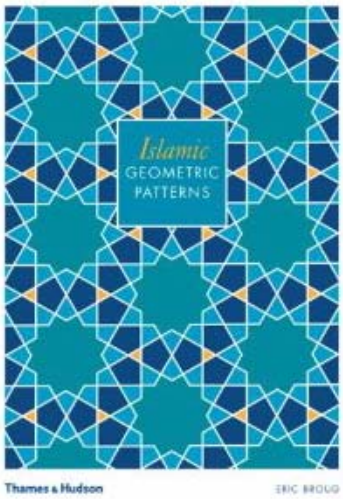
Esrefoglu Pattern, in Google SketchUp

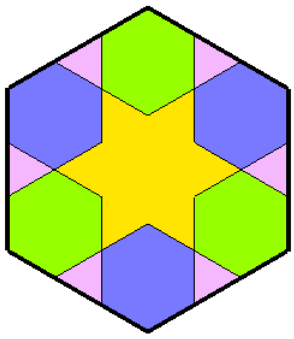


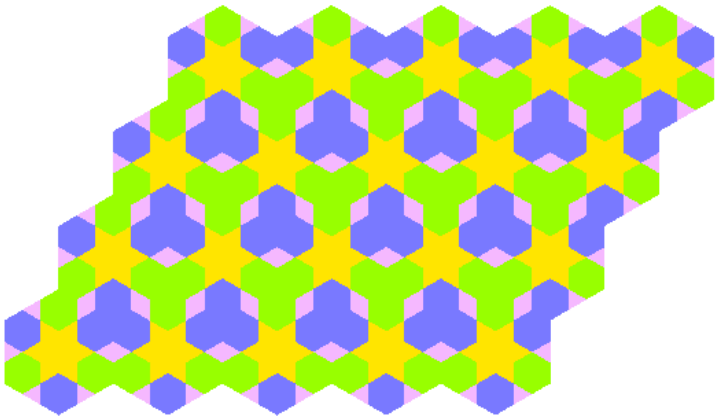
One of my favorite geometry books is *Islamic Geometry Patterns* by Eric Broug. The book contains instructions on 19 beautiful patterns found throughout the Middle East and Asia, and Eric's main tools are pencil, straight edge, protractor, and compass.

I've had a great time going through his patterns and creating them in SketchUp (which is much easier!)

This project shows how to create a pattern from the Esrefoglu mosque in Beysehir, Turkey.

This pattern is based on a hexagon, and the lines inside it are traced along guide lines. When the hexagon is tessellated, you can get patterns like the one shown below on the right.





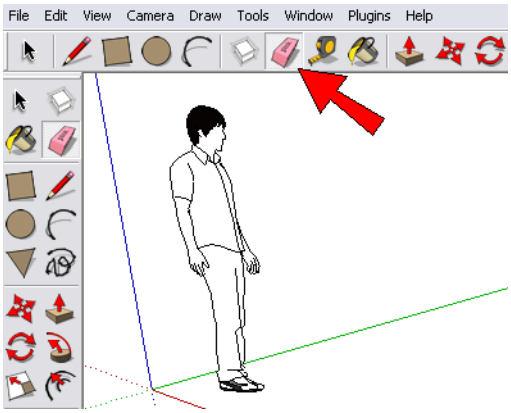
Teacher Note: All text that appears in **red** is for the teacher version only, and does not appear in the student version.

For this project, it helps to have some basic knowledge of Google SketchUp (though detailed instructions are provided). In particular, it's important to know how to zoom and pan the view. If you need more information on how to get started, and a description of some basic tools, please read 3DVinci's Getting Started Guide (PDF).

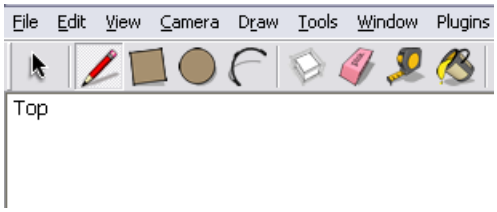
PC users: go to http://www.3dvinci.net/SketchUp_Intro_PC.pdf.
Mac users: go to http://www.3dvinci.net/SketchUp_Intro_MAC.pdf.

