Distance Learning at the Cleveland Museum of Art

Tessellation Exploration!

Grades 7-12

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Teacher notes:
Please have students bring pencils and the Viewing Guide to the distance learning program. Students will be completing this activity sheet during the lesson.

*Optional - If you would like the class to do the “Everyday Tessellate” activity during the conference, please bring t6re34he suggested materials. (Photocopies of Everybody Tessellate!, 8.5” x 11” card stock or paper, pencils, markers, rulers, scissors, index cards, scotch tape.)
**How to Prepare Your Class for the Distance Learning Presentation**

Teacher Information will be sent or made available to you prior to the program.

Please familiarize yourself with the materials and discuss them with your class.

Have the Teacher Information Packet (T.I.P.) materials on hand in the classroom, ready for the program. These materials may be used during the videoconference.

Be prepared to facilitate by calling on students yourself during the lesson. Students are sometimes initially shy about responding to questions during a distance learning lesson.

Explain to students that this is an interactive medium and encourage them to ask questions.

Reinforce topics discussed in the program by asking students to complete some of the suggested pre- and post-conference activities in the Teacher Information Packet.

We ask teachers, after the program, to please fill out the Evaluation Form and return it to:

Dale Hilton/Distance Learning  
The Cleveland Museum of Art  
11150 East Boulevard  
Cleveland, OH 44106

Thank You!
Tessellation Exploration!

Grades 7-12

Teacher Information Guide:

Program Objectives:

Students will learn and understand...

1. How different cultures have used math in the form of tessellations in their artwork.
2. The differences between various types of tessellations.
3. How math can be used to create art.

Common Core State Standards Applicable:

English Language Art & Literacy in History/Social Studies, Science, and Technical Subjects- 7th Grade

CCSS.ELA-Literacy.SL.7.1
Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher led) with diverse partners on grade 7 topics, texts, and issues, building on others’ ideas and expressing their own clearly.

CCSS.ELA-Literacy.SL.7.5
Include multimedia components and visual displays in presentations to clarify claims and findings and emphasize salient points.

CCAA.ELA-Literacy.W.7.6
CCAA.ELA-Literacy.WHST.7.6
Use technology, including the Internet, to produce, publish, and update individual or shared writing products in response to ongoing feedback, including new arguments or information.

CCSS.ELA-Literacy.W.7.7
CCSS.ELA-Literacy.WHST.7.7
Conduct short research projects to answer a question, drawing on several sources and generating additional related, focused questions for further research and investigation.

8th Grade

CCSS.ELA-Literacy.SL.8.1
Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher led) with diverse partners on grade 8 topics, texts, and issues, building on others’ ideas and expressing their own clearly.

CCSS.ELA-Literacy.SL.8.5
Integrate multimedia and visual displays into presentations to clarify information, strengthen claims and evidence, and add interest.

CCAA.ELA-Literacy.W.8.6
CCAA.ELA-Literacy.WHST.8.6
Use technology, including the Internet, to produce, publish, and update individual or shared writing products in response to ongoing feedback, including new arguments or information.

CCSS.ELA-Literacy.W.8.7
CCSS.ELA-Literacy.WHST.8.7
Conduct short research projects to answer a question (including a self-generated question), drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration.

Grades 9-10
CCSS.ELA-Literacy.SL.9-10.1
Initiate and participate effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grades 9–10 topics, texts, and issues, building on others’ ideas and expressing their own clearly and persuasively.

CCSS.ELA-Literacy.SL.9-10.5
Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest.

CCSS.ELA-Literacy.W.9-10.7
CCSS.ELA-Literacy.WHST.9-10.7
Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.

Grades 11-12
CCSS.ELA-Literacy.SL.11-12.1
Initiate and participate effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grades 11-12 topics, texts, and issues, building on others’ ideas and expressing their own clearly and persuasively.

CCSS.ELA-Literacy.SL.11-12.5
Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest.

CCSS.ELA-Literacy.W.11-12.6
CCSS.ELA-Literacy.WHST.11-12.6
Use technology, including the Internet, to produce, publish, and update individual or shared writing products in response to ongoing feedback, including new arguments or information.

CCSS.ELA-Literacy.W.11-12.7
CCSS.ELA-Literacy.WHST.11-12.7

Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.

