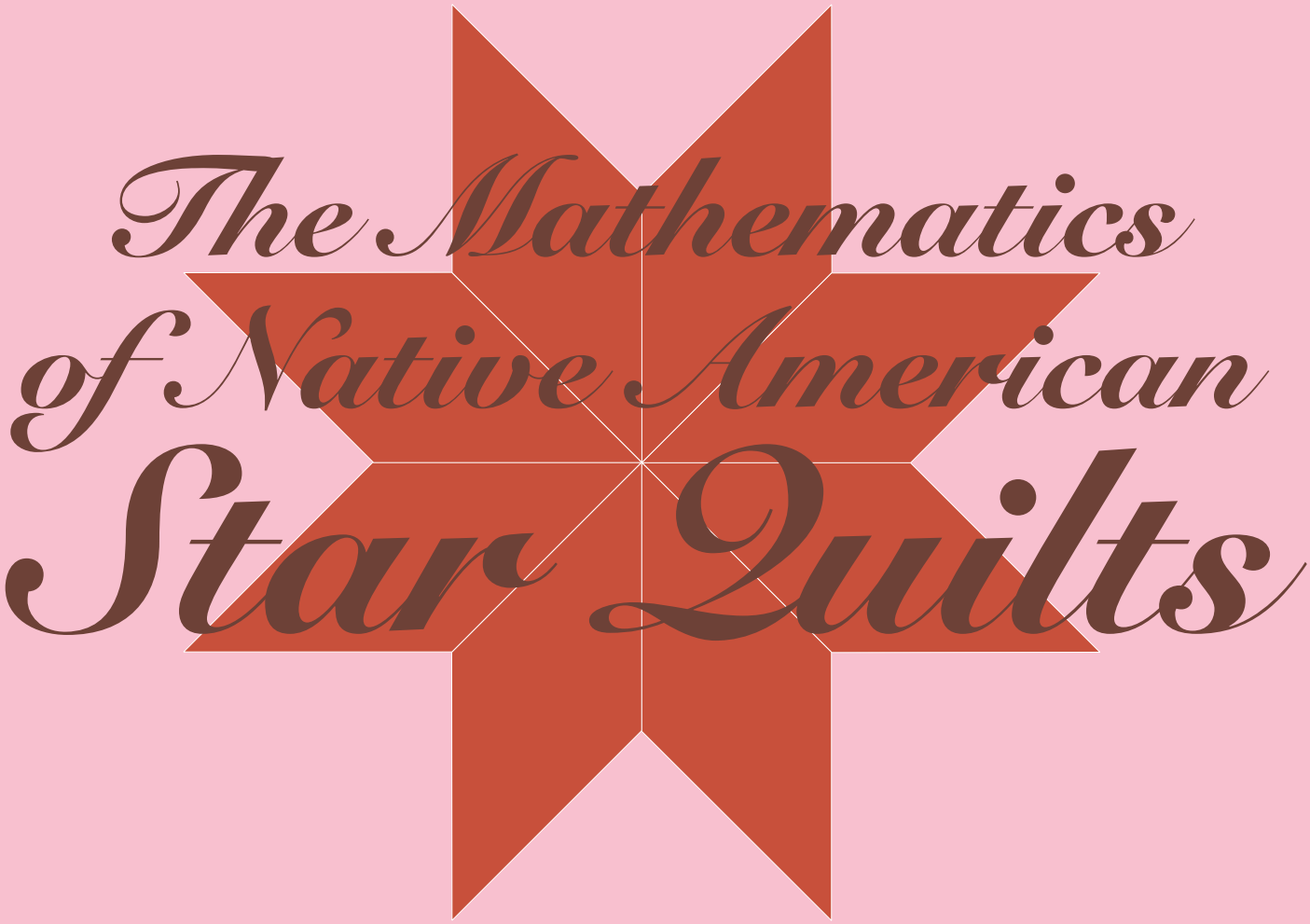
The Mathematics of Native American Star Quilts



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A SIXTH-GRADE STUDENT IN MY class commented, "I told my mother about the star quilts we made and the math we did—she makes a lot of quilts. . . . My Mom said she wasn't very good at math. I told her, 'No, Mom, you're very good in math and this is why. . . .' "

Introduction to Quilting

QUILT MAKERS NEED TO APPLY AN EXTENSIVE amount of mathematical knowledge to a quilt project. A quilter must determine the amount of material needed and how the different pieces fit together to create a beautiful, quality product. From my quilting experience, I see the application of such mathematical topics as algebra, geometry, and arithmetic, along with an appreciation for the strong cultural aspect associated with quilting.

