

Beth Cipoletti and Nancy Wilson

BURSTING *with* GEOMETRY

By building a Lithuanian sunburst star with straws, students explore a number of geometric relationships and reinforce their mathematical vocabulary.

What is the role of an activity when students are learning geometry? “Students need to learn academic content through real-world examples. . . . Infusing dynamic, real-world contexts into classroom learning will invigorate teacher and student engagement” (Partnership for 21st Century Skills 2002, pp. 4–5). Often, however, students become so involved in the work that connections bridging the activity to embedded geometric concepts and mathematical vocabulary are not adequately constructed, connections to creativity and innovation are not made, and opportunities are not provided for students to use their knowledge and skills. “A curriculum is more than

a collection of activities,” according to *Principles and Standards for School Mathematics* (NCTM 2000, p. 14). Without connections, students cannot build on previous knowledge to create new knowledge; instead, they learn facts that are isolated from any type of context (NCTM 2000).

Geometric concepts can be challenging to learn, because spatial reasoning is not easily acquired. Many students have difficulty describing the relationships that exist in a two-dimensional object by looking at a textbook representation. Learning and applying precise geometric terms and vocabulary can also be difficult. Definitions should evolve from experi-

ences that include hands-on activities, mathematical reasoning, critical thinking, and high-level analyses. To be more specific, students should be able to experience constructing, drawing, measuring, contrasting, conjecturing, and classifying objects according to their properties. Activities that contain these elements will help strengthen students’ understanding of geometry.

Constructing a Lithuanian sunburst star will allow students to discover geometric relationships, investigate congruency and similarity, and develop spatial sense through transformations while exploring the history and traditions of a different country. The related activities in the multidisciplinary unit

Constructing the Sunburst Star

Visual learners may wish to use different colored straws to make each triangle. Using different colors will be easier for students to reference during discussions.

MATERIALS

8 plastic coffee-stirrer straws
Yarn or string (1 yard)
Scissors

DIRECTIONS

1. Use the straws to construct two equilateral triangles. Use yarn to tie the straws together near the ends of the straws (see **figs. 1a** and **1b**). The two finished equilateral triangles need to be congruent. To verify the congruency of the two triangles, place one on top of the other to see if they coincide; rotate the top one to verify that the triangles are equilateral. Use a contrasting colored sheet of construction paper and draw one straight line down the middle of the page that is parallel to the shorter $8\frac{1}{2}$ inch side.
2. Position the construction paper so that the drawn line is horizontal. Make a star (a twelve-sided polygon, or *dodecagon*) by flipping one equilateral triangle across the horizontal axis; place it on top of the other triangle. Tie them together with yarn, as indicated (see **fig. 1c**).
3. Place one of the remaining straws equidistant from one of the nonvertical, nonhorizontal pairs of parallel straws so that it intersects the center of the star. Tie the straw to the ornament at the top and bottom (see **fig. 1d**).
4. Place the remaining straw equidistant from another pair of nonvertical, nonhorizontal parallel straws so that it intersects the center of the star. Tie the straw to the ornament at the top and the bottom (see **fig. 1e**).
5. Additional decorations may be added, such as pom-poms, ribbons, glitter, and so on.
6. Attach a loop of yarn at one vertex of the star (see **fig. 1f**) for hanging.

Fig. 1 Students use straws and string to construct this sunburst star, which is rich with mathematical concepts.



(a)

Tying the straws together



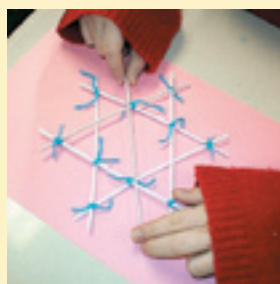
(b)

Constructing an equilateral triangle



(c)

Completing a six-pointed star



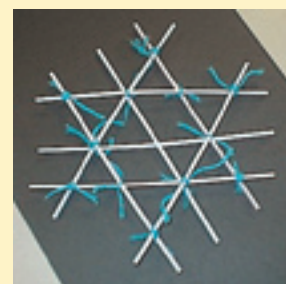
(d)

Placing a parallel straw



(e)

Placing an intersecting straw



(f)

Completing a Lithuanian sunburst star

will help students make connections by recognizing and applying mathematics across the curriculum and outside the walls of the math classroom so as to build and make sense of their mathematical understanding. An activity such as this also provides a vital bridge between school and home by allowing students to share their mathematical knowledge and communicate with their family, friends, and community using geometric language in a fun and purposeful way.