Math-
7th Grade:
CCSS.Math.7.G.A.2
Draw (freehand, with ruler and protractor, and with technology) geometric shapes with given conditions. Focus on constructing triangles from three measures of angles or sides, noticing when the conditions determine a unique triangle, more than one triangle, or no triangle.

CCSS.Math.7.G.B.5
Use facts about supplementary, complementary, vertical, and adjacent angles in a multi-step problem to write and solve simple equations for an unknown angle in a figure.

CCSS.Math.7.G.B.6
Solve real-world and mathematical problems involving area, volume and surface area of two- and three-dimensional objects composed of triangles, quadrilaterals, polygons, cubes, and right prisms.

8th Grade:
CCSS.Math.8.G.1
Verify experimentally the properties of rotations, reflections, and translations.

CCSS.Math.8.G.A.2
Understand that a two-dimensional figure is congruent to another if the second can be obtained from the first by a sequence of rotations, reflections, and translations; given two congruent figures, describe a sequence that exhibits the congruence between them.

CCSS.Content.8.G.A.3
Describe the effect of dilations, translations, rotations, and reflections on two-dimensional figures using coordinates.

CCSS.Content.8.G.A.4
Understand that a two-dimensional figure is similar to another if the second can be obtained from the first by a sequence of rotations, reflections, translations, and dilations; given two similar two-dimensional figures, describe a sequence that exhibits the similarity between them.

High School:
CCSS.Math.HS.G-CO.2
Represent transformations in the plane using, e.g., transparencies and geometry software; describe transformations as functions that take points in the plane as inputs and give other
points as outputs. Compare transformations that preserve distance and angle to those that do not (e.g., translation versus horizontal stretch).

**CCSS.Math.HS.G-CO.10**
Prove theorems about triangles.

**CCSS.Math.HS.G-CO.12**
Make formal geometric constructions with a variety of tools and methods (compass and straightedge, string, reflective devices, paper folding, dynamic geometric software, etc.).

**National Education Standards:**

*For Fine Arts - Visual Arts (grades 5-8, 9-12):*
- Understanding and applying media, techniques, and processes.
- Using knowledge of structures and functions.
- Understanding the visual arts in relation to history and cultures.
- Making connections between visual arts and other disciplines.

*For Mathematics – Geometry (grades 6-8, 9-12):*
- Analyze characteristics and properties of two-dimensional geometric shapes and develop mathematical arguments about geometric relationships.
- Specify locations and describe spatial relationships using coordinate geometry and other representational systems.
- Apply transformations and use symmetry to analyze mathematical situations.
- Use visualization, spatial reasoning, and geometric modeling to solve problems.

*For Language Arts - English (grades K-12):*
- Evaluation Strategies
- Communication Skills
- Applying Knowledge
- Evaluating Data
- Developing Research Skills

**Program Description:**
The Cleveland Museum of Art has an extensive collection of tessellated art. It is with some of these pieces that this lesson was written. The use of math and tessellations in art is more common than most people think. Different cultures have used patterns and tessellations in their artwork as a decorative and symbolic part of their heritage. Artists
have been mesmerized by the beautiful complexity of tessellations, trying to imitate the
forms that they see in architecture and nature.

In this lesson, we will explore how math is used to create a variety of objects, from
intriguing artwork of the ancient Egyptians, to the intricate work of M.C. Escher. The
museum’s collection will be used to illustrate mathematical concepts about polygons and
different kinds of tessellations. Students will see that math is used extensively in the
creative world of art and architecture.

Prior to the Program:
1. Have students review the vocabulary. They should have a clear understanding of
   the terms provided.
2. Discuss how art and math can be related. What artists and cultures have used
   math and/or tessellations in their artwork?

Selected Vocabulary:
Polygon - a figure formed by three or more segments connecting only at their end points

Vertex of a polygon - point where two sides meet. Two or more of these points are
called vertices.

Side - one of the line segments making up the figure.

Convex Polygon - a polygon in which no interior angle is greater than 180 degrees (all of
the interior angles “point out.”) A line segment drawn between any two vertices of a
convex polygon would remain inside the boundaries of the figure.

Concave polygon - a polygon is concave if at least one of its internal angles is greater
than 180 degrees. A concave polygon must have at least four sides. (It appears to “cave
in.”) In a concave polygon, you could draw a line segment between a pair of vertices that
would fall outside of the boundaries of the figure.

