For each group:
- clay (see Management 2)
- toothpicks
- 1 container such as a half-gallon milk carton

Background Information
Geo-panes are defined as the pattern of panes, or soap film, created by dipping shapes into a water and soap solution. Patterns which might be expected to form around the sides of the polyhedrons meet, instead, near the center. The elastic, rubbery skin (surface tension) of the soap film stretches to cover the smallest possible area or minimum surface. Less area is covered when the soap film comes toward the center than if it were to cover the faces around the geometric shape.

The activity begins with the triangle and the square. They have two dimensions, length and width. A third dimension, height, is added when the tetrahedron, cube, triangular prism, and pyramid are built. These three-dimensional shapes are also known as polyhedrons, many-sided figures.

Students might also explore the relationship between vertices, edges, and faces for the polyhedrons they made. The formula, called Euler’s (pronounced oilers) Theorem, states that \( v + f = e + 2 \). This is true for all convex polyhedrons. These are polyhedrons whose frameworks, if covered, have no indentations.

<table>
<thead>
<tr>
<th>Shapes</th>
<th>2-D</th>
<th>3-D</th>
</tr>
</thead>
<tbody>
<tr>
<td># of Vertices (points)</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td># of Edges (line segments)</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td># of Faces (sides)</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

Management
1. This activity will take about 60 to 90 minutes.
2. All figures are made using whole toothpicks.
3. To anchor the toothpicks at the vertices, use oil-based (plasticine) clay rolled into 1 cm balls. Scratch paper helps protect desks while rolling clay. You may prefer to use raisins or dry legumes (soak several hours to soften) instead of clay.
4. Groups of three or four should build the four polyhedrons shown on the activity sheet, each member being responsible for at least one.

5. Spread newspaper over the dipping area (tables or floor), preferably away from desks. Dipping can be done outside if the air is still.

6. For each container, pour water to a depth of no less than 9 cm, add a good squirt of liquid soap, and stir gently so bubbles do not form. If you prefer, have students measure about one liter of water and 15 ml of soap for each container. Another 15 ml of granulated sugar or glycerin (found in drugstores) may be added to strengthen the solution.

7. Caution students to dip carefully so the surface of the soapy water stays relatively free of foam and bubbles. Skim them off if necessary. The bubbles can make it difficult to see the pattern or can actually change it.

8. Students will want to experiment with more complex designs of their own. Suggest they use smaller sections of toothpicks for these.

9. To cut through the soapy film when cleaning up, sprinkle some vinegar on the wet areas and rub dry.

**Procedure**

1. Give each student a small lump of clay, about 12 toothpicks, about 50 cm of thread, and the activity sheet.

2. Have each student build a square or triangle with the toothpicks and clay. They should record the number of vertices and edges.

3. Borrow a triangle and dip it in the soapy water. Explain that, for this activity, the resulting pane will be called a geo-pane. Students should record that it has one face or flat surface. Repeat with the square. Students might notice that both two-dimensional shapes have one face.

4. Ask students to predict what will happen when they dip a three-dimensional shape in the soapy water. Give students a chance to verbalize their ideas before writing their predictions.

5. Instruct students to use their triangle or square to build one of the three-dimensional shapes. Each group should decide who will build which shape so that all of the polyhedrons shown are represented.

6. Have students record the number of vertices, edges, and faces for these shapes BEFORE they go anywhere near the soapy water. Help them determine the number of faces, if needed, as this may be a new term to them.

7. Show students how to slip the thread under one, and only one, toothpick and hold the thread by both ends as shown on the activity sheet. Do not tie the thread to the toothpick.

8. Students should carry their shapes to the dipping area and take turns completely submerging them in the soapy water. They should dip each shape several times to see if the pattern stays the same. Students will likely want to build and try additional shapes.

9. Hold a concluding discussion and have students write about what happened.
# GEO-PANES

What kind of Geo-pane can be made with a 3-D shape?

1. Build these shapes with toothpicks and 1 cm clay balls. Fill in the chart below:

<table>
<thead>
<tr>
<th>Shapes</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td># of Points-Vertices (clay balls)</td>
<td></td>
</tr>
<tr>
<td># of Line Segments-Edges (toothpicks)</td>
<td></td>
</tr>
<tr>
<td># of Faces (sides)</td>
<td></td>
</tr>
</tbody>
</table>

2. Hang each shape from a thread and dip completely into a water and soap mixture. Lift it out and observe.

* What do you think will happen?

[Blank lines for responses]

* Describe what happened:

[Blank lines for responses]