Set Up the Hexagon "Template"

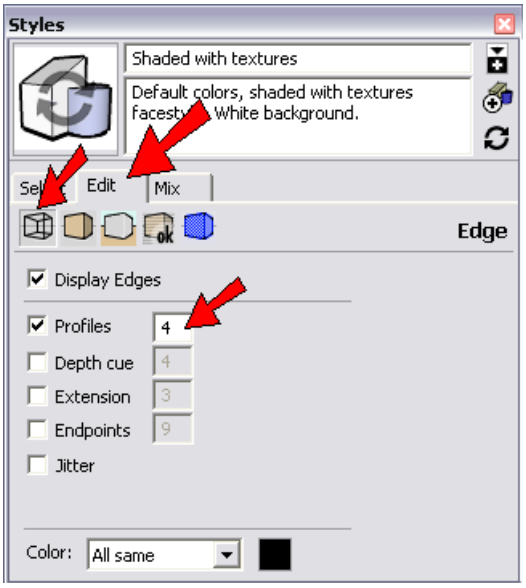
1. Open Google SketchUp. If your file contains a person standing on the ground near the origin, click the **Eraser** tool and erase him or her.



2. From the main menu, choose **Camera / Standard Views / Top**. Now you're looking down on the "ground," and the word **Top** appears in the top left corner of the SketchUp window.

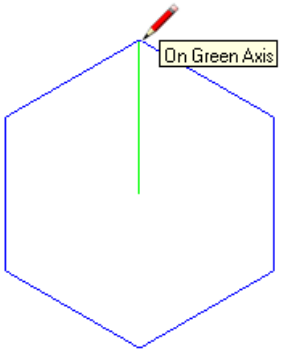


3. To make tracing easier later, we'll set up the model's style to have thick edges around exterior borders. From the main menu, choose **Window / Styles** to open the **Styles** window. Open the **Edit** tab, and click the first icon at the top of this tab, which opens the **Edge** settings. Check **Profiles** (if it isn't checked already), and set a large profile value such as 4. Then close the **Styles** window, or at least minimize it or move it away from the center of the window.

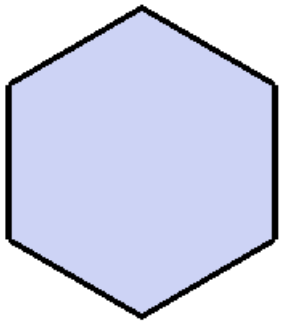


4. To draw the hexagon, choose **Draw / Polygon** from the main menu. Before clicking anywhere, look at the **Sides** field in the lower right corner. If the number of sides is not 6, then type 6 (don't click in this field, just type the number) and press Enter.

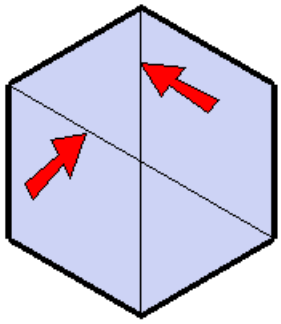
5. Click anywhere to place the center of the hexagon (don't click the origin, since future lines will be harder to see), then click a second point anywhere in the green direction.



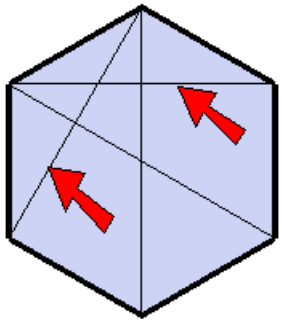
After clicking, the hexagon face is filled in, and the edges around it are thick because of the high profile setting.



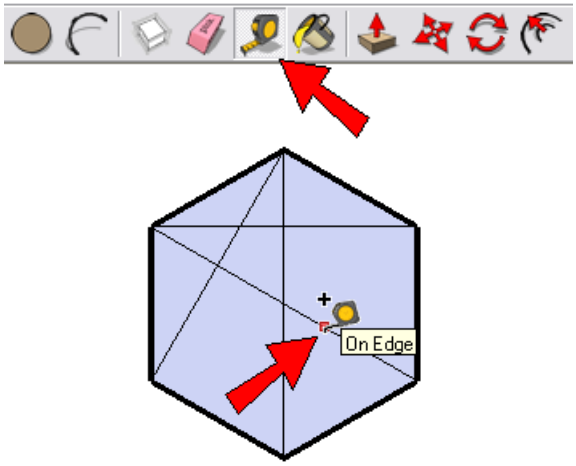
6. Activate the **Line** tool and draw the two corner-to-corner lines shown below.