The need to know and be able to use math skills in all walks of life is anticipated to increase over time. On one level, constructing Lithuanian sunburst stars is nothing more than a fun activity for students. However, by embedding the construction in a Standards-based, project-based geometry lesson connected to other disciplines, it becomes a multifaceted worldly experience on which students can construct new understanding.

CONTEXT AND GOALS

This activity introduces the Lithuanian holiday tradition of decorating with straw ornaments in geometric shapes. Directions are provided for making a Sunburst star within the context of a lesson that connects geometry with disciplines such as visual arts and social studies. Students can construct these decorations using everyday plastic coffee-stirrer straws and yarn or string (Metcalf 1969).

To strengthen the connection between concepts and activities, the directions have been written (see p. 224) to emphasize embedded geometric language. In Cipoletti and Wilson's (2004) work with origami and other paper-folding activities, they found that the language in the directions was not written to support mathematical communications or understanding. They propose replacing everyday language with precise mathematical language and highlighting

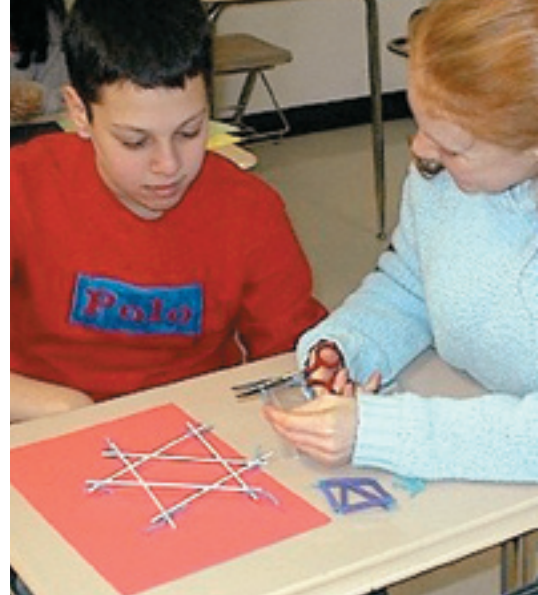
it by using a bold font or italics. In addition, they found that when the directions are rewritten using mathematical language, the connection between definition and application is strengthened by affording students and teachers opportunities for mathematics language acquisition and expression.

Before working with students to construct the Sunburst star, key mathematical vocabulary should be addressed. Students could be instructed to write the words in their math journals and illustrate the definitions. After the star is completed, students can refine their definitions once they have discussed the construction with classmates. Students should work in pairs to avoid frustration. The star is easier to construct if one student holds the straws together while the other student ties the knot.

BACKGROUND FOR STUDENTS

Eastern and northern Europeans have long decorated their homes, and later Christmas trees, with geometric shapes made from wheat, straw, or reeds. Wheat decorations were considered by ancient people to be a mystic promise to the end of winter; placing wheat in the home was believed to ensure the coming of spring. Over time, these geometric decorations transitioned into becoming a part of the traditions associated with the Christmas season.

In America during the early 1900s, Lithuanian immigrants experienced difficulty locating straw for the ornaments, so they began to use paper. Plastic replaced it because it was easier to find and more durable than either paper or wheat. The tradition continues with the creation and hanging of these straw ornaments during many Lithuanian Christmas celebrations (Smithsonian Institution n.d.). Many of the Lithuanian straw ornaments are named; one such design is the Lithuanian sunburst star (Metcalf 1969).



Students work in pairs tying triangles together.

INTRODUCING THE ACTIVITY

Constructing these straw geometric shapes provides an excellent foundation for integrating geometric concepts with content from other disciplines such as social studies, geography, visual arts, and language arts while enhancing creativity, innovation, teamwork, and communication. The culture and traditions of Lithuania and other Baltic countries can be explored within a global context while students use two-dimensional representations to construct geometric shapes, apply transformations, redefine and relearn their understanding of geometric terms, and model communication using geometric language.