Regular Polygon - a polygon that is equilateral and equiangular.

Tessellation - an arrangement of closed figures, such that the plane is completely covered
with no gaps between figures
Regular tessellation - a tessellation, or tiling, involving one regular polygon (only possible with squares, equilateral triangles, and hexagons).

Non-regular tessellation - a tessellation using non-regular polygons.

Schläfli symbol - this is the notation used to specify tessellations, such as \{6, 3\}. The first number (6) is the number of side the polygon has, and the second number (3) is number of polygons that touch at each vertex of the tessellation.

Pure tessellation - a tessellation using only one shape (could be regular or non-regular).

Semi-pure tessellation - a tessellation involving more than one shape.

Semiregular (Semi-regular) tessellation - a semi-pure tessellation of regular polygons (more than one regular polygon is used) in which the arrangement at each vertex is the same. (The same shapes appear, in the same sequence.)

Demiregular (Demi-regular) tessellation - a semi-pure tessellation of regular polygons (more than one regular polygon is used) in which the arrangement at each vertex is not the same.

Teaching Extensions:

1. Language Arts

   Have students choose and research an artist or culture that uses tessellations. Allow students to present their findings to the class through a PowerPoint presentation.

   Materials needed: Computers, internet, PowerPoint program, research books and materials

2. Math

   Photocopy the enclosed Math worksheets, *Tessellations: The Angle Sum of a Convex Polygon*, for each student to complete after the lesson.

3. Visual Arts

   *(This activity can be done during the videoconference, if the class brings the materials to the session. Otherwise it could be done as a follow-up activity.)*

   Photocopy *Everybody Tesselate!* for each student. Have students make their own tessellation in the form of M.C. Escher.

   Materials needed: Photocopies of *Everybody Tesselate!*, 8.5” x 11” card stock or paper, pencils, markers, rulers, scissors, index cards, scotch tape.
TEACHER RESOURCE LIST

Recommended Reading:

Web Sites:
For students...

Provides samples, descriptions and do it yourself instructions.

A short activity that allows students to see how certain shapes tessellate.

Math is Fun [http://www.mathisfun.com/geometry/tessellation-artist](http://www.mathisfun.com/geometry/tessellation-artist)
An activity to create your own tessellation.

For teachers...

An introduction to Escher’s work and how he incorporated math into his art.

Provides great descriptions of tessellations and the geometry involved in tessellations.

This Teacher Information Packet and Distance Learning lesson were developed with assistance of Kristin LaGuardia, Teacher, Cuyahoga Community College, Cleveland, Ohio and Lenaia Burbank, Educator, The Cleveland Museum of Art.
Tessellation Exploration! Viewing Guide

Below are three pieces of art that are shown in the lesson that include a regular tessellation. What type of polygon is used in the regular tessellation on each piece?

A. Mummy Case -

B. A Bishop Saint with Donor -

C. The Terrible Adventures of Scholastica -

Define and draw an example of each of the following tessellations:

<table>
<thead>
<tr>
<th>Types of Tessellation</th>
<th>Definition</th>
<th>Diagram/Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regular Tessellation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Semi-Pure Tessellation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Demi-Regular Tessellation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-Regular Tessellation</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Tessellation Examples:

What polygons do you see at each vertex?

Semiregular Tessellation Example 1

Semiregular Tessellation Example 2

What polygons do you see at each vertex?
Demiregular Tessellation
Example 1

At vertex A:
____________________________
____________________________
____________________________
____________________________

At vertex B:
____________________________
____________________________
____________________________
____________________________

Demiregular Tessellation
Example 2

At vertex A:
____________________________
____________________________
____________________________
____________________________

At vertex B:
____________________________
____________________________
____________________________
Tessellation Exploration! Viewing Guide – Answers

Below are three pieces of art that are shown in the lesson that include a regular tessellation. What type of polygon is used in the regular tessellation on each piece?

