Frank Lloyd Wright: Materials Science and Algebra in Prairie Style Art Glass

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Introduction

This lesson is intended for students in Grades 7 - 10 as an introduction to the mathematics and materials science of Frank Lloyd Wright's Prairie Style art glass.

Stained glass was used to illuminate church windows as early as 700 CE. During the medieval ages, it was developed into a high art form. Even today, people are inspired by stained glass windows, both ancient and modern. The American architect Frank Lloyd Wright often used leaded art glass for windows and other design elements. His use of the Prairie Style, seen in many famous buildings in Illinois, is characterized by art glass with geometric designs. The bold, linear patterns can be described using the language of mathematics.

Scientists often look for patterns in nature. One may also see patterns in an identifiable art style. Artists who embrace design constraints, whether intentionally or subconsciously, will leave patterns in their creations. This activity involves identifying patterns, describing them as design constraints, and then attempting to create an appealing work within those constraints. Students will also learn what types of materials are used in stained glass to give it color.

Logistics

Materials (*per team of two or three students):*

- Student Pages
- 1 sheet of graph paper (20x30 squares or larger)
- 1 sheet of tracing paper
- 1 sheet of construction paper
- 1 roll of tape
- 1 ruler or straight edge
- 1 computer with internet access
- Colored markers

Time: 80 minutes (may be split over multiple class periods)

Objectives

- Explore the mathematical design constraints of Frank Lloyd Wright's Prairie Style art glass.
- Research the materials added to glass which give it color and other optical properties

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Standards

Next Generation Science Standards:

MS-ETS1-1, Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts.

Common Core State Standards for Mathematics:

7.NS.A.3, Solve real world and mathematical problems involving the four operations with rational numbers

8.EE.C.7, Solve linear equations in one variable

8.EE.C.8, Analyze and solve pairs of simultaneous linear equations

HSH.REI.B.3, Solve linear equations and inequalities in one variable, including equations with coefficients represented by letters

Prior Knowledge

This activity will connect with and build upon the following prior knowledge:

- Basic geometry: lines and line segments
- Parallel and perpendicular lines
- Plotting points on a coordinate plane
- Graphing linear equations in standard form
- Slope and y-intercept

Suggested Inquiry Approach

1. Show example photos of Prairie Style art glass. Photos may be found with a Google image search using keywords “wright prairie style art glass”. Allow students to characterize the constraints of the style, first with their partners, and then as an entire class.

2. Students choose an appropriate height for their window, draw its outline on graph paper, and add coordinate axes. Then they select six pairs of horizontal and vertical lines to draw on their graph paper. While students are plotting their lines, look for opportunities to ask questions such as:

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- What do you notice about the lines formed by these pairs?
- What type of equation illustrates a horizontal line?
- What type of question illustrates a vertical line?
- What is the slope of a vertical line?
- What is the slope of a horizontal line?
- What can be said about the y-intercepts of vertical and horizontal lines?

3. Next they select five or six pairs of diagonal lines to add to the design. While students are plotting their lines, look for opportunities to ask questions such as:

    - What do you notice about the lines formed by these pairs?
    - What slope values are illustrated by these diagonal lines?
    - Where does each pair of diagonal lines intersect?
    - Consider how each equation in this activity is paired with a "partner" equation. Given a single linear equation in standard form, how would you algebraically represent its "partner" equation?

4. Placing their tracing paper "glass" over their graph paper, students select which line segments they want to actually be a part of the window. They draw these line segments onto the "glass".

5. Students go to the internet to research what materials were used to add color to glass. Students must obtain your approval before actually coloring their windows. Keep the colored markers in your possession until the students have shown you sufficient information. When they are completed you may allow students to frame their work for display in a classroom window.

Debrief questions

- Are mathematical design constraints compatible with artistic creativity?
- Can you think of other arts which employ design constraints?
- Are there any colors of stained glass which can be made from more than one material? If so, how would you choose the material?

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Extensions

- Have students identify examples of key terms in Geometry using their window and the list of vocabulary words on the final page.
- Some of the materials used in stained glass are expensive. Predicting the cost of a window requires knowing the amount of each color needed. Have students calculate the area (measured in blocks or square centimeters) of each different color used in their design.
- Use pairs of equations with integer coefficients, then fractional coefficients.
- Provide students with a single equation and have them develop a "partner" equation which is perpendicular, but shares the same y-intercept.
- Provide students with a single equation and have them develop a "partner" equation which is parallel.

Resources

- Purple Math – "Using slope and y-intercept to graph lines" www.purplemath.com/modules/stopgraph2.htm
- Algebra-class.com – "Graphing a linear equation using slope intercept form" www.algebra-class.com/slope-intercept-form.html
- Algebra-class.com –"Using a table of values to graph linear equations" www.algebra-class.com/table-of-values.html
- Frank Lloyd Wright Buildings in IL: http://franklloydwrightsites.com/illinois/illinois.htm
- Robie House in Chicago: http://architecture.uchicago.edu/locations/robie_house/
- Dana Thomas House in Springfield: http://www.dana-thomas.org/
- Materials that give stained glass its color: http://1st-glass.1st-things.com/articles/glasscolouring.html http://nano--tech.blogspot.com/p/history.html http://geology.com/articles/color-in-glass.shtml http://chemistry.about.com/cs/inorganic/a/aa032503a.htm

Stained glass was used to illuminate church windows as early as 700 CE. During the medieval ages, it was developed into a high art form. Even today, people are inspired by stained glass windows, both ancient and modern.

In this activity you will study the mathematics and materials science involved in making stained glass. Using this knowledge you will create a design using the Prairie Style made famous by architect Frank Lloyd Wright.