The Lithuanian sunburst star lesson is one component of a multidisciplinary project-based unit. The projects in these units have built-in scaffolding to reinforce geometric concepts and vocabulary. They also provide an excellent springboard for exploring the cultures and traditions of different countries; using research skills; and learning about geographical differences, climate, languages arts, and related arts. As such, the projects can be used for middle school team curriculum development. The learning objective articulates how students will connect geometry, visual arts, history, culture, and traditions.

Table 1 The activities of this lesson connect the expectations of several disciplines.

NCTM's Geometry Standard and Expectations	Students will analyze characteristics and properties of two-dimensional geometric shapes; apply transformations; use visualization and spatial reasoning to solve problems; and recognize and apply geometric ideas and relationships in areas outside the math classroom, such as art, science, and everyday life while making and investigating mathematical conjectures and arguments. standards.nctm.org/
NCTM's Curriculum Focal Points	Students will develop an understanding of similarity and analyze two-dimensional figures. www.nctm.org/focalpoints.aspx
Kennedy Center ArtsEdge's Visual Art Standard	Students will understand the visual arts in relation to history and cultures. artsedge.kennedy-center.org/teach/standards.cfm
NCSS's Social Studies Standards	Students will explore culture; time, continuity, and change; people, places, environments; and global connections. www.socialstudies.org/standards/strands/
Partnership for 21st Century Skills	Students will engage in teamwork, increase global awareness, and communicate information using different media. www.21stcenturyskills.org/

TYING THE LESSON TOGETHER

The objectives of this lesson are three-fold. Students will—

1. build a Lithuanian sunburst star by hand;
2. use precise mathematical language to describe characteristics, relationships, and transformations; and
3. make conjectures while studying the culture and history of Lithuania.

The outcomes of these objectives and their alignment to specific NCTM standards, as well as those by other subject areas, can be seen in **table 1**.

By making conjectures regarding characteristics, relationships, and transformations, students will gain confidence in observing, expressing, and making such conjectures. In addition, as the next section explains, students will be able to describe the tradition of making Lithuanian straw ornaments.

The activities will help teachers identify areas where improvement can be made and reveal suggestions to achieve a greater mathematical understanding. Communication skills will be evident in the effectiveness of their ex-

planation of the Lithuanian traditions.

Students can be assessed in these areas:

1. their understanding and use of key vocabulary mathematical words and terms;
2. mastery of describing characteristics, relationships, and transformations using precise mathematical language;
3. their analysis of two-dimensional figures and conjectures (NCTM's Geometry Standard);
4. their understanding of proportionality and similarity (NCTM's Curriculum Focal Points);
5. their understanding of the connection of visual arts to Lithuania's history and culture (Kennedy Center ArtEdge's Visual Arts Standard);
6. identification of connections among traditions, culture, and immigration (NCSS's Social Studies Standards);
7. teamwork, communication, use of information and media, and appreciation of connections between Lithuania and the United States.

DISCUSSION POINTS

A teacher can employ many different techniques to lead class discussions. For example, students can use the “think-pair-share” model for group discussion and share their thinking or responses to questions with a partner. Then student-pairs share their thoughts with the class as the teacher serves as facilitator.

For any discussion point to be effective, the teacher needs to provide the appropriate context that is age and grade appropriate and aligned to the objectives of the lesson. Discussion points are provided for line relationships, symmetry, and transformations such as flips and slides.

In addition to the star, students will need construction paper and nonpermanent marking pens to be able to visually explore the mathematics concepts fully. Use the background paper created in the activity. The line on the paper can be used in explorations for symmetry and as a reference for identification of parallel lines under discussion. Rotating the paper 90 degrees changes the line from a vertical to horizontal reference. Stu-

Social Studies Context of the Lesson

A BRIEF HISTORY

Lithuania is located in eastern Europe between Sweden and Russia, and it borders the Baltic Sea. It has had a tumultuous history. Russia took control of a large part of Lithuania in 1795. The Tzar of Russia banned the use of the Lithuanian language and printing of books after the 1863 insurrection. This ban was in effect for forty years, until 1904 (www.scantours.com 2008).

At the end of World War I, Lithuania declared its independence, which lasted from 1918 to 1940. During the onset of World War II, the Soviet Union annexed the country. In 1990, Lithuania again proclaimed its independence from the Soviet Union. However, it took the collapse of the Soviet Union in 1991 to allow Lithuania to actually break away (www.scantours.com 2008).