Quilting activities in the mathematics classroom engage students in the use of mathematics in the real world. The NCTM's *Principles and Standards for School Mathematics* (2000) advocates providing students with opportunities to "learn about mathematics by working on problems arising in contexts outside of mathematics" (pp. 65–66). This activity uses the social and historical context of the Lakota culture to examine the mathematics used in making star quilts. The mathematics activity I present in this article is a lesson that I frequently teach to middle school students. Through this activity, students see the connection of mathematics to real-world activities, appreciate the tremendous mathematical knowledge required of quilters, learn geometrical ideas, and bring Native American history and mathematics together.

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Northern Plains Native American Star Quilts: A Brief History

QUILTING BECAME IMPORTANT TO THE NORTHern Plains Native Americans in the late nineteenth century. Before this time, the bison were central to the Lakota, Dakota, and Nakota culture and the painted skins were an art form that related stories important to the tribes' heritage. The painted skins also described historical events. With the buffalo's extinction, this art form ceased and was replaced with a new medium, the making of "star quilts," or *wicahpi sina* (Powers 1988).

Missionaries introduced quilting to Native American girls at boarding schools in the late 1800s (see Powers 1988). After returning home, the girls applied traditional geometric patterns learned from beadwork and buffalo-hide designs to quilting. This particular art form features an eight-pointed star, known as the Northern Star on Northern Plains reservations. (See **fig. 1** for an example of a star quilt.)

The star quilt is made from material cut into rhombus, or diamond-shaped, pieces. The rhombus is formed by reflecting a single isosceles triangle about its noncongruent side. Eight rhombus pieces are placed with the smaller angle rotated about a central point to form the initial star pattern. From that central star, quilters add other rhombi outward to form a larger eight-pointed star.

Personal meanings are found in these quilts (Collmer 1989). Symbolic emblems from the tribes' traditions are found in the corner edges of the quilt. Quilts play an important role in the births and deaths of the Lakota Sioux. *Yuwipi*, or "the give away," is a private ceremony among extended family and friends held to honor births, deaths, marriages, and graduations (Powers 1988). For girls and boys on basketball teams on a Montana reservation, the star quilts given to the athletes have tremendous meaning—to give such a quilt communicates a great sense of respect, honor, and admiration for that person.

Star quilts hold several symbolic representations of life, spirituality, and community for the Native Americans. The star quilt tells a story, just like the painted buffalo hides. The colors red, black, white, and yellow are symbolic to the Lakota. Black Elk is quoted as saying, "Black is for the west where the thunder beings send us rain. White is for the north, where the great white cleansing wind comes. Red is for the east where springs the light and the morning star. Yellow is for the south, where summer comes along with the power to grow" (Neihardt 1932, p. 2).

The interdisciplinary nature of these star quilts introduces students to the cultural, social, and artistic importance that they contain, along with rich mathematical ideas. It introduces students to mathematical ideas, such as symmetry, reflection, rotation, angle measurement, geometric characteristics and properties, and numerical patterns.

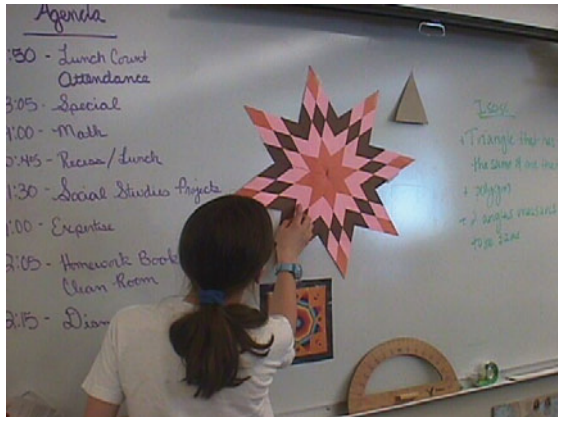


Fig. 1 A completed star-quilt pattern shows the quilt's reflecting colors

Northern Plains Native American Star Quilt Activity

A Teacher's Guide

Learning goals: The purpose of this activity is to demonstrate and apply the mathematics involved in making star quilts. It provides a solid connection between mathematics and the Native American culture. The investigations and constructions work to broaden students' knowledge of mathematical applications within a cultural context.