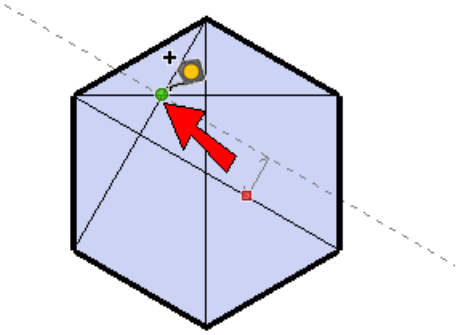
7. Then add these two lines:



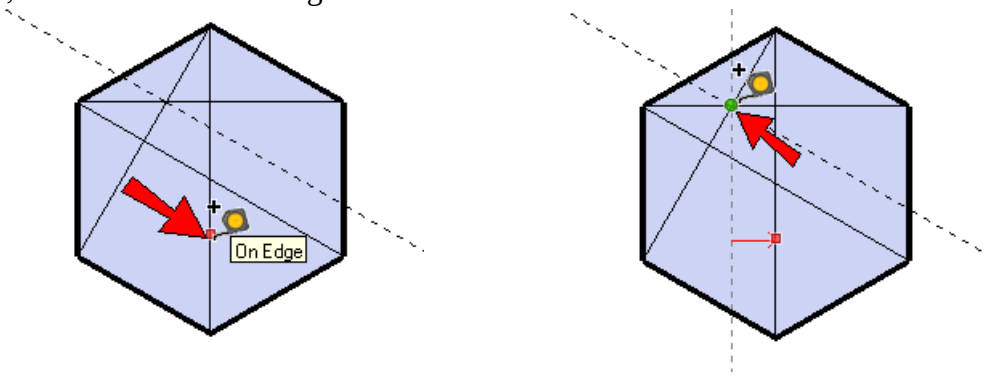
8. Now it's time to add some guide lines, which are temporary lines that you'll use later for tracing. Click the **Tape Measure** tool, and make sure there's a "plus" sign attached to your cursor. (If there isn't one, press Ctrl or Option to add it.) Then click the line indicated below, looking for the "On Edge" popup.



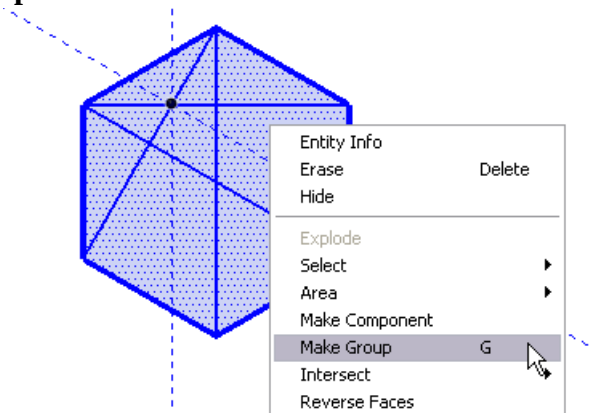
9. Then click the intersection point indicated below. This creates a guide line parallel to the line you clicked in the previous step, passing through that intersection point.



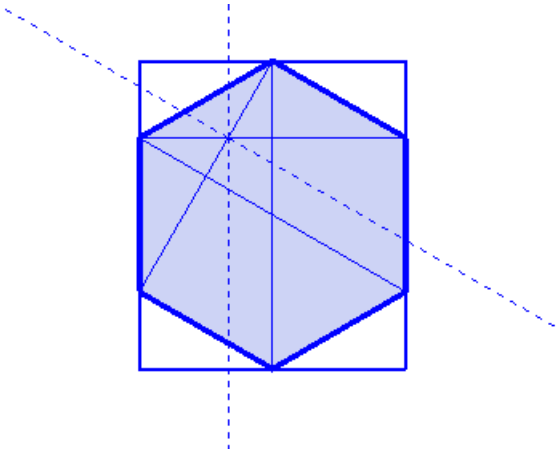
10. To create the next guide line, click the line shown below on the left, then click the same intersection point you clicked before, shown below on the right.



11. This provides all of the geometry we'll need for the pattern. So we'll "wrap" it all up as a group, so that it can easily be erased later. Select everything by pressing Ctrl+A (PC) or Cmd+A (Mac), right-click on any selected face, and choose **Make Group**.



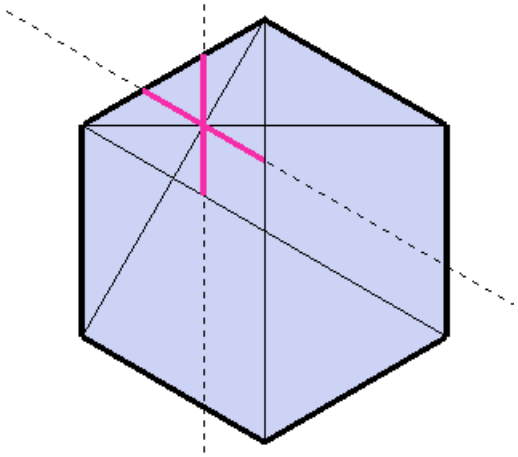
The group should be highlighted and outlined in blue, which means it's now acting as a single object and not a collection of edges and faces.