A. *Mummy Case* - **Squares**

B. *A Bishop Saint with Donor* - **Squares**

C. *The Terrible Adventures of Scholastica* – **Hexagons (on floor)**

Define and draw an example of each of the following tessellations:

<table>
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<tr>
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<th>Definition</th>
<th>Diagram/Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regular Tessellation</td>
<td>It is one involving regular polygons. Regular polygons are polygons that are equilateral and equiangular</td>
<td></td>
</tr>
<tr>
<td>Semi-Pure Tessellation</td>
<td>A tessellation involving more than one shape</td>
<td></td>
</tr>
<tr>
<td>Demi-Regular Tessellation</td>
<td>A semi-pure tessellation of regular polygons in which the arrangement at each vertex is not the same</td>
<td></td>
</tr>
<tr>
<td>Non-Regular Tessellation</td>
<td>A tessellation using non-regular polygons.</td>
<td></td>
</tr>
</tbody>
</table>

**Tessellation Examples:**

Semiregular Tessellation Example 1
What polygons do you see at each vertex?

- **Octagon**
- **Octagon**
- **Square**

Semiregular Tessellation Example 2
What polygons do you see at each vertex?

- **Hexagon**
- **Square, Triangle**
- **Square**
Demiregular Tessellation
Example 1

At vertex A:

- Hexagon
- Hexagon
- Triangle
- Triangle

At vertex B:

- Triangle, Triangle
- Triangle, Triangle
- Triangle
- Triangle

Demiregular Tessellation
Example 2

At vertex A:

- Hexagon
- Square
- Triangle
- Square

At vertex B:

- Hexagon
- Square
- Square
- Triangle
Tessellation Exploration! The Angle Sum of a Convex Polygon
Part I

Using a straightedge, draw a triangle.

What is the angle sum of a triangle? ____________

Using a straightedge, draw any convex quadrilateral ABCD. Draw diagonal AC.

What is the angle sum of triangle ABC? _________
What is the angle sum of triangle ACD? _________

What conclusion can you draw about the angle sum of quadrilateral ABCD? ________________________
Using a straightedge, draw any convex pentagon ABCDE. From vertex A, draw all of the possible diagonals.

Pentagon ABCDE is now divided into _____ triangles.
What is the angle sum of ABCDE? ____________

Continue this pattern with the next polygon. Draw a convex hexagon and draw all of the diagonals from one of the vertices. Look for a pattern relating the number of sides of the polygon to the number of triangles into which the polygon is divided. Once you have determined the number of triangles, multiply that number by the triangle angle sum to determine the angle sum of the polygon itself.

What is the angle sum of the hexagon?__________
Now let’s generalize this for a polygon with \( n \) sides.

A polygon with \( n \) sides can be divided into ______________ triangles by drawing all of the possible diagonals from one vertex.

The angle sum formula for a polygon with \( n \) sides is ____________________.

Use the formula you derived to determined the angle sum of the following polygons:

a. Heptagon ___________

b. Octagon ___________

c. Nonagon ___________

d. Decagon ___________

e. 15-gon ___________

f. 47-gon ___________
Tessellation Exploration! The Angle Sum of a Convex Polygon - ANSWER KEY

Part I

Using a straightedge, draw a triangle.

What is the angle sum of a triangle? 180

Using a straightedge, draw any convex quadrilateral ABCD. Draw diagonal AC.

What is the angle sum of triangle ABC? 180
What is the angle sum of triangle ACD? 180

What conclusion can you draw about the angle sum of quadrilateral ABCD? 360 Degrees, the sum of two triangles
Tessellations:
Part II

Using a straightedge, draw any convex pentagon ABCDE. From vertex A, draw all of the possible diagonals.

Pentagon ABCDE is now divided into 3 triangles.
What is the angle sum of ABCDE? 3(180) = 540

Continue this pattern with the next polygon. Draw a convex hexagon and draw all of the diagonals from one of the vertices. Look for a pattern relating the number of sides of the polygon to the number of triangles into which the polygon is divided. Once you have determined the number of triangles, multiply that number by the triangle angle sum to determine the angle sum of the polygon itself.

What is the angle sum of the hexagon? 720
Tessellations:
Part III

Now let’s generalize this for a polygon with \( n \) sides.

A polygon with \( n \) sides can be divided into \( \frac{n-2}{2} \) triangles by drawing all of the possible diagonals from one vertex.

The angle sum formula for a polygon with \( n \) sides is \( \sum (n-2)180 \).