Questions:

- What mathematical principles constrain the designs of the Prairie style?
- What materials are added to glass to give it color and other optical properties?

Materials for this Activity: You and your partner will need:

- A computer with internet access
- 1 sheet of graph paper
- 1 sheet of tracing paper
- 1 sheet of construction paper
- 1 black marker
- 1 roll of tape
- 1 ruler

Procedure:

1. Characterizing the Prairie Style

Watch the slide show presented by your teacher. Look at the examples of Prairie Style stained glass. With your partner, record some observations about the patterns you see. Look for things which most of the windows have in common. Try to describe at least five observations about the "rules" of this style.

- _____
- _____
- _____
- _____
- _____
- _____

As a class, share your observations. Any valid observations which are not already on your list should be added below:

- _____
- _____
- _____
- _____
- _____
- _____

2. Design – Choosing Horizontal and Vertical Lines

On a sheet of graph paper, you are about to draw a rectangle, roughly in the center of the page. The rectangle will be 20 squares wide and somewhat taller than the width. Consider your observations above and decide what the proper height should be. Choose an even number of squares.

Height = _____ squares

Go ahead and draw the rectangle in the center of your graph paper. This will be the size of your window design.

Draw a coordinate plane with the origin at the center of your rectangle. Label the *x* and *y* axes.

A number of equations are listed below. They are presented in pairs. Each pair represents two lines that could be drawn on your coordinate plane.

Don't draw them all! Just pick three pairs from the left column and three more pairs from the right column. Circle the six equation pairs you have selected.

Pick 3 of these pairs:	and 3 of these pairs:
y = 1, y = -1	x = 0, x = 0
y = 2, y = -2	x = 2, x = -2
y = 4, y = -4	x = 3, x = -3
y = 6, y = -6	x = 4, x = -4
y = 8, y = -8	x = 5, x = -5
y = 10, y = -10	x = 6, x = -6
y = 12, y = -12	x = 7, x = -7
y = 13, y = -13	x = 8, x = -8
y = 14, y = -14	x = 9, x = -9

Draw the lines represented by your chosen equations on your graph paper. You should have six vertical lines and six horizontal lines when you are finished.

3. Design – Choosing Diagonal Lines

More equation pairs are listed below. Select and circle five or six of these pairs. Add their lines to your coordinate plane.

y = x + 1, y = -x + 1	y = x + 2, y = -x + 2	y = x + 3, y = -x + 3
y = x + 4, y = -x + 4	y = x + 5, y = -x + 5	y = x + 6, y = -x + 6
y = x + 7, y = -x + 7	y = x + 8, y = -x + 8	y = x + 9, y = -x + 9
y = x - 1, y = -x - 1	y = x - 2, y = -x - 2	y = x - 3, y = -x - 3
y = x - 4, y = -x - 4	y = x - 5, y = -x - 5	y = x - 6, y = -x - 6
y = x - 7, y = -x - 7	y = x - 8, y = -x - 8	y = x - 9, y = -x - 9

You should now have a rectangular frame with a bunch of straight lines. These lines intersect in many places. Between each of these intersections is a line segment. Some of these line segments will become part of your

window. Some will not. You must decide which line segments give the most pleasing design, without violating the "rules" of the Prairie Style.

4. Tracing Selected Line Segments

Place a sheet of tracing paper over your graph paper. To keep everything steady, you might use a bit of tape to fix the tracing paper to the graph paper, and the graph paper to your table.

The tracing paper is the "glass" of your window. Using a black marker and a ruler, trace the outer rectangle of your window.

Review the list of "rules" for the Prairie Style stained glass.

Now start selecting line segments from your graph paper to trace onto your "glass". Use a black marker and a ruler to trace the desired line segments. You need not actually count them, but using about half of the line segments should give you a good window design.

Once you have finished tracing line segments onto your "glass", lift it from the graph paper and review your design. Does it look something like the Prairie style designs of Frank Lloyd Wright? Make any additions you think are needed to perfect your design. Feel free to bend a rule or two at this point if you think you should.

5. Adding Color

Your design has many small geometrical shapes. Each shape represents a separate piece of glass. About 75% of the pieces should be left clear and uncolored. The Prairie Style window is intended to admit light and color, but also to allow one to see outside, just like a regular window.

Decide which pieces of your glass will be colored. Approximately 1 piece out of 4 should be colored. Decide what colors you wish to use. Your palette is restricted to the colored markers you have.

Choose two or three colors and record them in the table below:

Color	Materials added to glass which produce this color	Adverse impacts of using this material

Before your teacher gives you a colored marker you will have to do some research to learn what materials are added to glass to give it that color. You may research both ancient and modern coloring techniques. Record what you learn in the table above. Be sure to consider any possible consequences or negative impacts associated with the chosen materials.

To help you find information, several links have been assembled here:

Go to the **trackstar.4teachers.org** website

Enter the following track number: **458125**

Enter the password: **FUSION**

Select "View in Frames".

When you have finished coloring your glass, you may wish to frame it. Take a sheet of construction paper and cut out an opening of the appropriate size to hold your stained glass.

Optional Extension:

Place a sheet of tracing paper over your window. On the tracing paper, outline and identify as many of the following Geometrical features as possible.

acute angle	parallel lines
obtuse angle	parallelogram
right angle	perpendicular lines
adjacent angles	quadrilateral
complementary angles	rectangle
supplementary angles	reflection
congruent polygons	rhombus
corresponding angles	right triangle
line of reflection	square
line of symmetry	straight angle
similar polygons	trapezoid
isosceles triangle	vertical angles