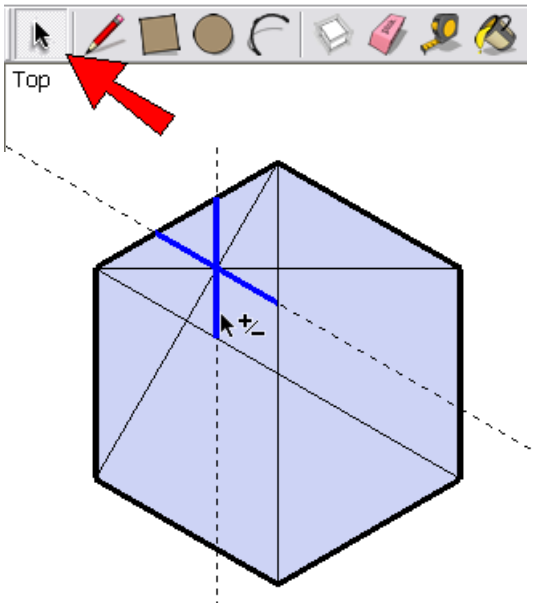
12. Unselect the group by right-clicking in blank space.

Trace and Copy

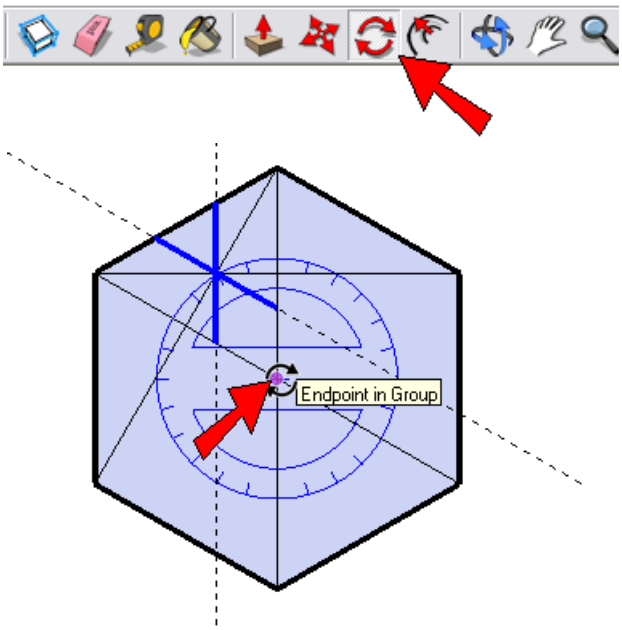
1. Activate the **Line** tool and trace over the guide lines where shown below in magenta (your lines will be black - magenta is used here for highlighting purposes). Be sure to click exactly on the intersection points between lines and guide lines. To end a line without continuing on to draw connecting lines, press the Esc key.



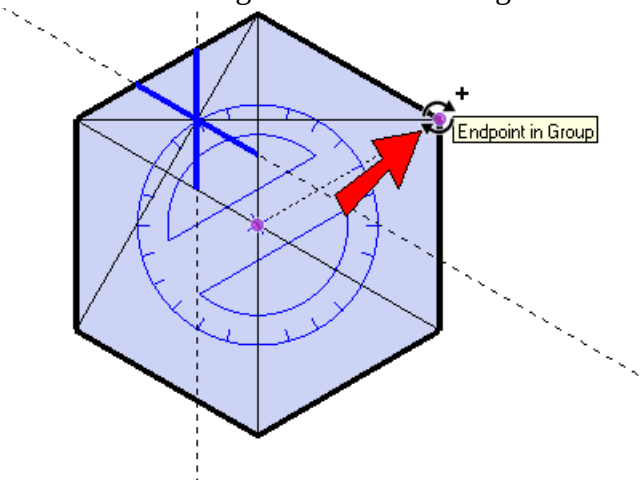
2. These two lines will be rotate-copied around the center of the hexagon. First activate the **Select** tool (using the icon shown below or press the Spacebar). Press and hold the Shift key which enables you to select multiple objects, and click both lines (there should be 4 total segments). If you click the wrong object by mistake, just click it again to unselect it.

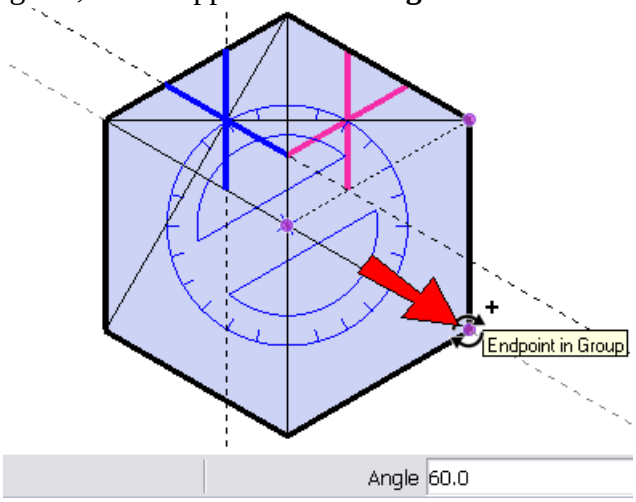


3. With the two lines still selected, activate the **Rotate** tool (shortcut key: Q). Click to place the protractor at the center of the hexagon, where indicated below.