Use the formula you derived to determined the angle sum of the following polygons:

\begin{align*}
g. \text{ Heptagon} & \quad 900 \\
h. \text{ Octagon} & \quad 1080 \\
i. \text{ Nonagon} & \quad 1260 \\
j. \text{ Decagon} & \quad 1440 \\
k. \text{ 15-gon} & \quad 2340 \\
l. \text{ 47-gon} & \quad 8100
\end{align*}
Everybody Tessellate!

Everyone has a little M.C. Escher inside of them. Follow the steps below to create your own tessellation.

- Using the index card cut it into a square or rectangle.
- Cut shapes out of the square. (Step 2) You can cut any shape you would like.
- Take the cut out shape and tape it to the opposite side of the square. (Step 3)
- You now have your template!
- Place your template on the 8.5” x 11” card stock or paper and trace it.
- Move the template over and trace it again so that it interlocks with the other image.
- Continue this until the entire sheet has been filled.

Some things to think about when planning your tessellation:

- How complex do you want to make your figure?
- How will you use color or imagery to alter your tessellation?
- Do you have a theme?

Step 1

Step 2

Step 3
The Cleveland Museum of Art Distance Learning Evaluation Form

Your Name______________________________________________________________
Your School_____________________________________________________________
School Address (with zip code) ____________________________________________
E-mail Address __________________________________________________________
Grade/Class of students (e.g. 10th grade French) ______________________________
Program Title ___________________________________________________________
Program Date ___________________________________________________________________

Thank you so much for your participation in our distance learning program. We would appreciate your response to these questions by circling the appropriate answer and returning the survey. Please Mail or Fax to Dale Hilton at 216-707-6679

5= Strongly Agree  4= Agree  3= Neither Agree nor Disagree  2= Disagree  1= Strongly Disagree

1. The teacher information packet was helpful for preparing my class and me for the distance learning lesson.
   5    4    3    2    1

2. The teaching style of the on-camera instructor was interesting, engaging and fostered interaction.
   5    4    3    2    1

3. The Teacher Information Packet was helpful in providing interdisciplinary extension activities that I did use or plan to use.
   5    4    3    2    1

4. The distance learning lesson successfully taught its objectives.
   5    4    3    2    1

5. The distance learning lesson was not interrupted by technical difficulties.
   5    4    3    2    1

6. The pre-requisites the distance learning lesson and extensions are aligned with The National Education standards.
   5    4    3    2    1

7. I plan to register for another distance learning lesson.
   (circle one)  Yes        No
   If no, why?______________________________________________________________

Page 21 of 24
8. I would like more information about The Cleveland Museum of Art’s Teacher Resource Center.
   
   (circle one)  
   Yes  
   No

9. Why did you choose The Cleveland Museum of Art Distance Learning?
   (circle one)
   
   a.) Price Point  
   b.) Quality of lessons  
   c.) Selection of lessons  
   d.) Ease of working with CMA  
   e.) Other

10. How did you hear about The Cleveland Museum of Art Distance Learning program?
    (circle all that apply)
    
    a.) CMA inservice  
    b.) CILC  
    c.) TWICE  
    d.) Conference  
    e.) Brochure  
    f.) The Cleveland Museum of Art website  
    g.) The Teacher Resource Center  
    h.) Other

11. Do you have any additional comments about the distance learning lesson?

__________________________________________________________________________
__________________________________________________________________________
__________________________________________________________________________

Please return the completed teacher evaluation form to:

Dale Hilton/Distance Learning  
The Cleveland Museum of Art  
11150 East Boulevard  
Cleveland, OH 44106

Please Mail or Fax to Dale Hilton at 216-707-6679
The Terrible Adventures of Scholastica: Illustration, Page 5, 1931
Maurits Cornelis Escher (Dutch, 1898-1972)
Wood engraving
2004.79

Crown, 1900s
Guinea Coast, Nigeria, Yoruba, 20th century
Cloth, glass beads, basketry, cardboard, wood, feather quills
1995.22
The Cleveland Museum of Art
Selected Images for Tessellation Exploration!

.Floor Mosaic Panel: Grape Harvester with Peacock, c. 400’s,
Byzantium, Northern Syria, Byzantine period,
5th century
Marble Tesserae
1969.112

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Byzantium, Northern Syria, Byzantine period,
5th century
Marble Tesserae
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