TRADITIONS

To northern and eastern Europeans, wheat is much more than a food source. The golden color of wheat and its stalks have long been associated with an early deity, the sun, and with the rays of the sun. Originally, wet pieces of wheat straw were strung together with string to form garlands, mobiles, and geometric-shaped decorations (Smithsonian n.d.).

Teachers need readily available resources when designing instruction. The sources below contain information about the Republic of Lithuania.

Source	Information About	Web Site Address
U.S. Department of State: Bureau of European and Eurasian Affairs	Geography, people, history, government, political conditions, economy, defense, foreign relations, U.S. relations, travel and business, and background notes	www.state.gov/r/pa/ei/bgn/5379.htm
Lithuanian home page	Government, institutions, cultural heritage, maps, and statistics	neris.mii.lt/indexe.php
Lithuanian State Department of Tourism	Tourism statistics and organizations, programs, collaboration, and Ministry of Transport and Communications	www.tourism.lt/en/
The Official Lithuanian travel guide	Culture, travel, food, regions, accommodations, activities, maps, and weather (Check English as the language)	www.travel.lt/turizmas/index.jsp
MapQuest	Maps and a set of quick facts	atlas.mapquest.com/atlas/main.adp?region=lithunia

dents should take notes in their math journals and draw pictures or diagrams to accompany the key geometry vocabulary words.

LINE RELATIONSHIPS

Knots can represent points of intersection. Have enough extra yarn to make small pom-poms or large knots that can be affixed to the points of intersection as decoration when the star is completed. (Supplying yarn in the school colors tie in nicely.)

After only attaching two straws, talk about the different angles that can be made (see **fig. 1a**). Revisit this question after more straws are

attached and the equilateral triangles are formed (see **fig. 1b**). What about the size of the angles now? Can they change? Have students make conjectures as to why or why not. In addition, have students identify and count the number and the parallel lines and the transversals associated with them. A number of characteristics can be identified, and many conjectures can be made.

Alternate interior and exterior angles can be identified. Place the Lithuanian sunburst star on the construction paper so that one of the straws of a pair of parallel straws coincides with the horizontal line drawn on the paper.

Have students push on the other straw of the pair of parallel straws while holding the star on the construction paper. They can predict the result of this change on those alternate interior and exterior angles. Students should also be able to identify pairs of supplemental angles.

This leads to discussions about *perpendicular* and *nonperpendicular*. Although the directions purposely do not require horizontal and vertical straws or perpendicular lines, most students will gravitate toward that form. Discussion on those vocabulary words is a good reinforcement.

After the two triangles are tied

together (see **fig. 1c**), parallelograms can be identified. A review of supplemental angle relationships can be initiated through the study of the parallel lines that form the sides of the parallelograms. The angles can change but within a restricted range after the first parallelogram has been built. This will show students that the angles must change together. Have the students conjecture as to why.

TRANSFORMATIONS

To explore the potential that the star has for transformations, students will need construction paper, plastic or transparency sheets, and nonpermanent marking pens. First, have the students use construction paper and draw a vertical axis and a horizontal axis in different colors so that it is clear which is which. Review the definitions of *horizontal*, *vertical*, and *perpendicular*. Students can take notes in their math journals or math notebook accompanied by pictures or diagrams to accompany key vocabu-

lary words. The students should then repeat drawing the axes on a sheet of plastic or transparency.

Have students place the construction paper on the table with the Lithuanian sunburst star on top. Students can place the star anywhere on the paper; different positions will allow for good discussions with their partners or within their groups, providing more evidence for conjectures. Students can be asked:

- What rotations provide the same figure as the first one?
- How many times can you rotate the star to get the original image?

Have the students place the transparency on top of the star overlapping the axis with the construction paper. Students can trace the straws of the star onto the transparency with a nonpermanent marking pen. Slide the transparency under the sunburst star, so that the stack is ordered in this way: paper, then transparency, then star. Students should align the paper and the transparency so that the axes coincide. Then the sunburst star should be placed on the transparency so that its straws coincide with the drawing.