The NCTM's Standards: Students will analyze characteristics and properties of two-dimensional geometric shapes and develop mathematical arguments about their properties. Students will use visual spatial reasoning and geometric modeling, apply number patterns, and explore relationships to solve problems. Students will use appropriate tools and formulas to determine measurements and will also recognize and apply geometric ideas in areas outside the mathematics classroom (NCTM 2000).

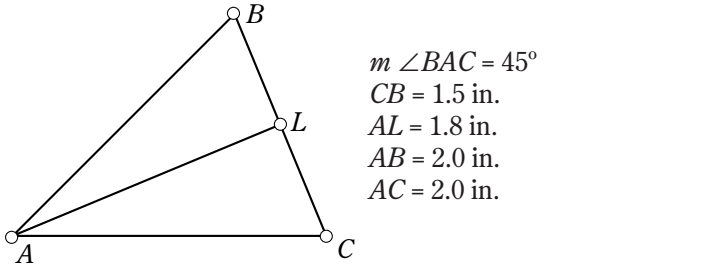
Materials: Each student will need these items:

1. One piece of flip-chart paper (27 in. × 34 in.) to represent the quilt matting;
2. Several colors of construction paper;
3. Scissors;
4. Protractors;
5. Rulers;

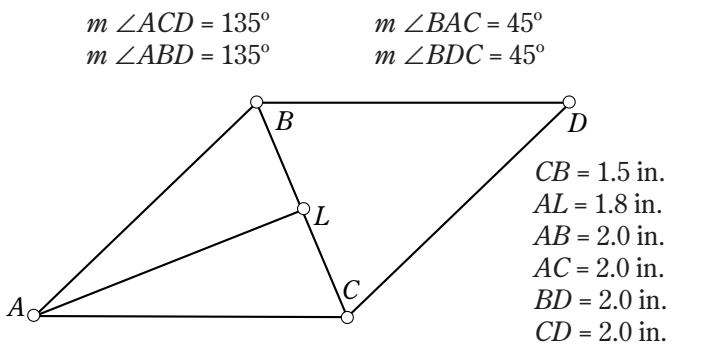
6. Card stock, stiff paper, or cardboard (I usually collect the backs of pads of paper);
7. Paper glue;
8. Clear tape;
9. A copy of the student worksheet; and
10. Pictures of Native American star quilts (for examples, see the Teacher Resources listing).

Setup: (1) Cut the card stock into 1.5 in. × 11 in. strips. These narrow strips are needed for the triangular templates, which should be made before the activity, and the rhombus templates that the students make during the activity. The rhombi need to have two acute angles of 45 degrees and two obtuse angles of 135 degrees. (2) Make triangle templates out of the card-stock strips with angles of 45, 67.5, and 67.5 degrees, with a base of 1.5 inches, and a height of 1.8 inches. These dimensions will enable the rhombus and isosceles triangle to fit nicely on the 1.5 in. strips of paper. Students will use the isosceles triangles to create the rhombus template needed for the activity (see **fig. 2a**). (3) Cut the remaining card stock into pieces large enough to fit a rhombus template. (4) Cut the construction paper into 1.5 in. × 11 in. strips for the students. Many times, quilters cut their material into strips, then make individual pieces from these strips. Cutting strips of card stock and construction paper mimics this preparation.

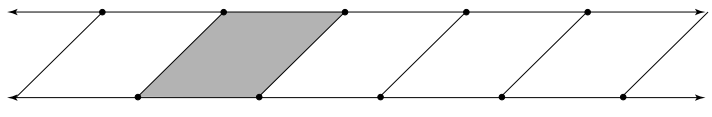
The time needed for this activity will be two 60-minute sessions, with one 60-minute session needed for assessment.