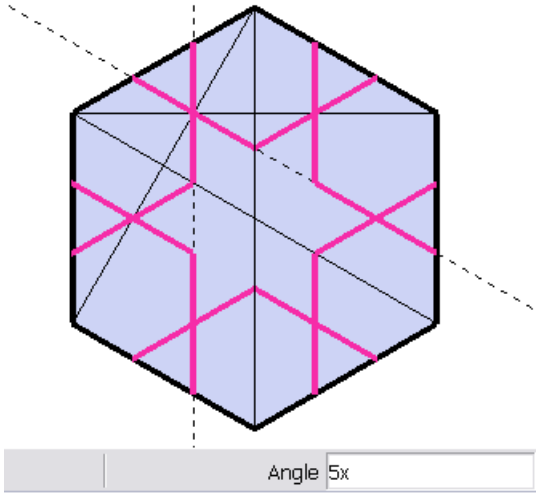


4. Press the Ctrl key (PC) or Option key (Mac). (You don't have to keep Ctrl / Option pressed, just tap it once.) For the first rotation point, click any corner of the hexagon. For the second rotation point, click any adjacent corner of the hexagon. The rotation angle should be 60 degrees, which appears in the **Angle** field.

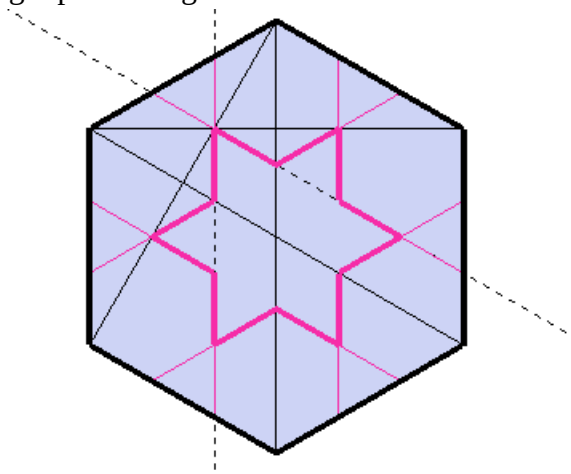




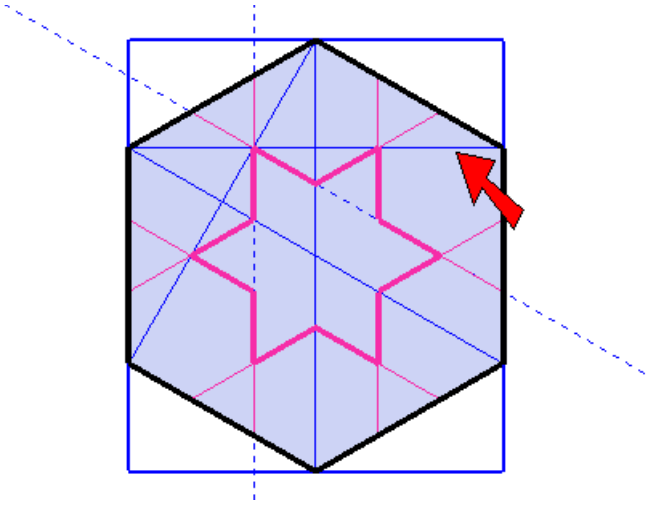
5. Right after the first copy is made, you can change the total number of copies. Type 5x, which appears in the **Angle** field, and press Enter. This makes a total of six copies of the two lines.



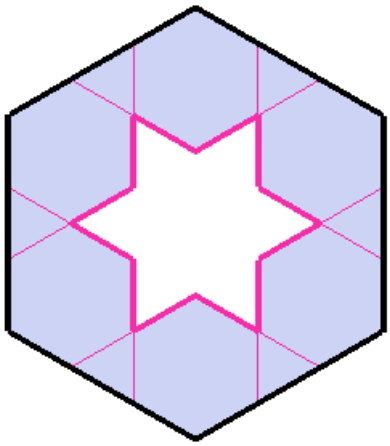
6. Now activate the **Polygon** tool again, and draw the same hexagon you made before, in the same exact place. You won't be able to see it, because it's directly on top of the hexagon that's now inside the group. But you'll notice that some of the copied lines which were thick before have now become thin - they are no longer exterior edges so they're no longer profile edges.