Slides

Have students gently hold the plastic sheet in place and slide the sunburst star two inches up, carefully keeping the vertical axes on the construction paper and sheet of plastic together, or coinciding. The teacher might need to demonstrate how this works. The student-pairs need to work together to keep the pieces together until the students are familiar with the process.

Students can be asked these questions:

- What do you see?
- How do the Lithuanian starburst star and the drawing of the star compare?
- Compare the axes between the one on the paper and the one on the star. What did the vertical axes do? What happened to the horizontal axes?

Repeat with more vertical slides. Have students draw the result after each slide in their journal or notebook. Making a quick sketch of each result will help those with figure or ground problems to keep track of what is happening. Prompt them by asking what conclusions can be drawn and why. Ask students to explore the result with horizontal slides and compare them with the consequences of vertical slides. Repeat with combination transformations that include both vertical and horizontal slides, such as moving it two inches up and one inch to the left. In doing so, always give the vertical slide first to mimic changes in direction modeled by slope. That will reinforce looking for vertical changes first, which will help later when students calculate slope.

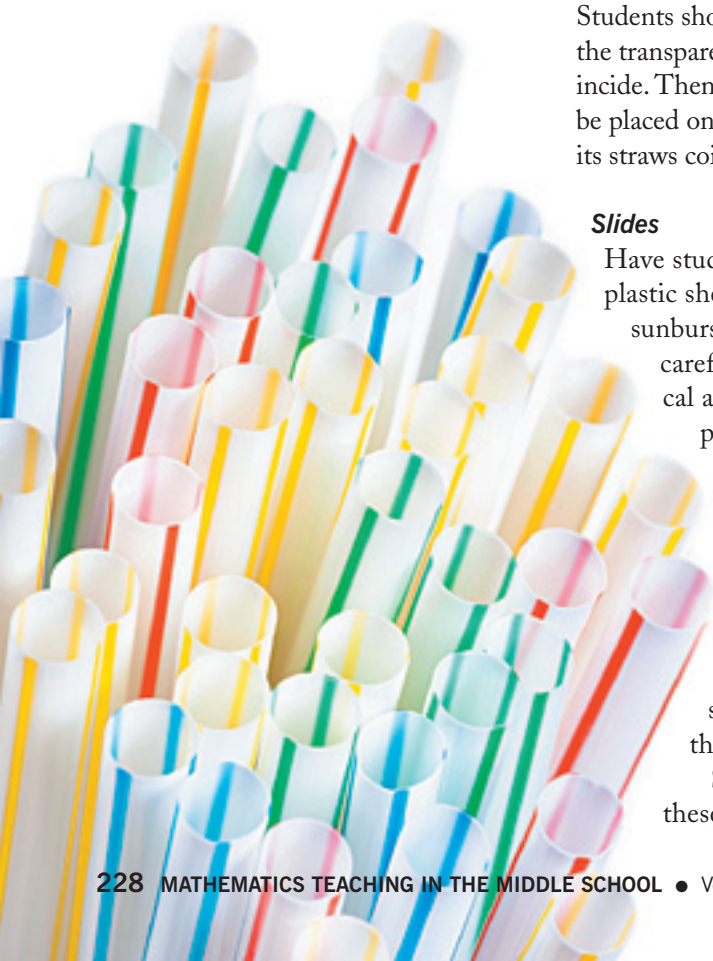
Flips

Gently holding the star in place, students may now flip the transparency from right to left and align the vertical axes. Compare the star and the *drawing* of the star on the plastic sheet.

- Where are the stars in relation to each other?
- How did that happen?
- Did their sizes change?

Students should describe and draw in their math journals what just occurred.

Have students flip the transparency from left to right again. Ask them to compare the results with the previous flip. Repeat the lesson with flips using the horizontal axis as the axis of rotation.



Note that you may need to start a discussion on the difference between a flip and a slide. Because of the likely symmetric properties of the star, the results of a flip and a set of slides could be the same. Have the students review the characteristics of flips and slides using a compare-and-contrast method, which will help make the distinctions clearer.

OTHER OBSERVATIONS

Students can talk about aesthetics. Why do parallel straws appear to be more pleasing? Did anyone in the class not choose to make the straws parallel? Why?

Have the students rotate the Lithuanian sunburst star on the background paper so that one set of parallel straws is perpendicular to the table edge. This could lead to a discussion about symmetry while in the perpendicular form.

