representations. Jessie’s inability to see or use these symbols created a greater challenge for her in learning the material.

**CONTEXTUAL CHALLENGES**

One of the toughest challenges was guiding Jessie to an understanding of concepts for which, because of her blindness, she had no context. As mathematics teachers, we often try to connect the abstract topics of the subject with examples of real-life situations to help students better understand them. The available contextual clues for a blind student are greatly decreased from that of a sighted student.

**Perspective**

One such contextual issue arose during a lesson using perspective drawing of three-dimensional figures. Jessie needed to feel what she could not see. When we studied polygons, I gave her pattern blocks to feel and trace. When the other students drew tessellations, she built hers using the blocks. Then we began working with three-dimensional solids. Jessie had worked with solids in previous mathematics courses, but, like many students, she seemed to have a hard time equating two-dimensional perspective drawings with the three-dimensional figures that they represented.

Perspective drawings give a two-dimensional account of how a three-dimensional figure is viewed. Jessie had no visual context for this perspective. For example, a prism is defined as containing two parallel congruent bases. Often, when a prism is drawn on two-dimensional paper, the drawing looks as if the bases intersect (see fig. 1).

To make this idea clear to Jessie, we had to trace each face of the prism on the paper and then indicate to her which face of the prism it represented. This was a laborious process. On paper, to indicate perspective, rectangles are sometimes drawn as parallelograms, and circles are sometimes drawn as ovals—another confusing point for Jessie. However, throughout the unit on surface area and volume, the solid figures were always available for her to touch and manipulate.

**Solids of Rotation**

A final example of Jessie’s limited context occurred during the last unit of the school year, in which I
combined several topics: graphing lines in the coordinate plane and finding the area and perimeter of the bounded region that they create. Jessie had done most of her graphing on a geoboard with rubber bands, an acceptable process for finding area and perimeter. The last part of this unit involved revolving those bounded regions about an axis and drawing the solid that was created.

This concept, difficult for my sighted students, was overwhelming for Jessie. No amount of verbal explanation from me seemed to help her wrap her brain around this idea, so I had to find a way to make it concrete for her. I needed to come up with some way of constructing a manipulative that would represent this concept.

From card stock, I cut out a right triangle and a rectangle and taped each to the end of a pencil. The pencil was my axis of rotation. When I rotated the pencil, Jessie was able to feel the triangle going around in her hand. She could trace the circular base that the triangle created and understood that the three-dimensional figure swept out was a cone. The rectangle became a cylinder in her hands (see fig. 2). Jessie eventually understood that all solids of rotation have circular bases and that she could find the surface area and volume of each. We even managed to revolve a trapezoid to create a frustum.

LOOKING BACK
My experience in teaching Jessie taught me that any student can reach his or her cognitive potential when instruction is tailored to individual needs. I began that school year with unrealistically high expectations of what Jessie could do. In the beginning, I expected her to keep pace with the rest of the class. After all, she was in an advanced class, wasn’t she? As I came to understand Jessie’s special needs, I learned that reading and understanding problems, drawing diagrams, and recording information all take more time, space, and organizational strategies. I learned that Jessie could reach my high expectation of learning the material, just not as quickly as my sighted students.

I sometimes underestimated Jessie’s capabilities. I doubted that a blind student could fully understand a visual subject like geometry. Yes, geometry is a visual subject, but visualization is not reliant solely on one’s eyes. Jessie could see the beauty of this subject with her hands. Small bumps on the paper became pictures in Jessie’s mind. Thumbtack punctures became scratch work for problem solving. Twirling rectangles became cylinders in Jessie’s palms. In essence, Jessie saw mathematics through her “mind’s eye” (this phrase is drawn from Fisher and Hartmann’s article [2005]).

Each student learns in his or her own way. Every year I differentiate my instruction to meet students’ needs. I have used multiple representations, had students act out problems, scheduled silent study time, had cooperative group activities, and tried to understand and implement teaching strategies that catered to all possible learning styles. Through my experience with Jessie, I learned that when instruction was differentiated for her individual needs, she too could learn without the use of her eyes.

Although I did not have time to research the best ways to help Jessie “see” geometry, I believe that she left my class with a solid understanding of the
subject. She was successfully able to complete all geometry objectives during this school year beside her sighted peers. This success I attribute to the persistence of all of us—Jessie, Mrs. Jones, and myself—in finding ways that helped Jessie make sense of the material.

Understanding geometry is not reliant on seeing objects and images with one’s eyes. Problems can be represented “visually” in many ways; they can be spoken, read, drawn, and felt. All students can learn; however, they all learn differently.

BIBLIOGRAPHY

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