(a)
The triangle template



(b)
The rhombus template



(c)
One rhombus is shaded to illustrate its place as one of many shown on a strip of construction paper.

Fig. 2 Templates for various shapes

Description of the activity

I have developed a worksheet that guides students through the exploration of the mathematics embedded in making the star quilts (see **Appendix A**). The worksheet is broken into three sections. The first section asks students to examine the mathematics needed to create the star quilt. In the second section, students make their own star quilt. The third section extends students' knowledge of the eight-pointed star to different shaped stars and focuses on the numerical patterns found within the star quilt. (Suggested student responses are found in **Appendix B.**)

Part 1: Investigation

1. Have students explore the Internet to learn about these quilts and report back. Show students various Native American star quilts, each having different tribal emblems. Talk with your students about the personal meanings behind them. (For examples of the Native American star quilts and their rich cultural meanings, see the Teacher Resources listings.)

2. Build upon any geometric properties that your students recognize in the quilt. It will be helpful to review ideas for the properties of an isosceles triangle, rhombus, reflection, and how to measure angles.

3. Have students use the worksheet to investigate the mathematics involved in making a star quilt.

4. Discuss the geometric properties of an isosceles triangle and how the triangular templates relate. Discuss how an error in measurement and how any errors made while cutting out these templates will influence their results. Ask students to explain how isosceles triangles and rhombi are related.

5. Have students construct a rhombus shape from an isosceles triangle, then cut out a rhombus template with their strip of card stock (see **fig. 2b**).

This section of the lesson will usually take about 60 minutes. Note: The human error caused when cutting the pieces demonstrates the complexity and preciseness needed in making star quilts. Providing

perfect templates prevents students from learning this important lesson. Human error will also produce results that foster great discussions about the propagation of error.

Part 2: Application

For the second part of the activity, students make their own eight-pointed star pattern from the 1.5 in. strips of construction paper and the rhombus template that they made earlier. Students use three different colors to begin their star. On using the third color, students begin to reflect the color pattern and make the different points of the star.

1. Students use strips of construction paper to make the quilt pieces. Ask students to fit the rhombus in such a way as to ensure the efficient use of the construction paper (see **figs. 2c, 3a,** and **3b**). Students should use the same color for each band so that they can see the geometric patterns. Red, black, white, and yellow are symbolic colors to the Lakota Sioux. Have students choose colors that are meaningful to them. At the end of the lesson, ask students to explain why they chose those colors for their quilt.

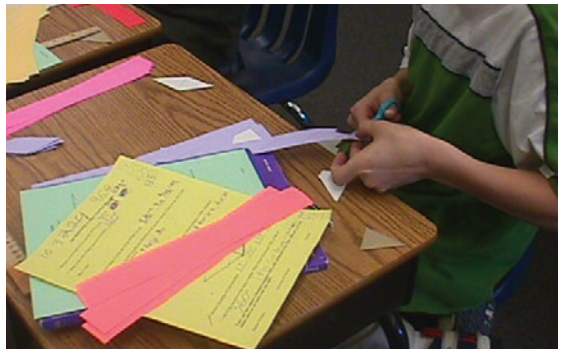
Note: The selection of colors is a vital part of this activity, since students are learning about the cultural significance as well as the mathematics involved in making star quilts. Later, when students share why they chose the colors, it provides tremendous insight into their point of view on the activity and can foster additional discussions.

2. Students begin to make the quilt by cutting out the first eight rhombus pieces to fit around the center point (see **figs. 3c** and **3d).** Students then examine the relationship between the number of pieces around the center point with the measure of the angle within the rhombus. Human error may cause some students' rhombus pieces to overlap or show gaps. This is an excellent time to discuss the propagation of error. Ask students to describe what they think will happen to their star quilt because of the gap or overlap. Record the discussion comments. Revisit these ideas after the students finish their quilt to address any misconceptions. The follow-up discussion becomes quite interesting as students compare their previous predictions with what really happened once work began.

3. Visit other students as they work, and ask such questions as these: "Where do you see octagons in the quilt?" "Why is that an octagon?" "Where do you see lines of symmetry?" "Why did you choose these different colors?"