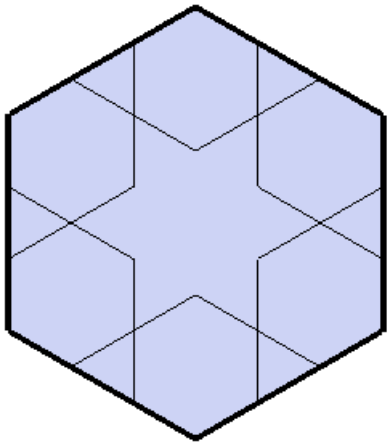
7. We're finished with the tracing and copying, so the group is no longer needed. Activate **Select** and click on an edge that you know is within the group but was NOT traced over, such as the edge shown below. The entire group should highlight.



8. Press the Delete key, and this is what's left:

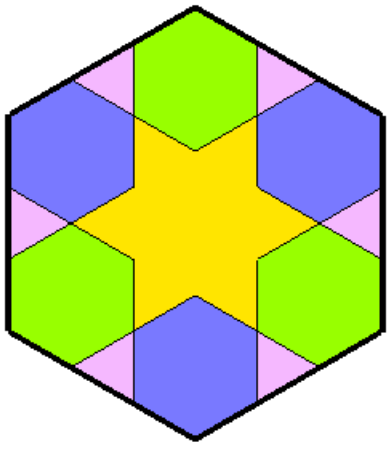


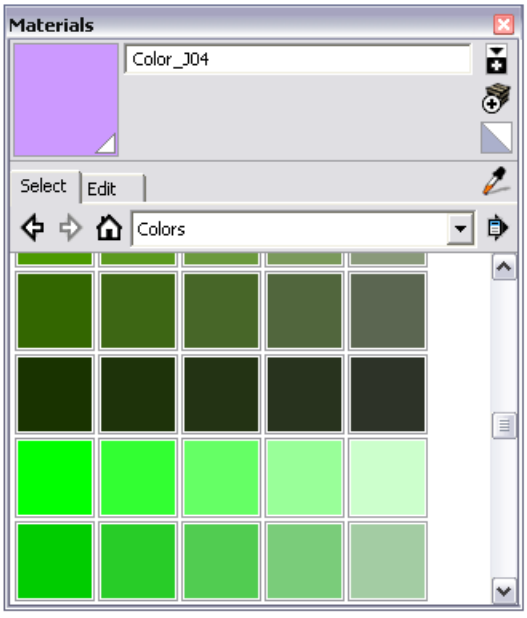
9. To fill in the hole, use **Line** to trace any edge around the hole.



Color and Tile

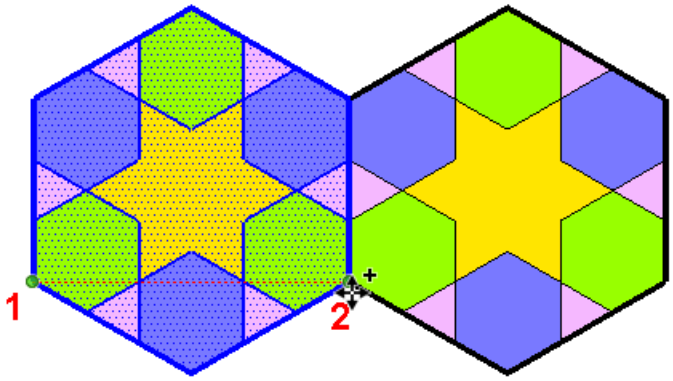
1. You can paint this hexagon using any color scheme you like. I used four colors. (To find colors and materials, click the **Paint Bucket** icon and find a collection you want to use.)



