Geometry is an essential component of mathematics instruction. “Geometry helps us represent and describe in an orderly manner the world in which we live” (NCTM 1989, 48). Research in the field of early childhood mathematics education (Fuys and Liebov 1993; Del Grande 1985; Fuudenthal 1973) confirms that children are naturally intrigued by, and motivated to learn more about, the geometry that defines their worlds. Although it is important to provide a rich geometry program in the primary grades, research reveals that the little attention given to geometry is typically for exposure purposes (Bruni and Seidenstein 1990; Porter 1989). Therefore, any classroom time devoted to geometry is precious.

As practitioners in early childhood mathematics, we have observed that many young children have numerous misconceptions about geometry, perhaps as a result of a lack of exposure to vocabulary and too few authentic experiences in the primary grades. It is also possible that misinformation conveyed by adults during formal and informal instruction minimizes and contradicts the budding geometric constructs of young children. To search for the source of misconceptions and to improve the geometry program, we must consider the current practices used to teach geometry.

Uncovering the Roots of Misconceptions

Squares and rectangles

A common activity involving geometry is for young children to recognize and name various shapes. Many children are taught the names of shapes through experiences with adults, peers, television, books, and computer games. Although these experiences may be rich, they may lack depth or be inaccurate. For example, children are often taught to categorize rectangles and squares separately. Typically, a polygon with four equal sides and four equal angles is referred to as a square, whereas the polygon with equal length, parallel sides, but unequal perpendicular sides is referred to as a rectangle. We hear children orally refer to rectangles as being “long” or “tall.” Their system for differentiating between squares and rectangles is based on narrow experiences with a few specific examples.

These constructions may cause confusion later as educators clarify for children that squares also fit the description of rectangles. The new information does not connect logically to what they have already learned. Although the first classification of rectangles versus squares is essentially correct, it does not allow for growth in understanding that a square is a more specific classification of a rectangle, just as a rectangle is a more specific classification of a parallelogram, and that a parallelogram is a specific classification of a quadrilateral (see fig. 1). The relationships go unexplored, and each shape is viewed exclusively. It seems that providing incorrect or incomplete information at the onset, in hopes of reteaching and altering the paradigms of thought later in students’ educational careers, has become an acceptable means of addressing a rather complex classification system.

We do not expect young children to understand fully the intricacies of quadrilaterals and their classification system, but we believe that children...
would fare better by learning about quadrilaterals as a whole versus focusing on a few specific examples and attempting to expand their understandings later. To aid understanding, define a quadrilateral as a four-sided figure and give students various-sized sticks with which to build a variety of quadrilaterals. After the formations are made, students can observe the creations of their classmates, and the teacher can initiate a discussion about the similarities and differences among the shapes. The discussion should include the terminology of corners and sides and lead students to further sort the quadrilaterals into several different categories. Students have the opportunity to discover and express the attributes of the quadrilaterals that they have explored. Within these categories, the names of particular quadrilaterals, such as square, rectangle, and parallelogram, could be introduced. This discovery-oriented approach involves looking at the similarities and differences between and among shapes instead of memorizing specific descriptors of individual shapes. This activity will set the stage for students to understand that many types of quadrilaterals exist and that these shapes have some elements in common.

**Trapezoids and triangles**

A staff member was asked to gather several tables for a special school event. As he returned with a table in the shape of a trapezoid, he asked, “Shall we use this triangular table?” Many adults use similar terms and incorrectly label shapes and solids in the presence of students. As role models, we must pay particular attention to the language of mathematics and must consider how our words are interpreted. Perhaps we should examine our own content knowledge of geometry. In many situations, the misuse of terminology is not intentional; rather, it is the result of gaps in learning and possibly the superficial way in which we learned the geometry lexicon. As young learners, we may have identified shapes by memorizing specific attributes, which we may not have fully understood. When memorization occurs without an attachment to well-developed concepts, learners use or hear erroneous terminology that can lead to misconceptions. Likewise, when young learners are offered only regular or common examples of shapes, they connect one label to one shape, which limits applicability and understanding.

A recent experience with first grader Grace highlights the issue. Grace was given the pattern in figure 2 and asked to continue it. She studied the pattern and began to read aloud. “Triangle, triangle, wrong triangle, triangle, triangle, wrong triangle, triangle... The next shape is a right triangle!”

Clearly, Grace’s construct of a proper triangle included only equilateral triangles. Ironically, right triangles were deemed “wrong triangles” by Grace. It is clear that Grace has learned only about one type of triangle in her mathematical experience, so this situation presented a perfect teachable moment. Because Grace called the unfamiliar shape a triangle, even though it was a “wrong” triangle, she was ready to learn about different types of triangles, various angles, and the labels equilateral triangle and right triangle.