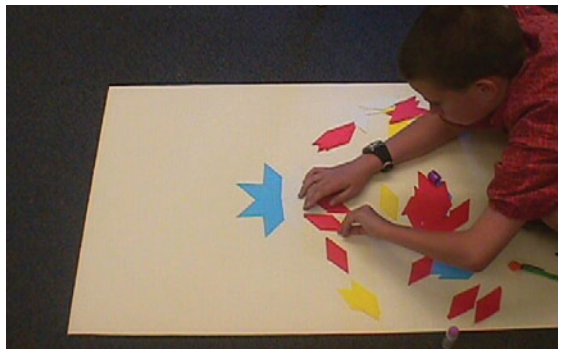
This activity usually completes the second session. (See **fig. 4** for the bulletin board display.) For

(a)
A student traces rhombus pieces.



(b)
A student cuts out rhombus pieces.

(c)
The pieces are then put together.



(d)
A student makes a star quilt.

Fig. 3 The various stages of star-quilt construction

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Fig. 4 The school's bulletin board displays completed quilts.

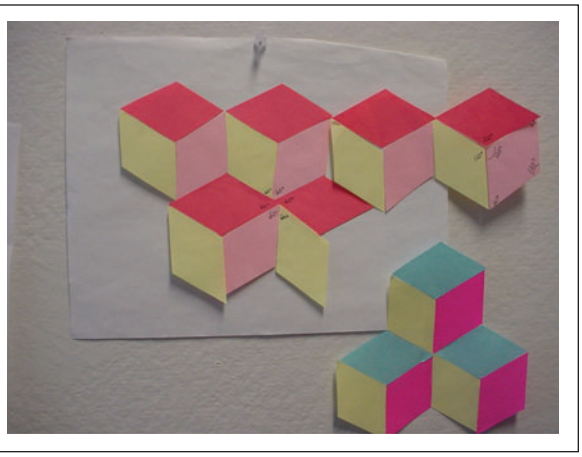

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Fig. 5 The Tumbling Blocks quilt pattern

students who finish early, ask them to begin section 3 of the worksheet. Since some students may not finish their quilt by the end of class, provide time to complete the last part of the worksheet.

Part 3: Assessment

1. As a journal writing activity, ask students to reflect on what mathematical properties they learned during this activity. Where did they use mathematics in making their quilt design? What did they learn about Native American culture? What did they learn that was unexpected?

2. As an assessment activity for the Star Quilt Lesson, students work in groups of four to make a variation of the star quilt, a pattern called Tumbling Blocks (see **fig. 5**). For this assessment, students find the measure of each angle in the rhombus based on its properties and their knowledge of six angles meeting at one common vertex and three angles meeting at another common vertex. A picture of the Tumbling Blocks quilt pattern gives students a visual representation of their task. To assist students who needed extra help, each group is allowed to ask four questions to help them make the quilt. Since so few questions can be asked, students choose them wisely. Producing the Tumbling Blocks quilt is an excellent assessment tool because of its connection to the six-pointed star quilt—these two quilts are one and the same. The selection of the colors for the rhombus pieces is what makes the difference in the appearance of the two quilts.

Expanding the Activity

THIS ACTIVITY WAS PLANNED SPECIFICALLY FOR upper-elementary and middle school students, but it can be adjusted to fit other grade levels. For students who need extended work, ask them to construct the isosceles triangle and rhombus with a compass and straightedge. Students can research Northern Plains Native Americans to provide further historical background and investigate the tools used to cut the pieces and sew the quilt at the turn of the century.

Teacher Resources

"America's Quilting History: The Diversity of Native American Quilts." www.womenfolk.com/historyofquilts/native.htm

"Books about Native American Quilts and Related Topics." www.si.edu/resource/faq/nmai/quilts.htm

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Appendix A
Students' Worksheets

Section 1: The Mathematics of Native American Star Quilts

1. Measure each angle in the triangle given to you. _____ _____ _____
2. What is the sum of these measured angles? _____ Why is that?
3. Measure the length of each side of the triangle (in cm). _____ _____ _____
4. Your measurements should resemble the properties of an isosceles triangle. If they do not, how could you explain the differences?
5. What are the properties of a rhombus? How could you use your isosceles triangle to make a rhombus?