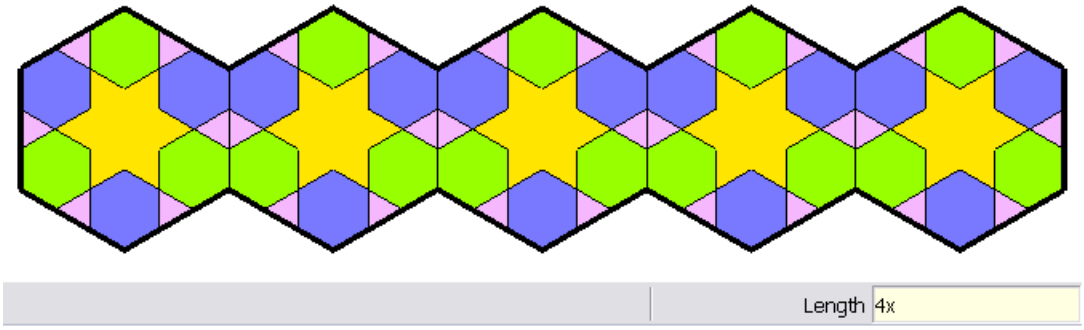


2. To copy the hexagon, select the whole thing and activate the **Move** tool.

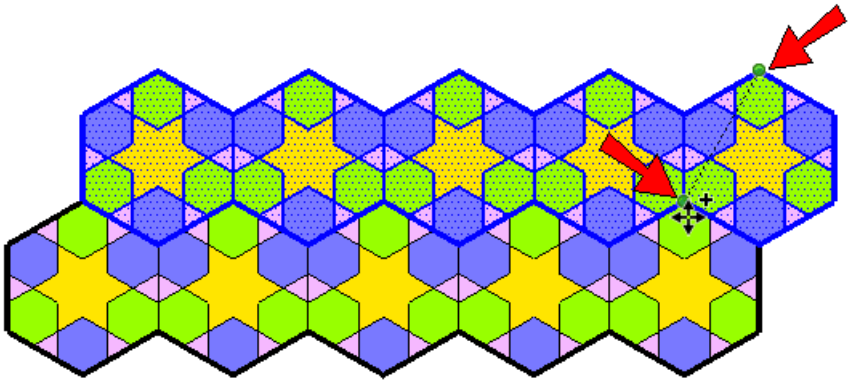
3. Press the Ctrl / Option key to make a copy, then click Points 1 and 2 shown below, to make the first copy.



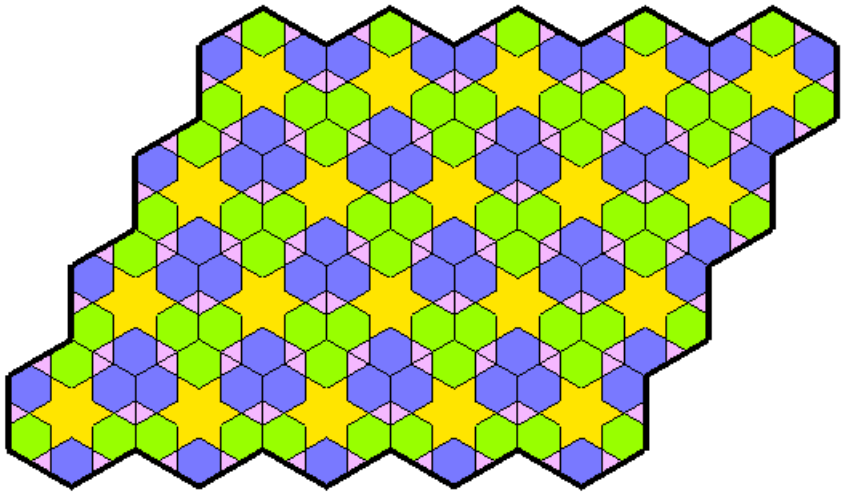
4. To make more copies, type 4x (or whatever number you want) and press Enter.



5. To make more rows, select everything once again, activate **Move** with Ctrl / Option, and use the points indicated below to set the copy distance.