One may argue that young children are not developmentally ready to process the extensive vocabulary and abstractions associated with geometry. However, later reconstructions may require much more intellectual sophistication. Does it make sense to set subsequent hurdles for children simply because we are afraid to give them academic challenges early on?

**Three-dimensional shapes**

Children are exposed to misconceptions about geometry from a variety of sources, including books. *The Silly Story of Goldie Locks and the Three Squares* (MacCarone 1996) was written to help teach mathematics and includes an introductory note to parents, as well as suggestions for follow-up activities. To an educator, this book’s familiar story line and instructional component
Although the text does state that the beds are shaped “like” a circle, triangle, and rectangle, few children would distinguish between “like” and actual without emphasis and further discussion, and parents and teachers may be misled as well.

Similarly, many young children are taught to label a cube as a square and a sphere as a circle. One popular preschool television show’s search for squares resulted in a collection of cubes, and a search for circles resulted in spheres. Although the faces of a cube are squares and a sphere depicted in two dimensions would be called a circle, the terminology and characteristics of two-dimensional and three-dimensional representations were not explored.

Asking students to search for particular shapes around the room or at home is a popular activity, but we must be careful about the questions that we ask and the responses that we give as students communicate their findings. This point is illustrated in the dialogue that occurred in a primary classroom between a teacher (T) and different students (S1 to S5).

T: What shapes did you find around the room?
S1: I found a rectangle.
T: Would you like to show us the rectangle you found?
S1: Right here [pointing to the front of the classroom door]. The door of our classroom.
T: So, the front part of the door looks like a rectangle?
S1: Yes.
T: Why did you call it a rectangle?
S1: I know it’s a rectangle because these two sides are the same [pointing to opposite sides] and these two sides are the same [pointing to the other pair of opposite sides].
S2: And there are four square corners!
T: So, everyone agrees that we can call this shape a rectangle? Could we call it anything else?
S3: A quadrilateral!
T: Does anyone see any other quadrilaterals on this door?
S4: I do. I see another rectangle on the side of the door. [Student 4 outlines the four edges making up the sides of the door.] It is really tall and thin.
T: Are there any other rectangles that make up the door? [Discussion continues, and students eventually name all six surfaces of the door as rectangles.]
T: We can see six different rectangles on the door. When you put those rectangles together to form a solid, like this door, it is no longer a rectangle. It is made up of six rectangles on its surface. It is called a rectangular prism. Let’s use these materials to build our own rectangular prisms [students receive cardboard attribute blocks and tape].

Even though the lesson’s focus was on two-dimensional shapes, the identification of the door as a rectangle warranted a discussion of three-dimensional solids, as well. It is better to introduce new terminology to students rather than subsequently attempt to distinguish between two- and three-dimensional shapes. Although all students may not remember the term rectangular prism, they will have been given the opportunity to discuss and explore the concept, which will be a building block for future geometric understanding.

Avoiding Misconceptions about Geometry in the Classroom

Educators should keep in mind several key elements as they introduce and teach geometry concepts to young children. The following list, although not exhaustive, is intended to inspire thoughts about program evaluation.

1. Emphasize the properties and characteristics of a concept. Allow exploration time so that students may experience the properties kinesthetically. Encourage children to experience geometric manipulatives through free play. When given a collection of geometric solids, students can physically manipulate the solids to explore which objects can roll and which can be stacked. Beyond free play, children can be encouraged to participate in more directed exploration, such as sorting by attributes and characteristics, which allows children to observe and think about the properties of shapes.

look appealing, and parents and teachers may think that they are contributing to an understanding of geometry. However, the book’s illustration of Goldie Locks’s three beds is problematic. (See fig. 3.) The first bed “was shaped like a circle”; the second, “like a triangle”; and the last, “like a rectangle.” In reality, the shapes look like a circle, a triangle, and a rectangle but are actually a cylinder, a triangular prism, and a rectangular prism. Although the text does state that the beds are shaped “like” a circle, triangle, and rectangle, few children would distinguish between “like” and actual without emphasis and further discussion, and parents and teachers may be misled as well.
2. **Provide many examples and nonexamples, even if the child is not ready to specifically name the nonexamples.** Nonexamples are equally as important as examples, because recognizing that a particular shape is not a circle requires the same knowledge as naming a shape as a circle. Requiring students to justify a response will reveal even more diagnostic information for use in planning instruction. Additionally, varying the shape’s position during presentation will help children understand that a shape remains constant regardless of its placement in space. Turning a shape so that it sits on a vertex is particularly helpful in offering a wide variety of shape orientations.

3. **Pay close attention to language use.** Give students the opportunity to demonstrate and explain their use of specific terms so that the educator can pinpoint possible misconceptions. According to the NCTM’s *Standards* document (1989), facility with the language should grow naturally from exploration and experience. Many young children will interchange words for two-dimensional and three-dimensional shapes as they are learning terminology. It is certainly permissible to accept their wording; however, teachers should always use shape names correctly as they respond to students (see fig. 4).