   Trace a rhombus quilt piece from your isosceles triangle below.
6. Measure the angles of your rhombus. _____ _____ _____ _____ Add all the measures of the angles together. What answer do you get? Why is that so?

   Trace and then cut out a rhombus template with your cardboard strip. This item will serve as your master piece as you make your star quilt.

Section 2: Making Native American Star Quilts

1. Looking at the sample star, how many pieces will you need for each color? _____
2. If each color strip makes four rhombus pieces, how many strips will you need for each color? _____ Explain how you got your answer.

   Select 3 different color strips to make a reflecting pattern. As the Native Americans quilt makers chose colors that had symbolic meaning, choose 3 colors that have symbolic meaning for you. Cut out rhombus pieces from your construction paper strips in a manner that is most efficient. Arrange your rhombus quilt pieces around one common vertex to form a star.
3. How many quilt pieces can be rotated to fit around this common vertex? _____ Why is this so?

   Build a complete quilt using 3 different colors. Once you have reached the third color, reflect your color pattern on the other side so that you can create a line of symmetry at the third color.
4. Where is the octagon in the star quilt?
5. How did the octagon form?
6. Where are the different lines of symmetry in the star quilt? How many lines of symmetry can you find? _____

Section 3: Questions to Think about in Making Different Types of Star Quilts

1. What happens if you wanted to make a six-pointed or four-pointed star? How will it affect the quilt's design?
2. What would be the measure of the interior angles of these new rhombi formed by the six-pointed or four-pointed star? How did you figure it out?
3. If a Native American eight-pointed star quilt had 7 different colors in it, how many pieces would be needed for each color? Explain how you got your answer.
4. What number patterns do you see in the star quilt for the different color bands?

Appendix B
Suggested Responses to the Worksheet

Section 1: The Mathematics of Native American Star Quilts

1. Answers will vary, but you should see angles close to 45, 67.5, and 67.5 degrees.

2. 180 degrees. The answers might be a little bit off because of measurement errors. The sum of the interior angles for a triangle is 180 degrees.

3. About 5 cm, 5 cm, and 4.8 cm.

4. Students usually notice that they have the properties of an isosceles triangle. If not, the differences could occur because of measurement errors or an error in the triangular template.

5. A rhombus is made up of four equal lengths, with the opposite interior angles being equal. Reflect the triangle on the base leg.

6. You should see angles within a measurement error of 45, 45, 135, and 135 degrees; 360 degrees; the sum of the interior angles for a quadrilateral is 360 degrees.

Section 2: Making Native American Star Quilts

1. 16 for the first color, 32 for the second color, and 24 for the third color

2. 4 strips for the first color (16 pieces/4 pieces per strip = 4 strips); 8 strips for the second color (32 pieces/4 pieces per strip = 8 strips); 6 strips for the third color (24 pieces/4 pieces per strip)

3. Some students will have 8. The angle measure is 45 degrees, so $45^{o} \times 8 = 360^{o}$. Other students may have 7 pieces fit around the center point.

4. Answers will vary. Students will notice different octagon patterns throughout the quilt pattern.

5. An octagon can be formed by connecting a line to the tips of the star points. An octagon can also be formed by cutting the large rhombus part of the star at the third color.

6. There are four lines of symmetry that cut through the quilt.

Section 3: Questions to Think about in Making Different Types of Star Quilts

1. The number of star points will decrease and the angles inside the rhombus will change.

2. A six-pointed star will cause two of the angles in the rhombus to decrease from 135 degrees to 120 degrees and the other two angles to increase from 45 degrees to 60 degrees. A four-pointed star has four angles of 90 degrees. The shape becomes a square. This answer brings up an interesting discussion of what a four-pointed star looks like.

3. $2 \times (1 \times 8)$ for the first color; $2 \times (2 \times 8)$ for the second color; $2 \times (3 \times 8)$ for the third color; $2 \times (4 \times 8)$ for the fourth color; $2 \times (5 \times 8)$ for the fifth color; $2 \times (6 \times 8)$ for the sixth color; and (7×8) for the seventh color

4. Answers will vary. Common responses are that 8 is a common factor for the number of different colored pieces and that 2 is a common factor, except for the last color. The number of pieces increases by a multiple of 8 or 16.