Various triangles and parallelograms can be identified, and conjectures about their congruence can begin. As students notice the same shape and sizes of figures nested in the star, conjectures about congruence provide a bridge to a discussion about similarity.

EXTENSIONS AND PROMPTS

Figure 2 presents some extensions and prompts. While students are actively engaged in constructing the Lithuanian sunburst star and participating in teacher-facilitated class discussions, they are—

- making conjectures;
- testing hypotheses; and
- exploring geometric concepts, relationships, and transformations.

Students could make presentations to report their findings and should

be expected to use mathematical language and illustrations or pictures to support their arguments. This will give them practice producing arguments and modeling behavior in presentations to prepare for the assessments that follow.

The prompts, which establish the real-world, global context of the unit, have enough flexibility to be delivered within the mathematics classroom, across grades, or across disciplines. The projects and project-based assessments connect to all the NCTM Curriculum Focal Points (2006) for grades 6, 7, and 8. Partners or cooperative groups could be assigned different projects or the students could be asked to work on parts of the projects throughout the school day in different classes.

The National Mathematics Advisory Panel (2008) recommends using



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Fig. 2 These extensions and prompts will help students think beyond the math classroom.

Prompt 1

Your class has been chosen to present an activity at Math Family Night.

- Give a short background discussion about the Lithuanian sunburst star and its role in the Lithuanian culture.
- Introduce what you have learned about parallel lines and the angles associated with them using your stars as illustrations.

Prompt 2

You work for a travel agency.

- Plan a trip for a group of middle school students and chaperones to Lithuania to see displays of straw ornaments, including the Lithuanian sunburst star.
- Develop a packet of materials and information for a Lithuanian trip.

Prompt 3

Your class wishes to visit Lithuania to see displays of straw ornaments, including the Lithuanian sunburst star.

- Create an itinerary.
- Present the plan to your family and the community to gain support and donations.
- Develop a travel brochure explaining the proposed trip and a presentation on straw ornaments showing what you have learned.
- Give your presentation during Family Math Night or to local business representatives.

formative assessments regularly in the classroom, because their frequent use leads to increased student learning. Therefore, teachers may elect to use these items as formative assessments. Culminating project-based assessments involving presentations on conjectures or travel brochures allow students to demonstrate their newly acquired or refined knowledge and skills and connect with a “real-world” context. The project-based cumulative assessments in **figure 2** are launched with a prompt designed to stimulate student interest and clarify expectations.

An essential element to a student’s success in mathematics is family involvement; many everyday opportunities exist for parents to support and encourage the development of their middle school child’s mathematical skills and understanding. NCTM activities for families (Mirra 2005) are

included in the projects and project-based assessments.

For example, the travel brochures could be displayed as a Family Math Night activity. The Lithuanian sunburst stars and other straw ornaments could be placed next to the brochures, or photographs could be taken of the displays so that the students could take the Lithuanian sunburst stars home.

STUDENTS’ EXPERIENCES

A middle school math teacher, who used this activity with her seventh-grade classes, made these comments:

This activity provides a great break away from the drill and practice that we find ourselves in so many times in the mathematics classroom. It is a wonderful reinforcement of skills and terminology taught in early geometry.

I was amused at how students applied the mathematical terminology throughout the project. Instead of saying “That piece goes here,” they would say things like “that piece is parallel; it intersects; or it is congruent with.” Ensuring that students worked with a partner reduces student frustration. A few weeks after we completed this project, we had a locker clean out; several of my students had their ornaments proudly displayed. (Personal correspondence 2005)

Her students made the following comments:

- “This project was very challenging, but the math relationship was understandable and helpful.”
- “A lot of fun!”
- “This project was excellent; it really helped me better understand congruency.”
- “The math terms in the directions were pretty hard. It forced us to realize the meanings of the terms, which made it easier.”
- “This project made you think.”
- “Challenging, hard.”

SUMMARY

The lesson, including the construction of the Lithuanian sunburst star ornament, provides an excellent foundation for a multicultural or multidisciplinary unit connecting geometric concepts with those from other disciplines. Students are not only learning geometry and using mathematical language but also exploring the cultures and traditions of Lithuania. While students are constructing their geometric understanding from objects that they made, they are making connections to other disciplines and increasing their global awareness.

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