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Art in the Mathematics Classroom: Islamic Geometry

In the first of a series of articles, Charlotte Webb explores the links between mathematics and art.

I recently discovered a new passion which combined my interests in mathematics and art. Joining an Islamic art class in the Jewellery Quarter in Birmingham has inspired me to further explore the links between mathematics and art, leading to running a workshop at the joint ATM/MA conference in 2019, on using art in the mathematics classroom. I have also had the opportunity to work with young students on mathematics inspired by Islamic geometry at the Royal Institution and at the Northern Ireland Science Festival.

For me, mathematics and art are intrinsically linked. From discovering the golden ratio in Leonardo Di Vinci’s *Mona Lisa* to noticing the geometrical shapes and tessellations in M. C. Escher’s *Metamorphosis*, I can find underlying mathematics throughout the art world. Yet, as a classroom teacher of mathematics, I often felt that my students believed being artistic and mathematical were mutually exclusive traits. One particular comment from a 15-year-old student stuck with me, “I’m not good at maths, I’m a creative person”. As someone who enjoys both mathematics and art, I wanted to break down this myth with my students.

In this article, I will explore some of the many ways we can use inspiration from the Islamic art world to inspire students to work collaboratively, develop geometrical reasoning and improve their skills with compass constructions.

Islamic geometric designs can be found in mosques, madrasas and palaces around the world. From the Alhambra palace in Granada to The Friday Mosque in Isfahan, geometric compositions can be found on buildings, ceramics, metal-work, coins, tapestries and paintings, demonstrating the huge variety of skills needed by the craftsmen who created these patterns.

These designs combine elements of mathematics, art and history. Learning about the origins of these incredible architectural masterpieces and the techniques used by ancient craftsmen, offers students the opportunity to discover mathematics in a cross-curriculum setting.

For students, deciphering the steps that lead to finished patterns is a mathematical puzzle to be solved. Constructing Islamic geometric designs uses creativity whilst offering the opportunity to hone construction skills. To construct the patterns using traditional methods, students need to work accurately with a ruler and pair of compasses to create these, often intricate, geometric designs. For younger students simply sharing some of these designs can spark discussions on types of symmetry, recognising polygons and transformations.

**Activity 1: Investigating tessellations**

The first activity uses the ATM mats (see figure 1) to explore regular and semi-regular tessellations as a precursor to working in Islamic patterns. I use this as a first activity for this cross-curriculum topic, offering students the opportunity to manipulate regular polygons and explore which shapes will tessellate regularly or semi-regularly. Students can work together (see figure 2) to test their conjectures (see figures 3 and 4) and convince others in the class that there are only 3 regular tessellations and 8 semi-regular tessellations.

Challenges I set include:

- Can you find all the regular tessellations? How can you be sure?
• Can you find all the semi-regular tessellations?
• Write down any conjectures you have.
• Can you explain why some regular polygons will tessellate and others will not?

Figure 1: ATM mats. Figure 2: Students exploring tessellations using ATM mats.

Further discussions can lead to understanding why some polygons will tessellate and others will not, comparing hexagons and pentagons for example. This can be a useful introduction to interior angles of polygons and an opportunity to review the angle sum around a point.

I find this activity to be an excellent vehicle for encouraging collaborative learning through using a common board for conjectures and inviting students to work in pairs or threes to test conjectures and collect evidence to either support or disprove these. Using the ATM mats means that the activity is accessible to all students and classroom discussions can support them in developing mathematical thinking through understanding the importance of explaining their reasoning.

In my view, developing a conjecturing atmosphere where students ask questions and do not accept answers without evidence, is the first step in demonstrating to students that mathematics can be creative.
Islamic Geometry: Basic design principles

Patterns found in Islamic geometric art are based on underlying grids of tessellating polygons. Many of these designs fall into three categories: four-fold, five-fold (see figure 5) and six-fold patterns, based on the numbers of sections into which a circle has been divided in order to create the pattern.

Figure 5: An example of a five-fold Islamic pattern.

The simplest, and most common, Islamic art patterns are based on the three regular tessellations (see figure 6): squares (four-fold), hexagons and triangles (six-fold). In these articles I will suggest activities for students based around four-fold and six-fold patterns.
Fourfold patterns

This family of patterns are based on squares, octagons and multiples of those. The underlying grid for four-fold patterns is built from five overlapping circles, as shown in figure 8. Common shapes include 8-pointed stars and crosses (see figure 8), although other irregular shapes do feature.

Activity 2: Collaborative four-fold tessellation wall

These instructions allow your students to create a fourfold pattern.

- Start with an octagon, either constructed from five overlapping circles as in figures 8 and 9, or using a printed template. Make sure all the students start with an octagon of the same size so the tessellation will work.
Figure 8: Creating the five overlapping circle grid.

Figure 9: Constructing an octagon from the five overlapping circles grid.

- Look carefully at the 8-pointed star, focus on where the lines meet with relation to the octagon. Add these lines to the octagon to create the 8-pointed star (see figure 10).

Figure 10: An 8-pointed star within an octagon

- By adding in additional “channels”, create the inner 8-pointed star (see figure 9).

Figure 11: An inner 8-pointed star.
Students can decorate their patterns and add them to a tessellation wall. It can help to use contrasting coloured backing paper (see figure 12).

![Image](image_url)

**Figure 12**: Students adding their 8-pointed stars to the collaborative tessellation wall.

The first thing to note is that strictly speaking this is not a tessellation. The students are making the 8-pointed stars and the crosses which make up the tessellation are represented by the spaces left behind on the coloured backing paper. You may prefer to create both stars and crosses so that the collaborative piece is a complete tessellation, the same template can be used as removing four squares (shown in blue) leaves the required cross (see figure 13).

![Diagram](image_url)

**Figure 13**: Removing squares.

I do think that using backing paper allows the students star designs to stand out (and makes a great display!) but it is important to emphasise that mathematically, a tessellation has no gaps.

You may think that this exercise is simply a teacher-lead exercise, with students following specific instructions to create the desired effect. When using this with students, however, I have found that giving them the image of the completed pattern and asking them to work out which lines they need to add, firstly to the octagon and then to the 8-pointed star, involves both careful observation and problem solving. The students first need to identify how the additional lines relate to the octagon, and then the star, then they have to apply...
this to their own drawing. This exercise is also a good way for students to practise accuracy with using a ruler.

The collaborative nature of this activity means that students can work at their own pace, without feeling pressure to finish in time. Simple designs look just as effective as the more elaborate patterns. Students who finish their star quickly can add elaborate details, using rotational symmetry for example, or they may choose to create multiple stars. Giving students coloured or patterned paper can take away the pressure of having to add decorations for any students who is finding that challenging.

Importantly, the overall effect of the tessellation wall (see figure 14) can be appreciated by all the students and each can feel proud that they have contributed to a larger piece of work, consolidating the feeling that the classroom is a collaborative learning environment and making a beautiful classroom or corridor display.

![Figure 14: A completed fourfold tessellation wall display.](image)

Next issue I will describe how to create six-fold patterns.

With thanks to my art teacher and artistic inspiration Hasret Brown ([http://www.hasretbrown.com/](http://www.hasretbrown.com/)) who helped me to reignite my passion in mathematics and art. Thanks also to Samira Mian ([https://www.samiramian.uk/](https://www.samiramian.uk/)) whose online courses have enabled me to continue exploring Islamic art patterns.

References:


I would love to see what you and your students create, please do share your work ([charlotte.webb@open.ac.uk](mailto:charlotte.webb@open.ac.uk), Twitter: @WebbMaths).

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