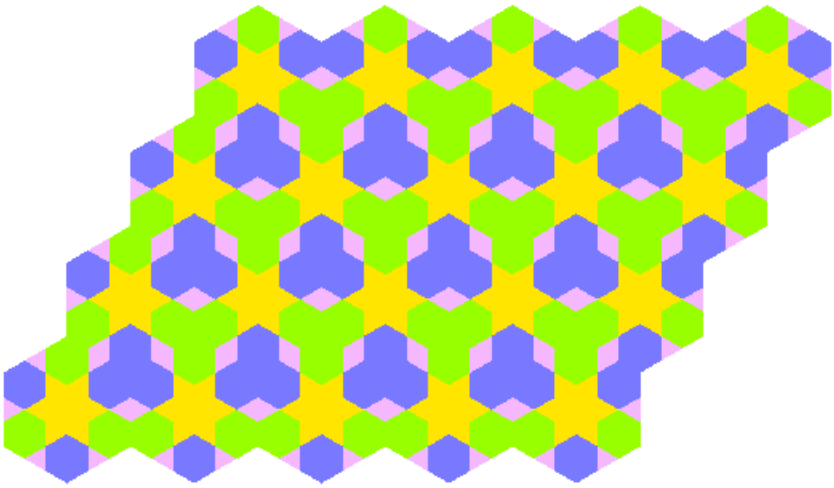


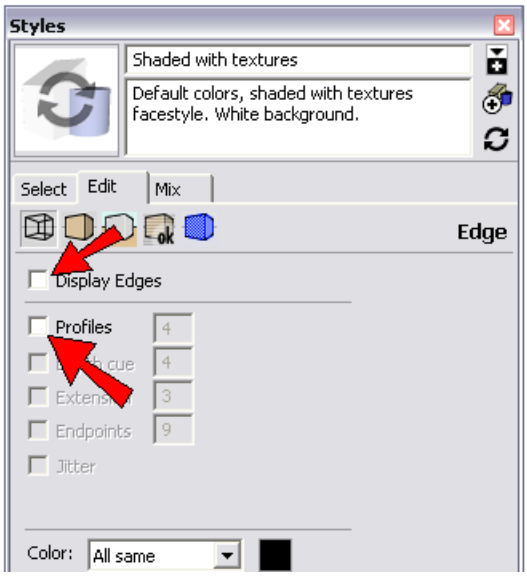
6. Then enter 3x (or a different number) to make more rows.



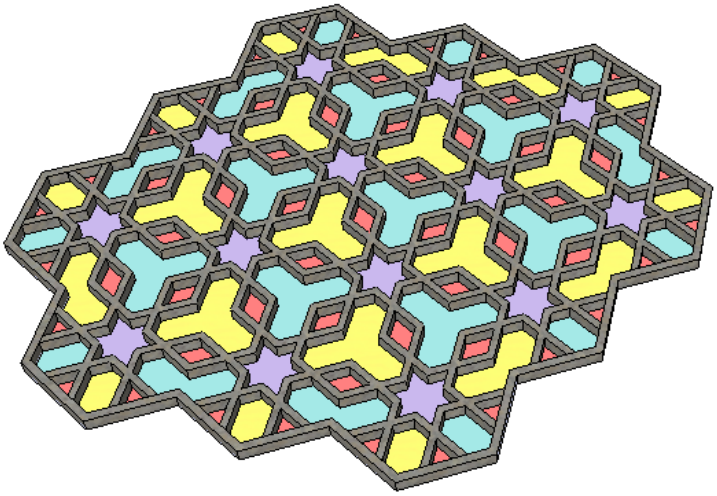
If you're good with components, you could make the hexagon into a component before copying it. This has the advantage of allowing you to make changes to any component so that they all update the same way.

7. To see the pattern without any edges, open the **Styles** window again and uncheck both **Display Edges** and **Profiles**.





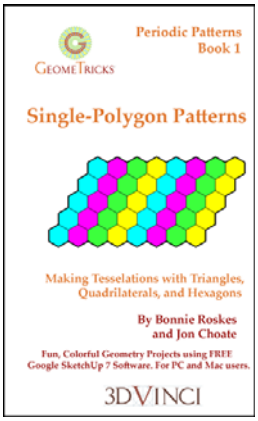
When you get really good with SketchUp, you can use this pattern to make something like this:

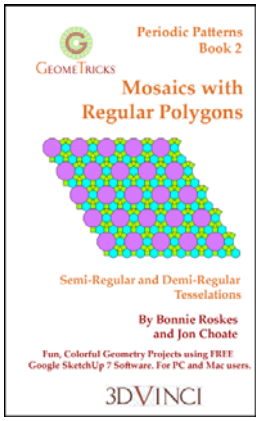


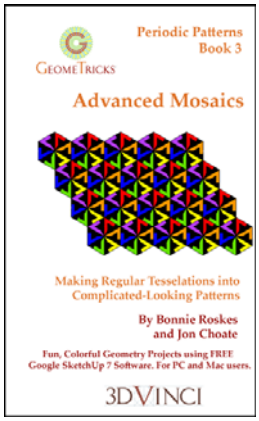
The model above uses components (each hexagon is identical), uses offsets to make “thick” bars which are pulled up to be 3D, and also has hidden edges. The whole outer shape was traced to make the frame. (Not really as hard as it looks!)

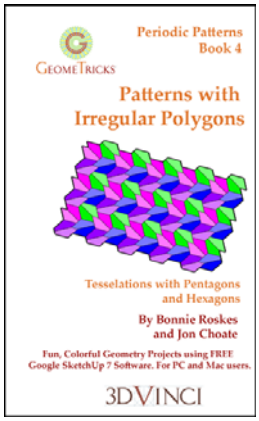
Teachers, Want More?

For more projects with tessellations, you’ll love 3DVinci’s GeomeTricks books on Periodic Patterns:









All books are available in print and as printable PDF. For details on GeomeTricks, go to http://www.3dvinci.net/ccp0-catshow/GM.html.

You can also sign up for our SketchUp Project of the Month subscription. Each month you will receive THREE FUN PROJECTS (one in math, two in 3D design) that can be used in K-12 classes. Details at http://www.3dvinci.net/ccp0-prodshow/POM.html. September’s project is about finding the intersection solid between perpendicular cylinders.