4. **Challenge understanding and broaden generalizations.** To encourage children to move to higher levels of thinking, use such questions as, How do you know that this shape is not a square? What changes would be necessary to make it a square? What do these shapes have in common? How are the shapes different? Using indefinite statements and oversimplifying information may inadvertently cause children to draw inaccurate conclusions about mathematical concepts.

**Ideas for Instruction**
As mathematics practitioners, we have learned that nothing is more important in building children’s geometric constructs than manipulation, exploration, and conversation. We offer two ideas that we think are particularly beneficial in helping students form accurate conceptions about geometry.

**Flat shapes and fat shapes**
This activity is intended to teach children to differentiate between two-dimensional shapes and three-dimensional figures. Students are given a collection of geometric solids and thin attribute block pieces and are asked to categorize the collection in several different ways and to share their findings in small groups. One sorting possibility that children discover places two-dimensional shapes in one group and three-dimensional shapes in another. Pull small groups of students together, and encourage group representatives to share sorting possibilities. After acknowledging the many sorting variations, direct all students to sort by dimension and to find “partners” across groups. Possible partner pairs may be the cylinder and circle or the cube and square. Encourage students to explain why they think that the two-dimensional and three-dimensional shapes are partners. Ask students to think why some three-dimensional figures have more than one partner (i.e., pyramid, cone), whereas others (i.e., cube and sphere) have only one. As students think through their explanations, encourage them to trace or stamp the figures with a one-sided paint print, creating two-dimensional depictions out of the three-dimensional figures. Through this type of tactile exploration and rich conversation, new vocabulary will surface and careful observation and description will be promoted.

**Property loops**
To further explore the properties of various shapes, we use a modified version of Venn diagramming...
called property loops. This activity allows children to think about examples of shapes that have particular characteristics in common and in contrast. The teacher displays the loops—strings or plastic hoops—on the floor and explains to the students that each loop has a title. The property titles, which are written on index cards and placed in sealed envelopes on each loop, are known only by the teacher at the onset of the activity. The teacher places some shapes in the loops that fit under the category labels then distributes the rest of the shapes to the students. Students observe the shapes placed in the loops and think about possible labels that could be hidden in the envelopes. During this process, students take turns adding to the loops additional shapes that in some way match the properties of those shapes already present. Before placing a shape, the student explains why a particular location was chosen (e.g., in a loop, in two loops, or not in any loop) for their shape, and the teacher confirms the response or discloses that the shape cannot be so placed because of the mystery titles. After all shapes are accurately placed and students discuss their ideas about the property titles, the envelopes are opened. Finally, the class verifies that the placement of each shape does, in fact, fit the property-loop titles.

During this exercise, students use logical reasoning to demonstrate their understanding of geometric properties and characteristics. The nature of this activity allows the teacher to address a range of difficulty levels. For kindergarten students, it is most appropriate to use only one loop with one characteristic, so that either a shape belongs in the loop or outside the loop (see fig. 5). For older children, the teacher may vary the formation of the loops (see fig. 6). The title given to each loop is another way to adjust the difficulty level or the lesson objectives. Possible titles may include such properties as size of shapes, color of shape, number of sides or corners, length of sides, or angles of shapes. This activity also allows a place for those shapes that are nonexamples of the properties being explored, because they are placed outside the property loops. As an extension, students can create their own property loops and determine the titles of each set.

**Possible variations and labels of property loops**

![Possible variations and labels of property loops](image)

**FIGURE 6**

![A property loop containing the label “No square corners” (right angles)](image)

**FIGURE 5**
Conclusion

We do not contend that mere knowledge of terminology and of shape properties encompasses all conceptions of geometry. However, the lack of accurate terminology and authentic experiences creates a disparity between potential and the realization of that potential in children. Clearly, a strong understanding of geometry is a necessary component of a child’s mathematical foundation.

Geometry instruction for young children should highlight shape properties, attributes, and characteristics, as well as the interconnective and hierarchical commonalities and differences between and among shapes, figures, and solids. Additionally, early childhood educators need to equip classrooms with numerous examples and nonexamples of geometric shapes and figures in a variety of forms. Furthermore, educators must use accurate terminology, label shapes correctly, and explain relative properties and characteristics. Moreover, geometry instruction must include precise fundamentals yet challenge students to achieve higher levels of thinking, striking a balance between enrichment and acceleration.

As educators, we must construct a foundation that is soundly reinforced, free of gaps, and untainted by misconceptions. Any weaknesses in presentation and program must be replaced, restored, and reconstructed. Constant evaluation and continual learning are essential tools for students and educators to use to continue to improve and shape up our geometry curriculum for young children.

References