Thinking 3D

FROM LEONARDO TO THE PRESENT

GEOMETRY TRAIL

Answers

Luca Pacioli was one of the most famous maths teachers of the Renaissance.

In the picture on the wall, which objects is he using to teach?

- Set square
- Drawing compass
- Chalk and tablet
- Dodecahedron model
- Two books
- A tablet marked 'Euclides'
- A glass rhombicuboctahedron (8 triangular faces and 18 square faces), half-filled with water, hanging from the ceiling.

Look around the exhibition to find polyhedra represented in different ways:

If you could only use one of these to study advanced geometry, which would you find most useful?

Answers will be subjective and varied but themes to draw on may be:

- Skeletal 2D drawings allow all the faces & edges to be visualised
- 3D models allow polyhedral to be handled, rotated.

Two books on maths published by Luca Pacioli are in this exhibition.

Compare these two books. Who illustrated the later one, and what made the diagrams more effective than the illustrations for the first book?

Leonardo da Vinci provided the illustrations for the later book (the only book he illustrated). The images are not only sharper and make better use of shading to give perspective, but the open, skeletal structure allows the back edges to be seen.

Nearby, find another way of illustrating 3D geometry which was a world first.

Albrecht Dürer's book *Institutiones Geometricarum* published in 1532, has illustrations of 'unlocked' polyhedra showing the flat nets from which each solid can be contructed.

The icosidodecahedron has 20 triangular faces and 12 pentagonal faces. The elevated icosidodecahedron is made by creating a pyramid of equilateral triangles on each face.

How many triangles would you need to do this? (20x3) + (12x5) = 120

Instead of being hand-written, these books were printed on printing presses, with woodcut illustrations. Pacioli wrote in Italian, and Dürer wrote in German (although the Latin translation is on display here.)

What difference would the new technology of the printing press and the choice of language have made for Renaissance learning?

Printing allowed books to be produced more cheaply and quickly than hand-written manuscripts, and reduced the likelihood of scribes introducing changes or errors. Complicated diagrams could be accurately reproduced. Writing in the local vernacular, rather than academic Latin, made these texts accessible to the wider population.

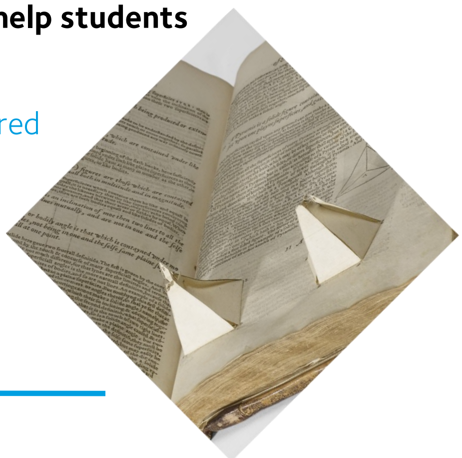
Euclid's *Elements* is the most influential textbook in the world. Written around 2,300 years ago, it collects the mathematical wisdom of the ancient Greeks, applying mathematical logic to the three-dimensional world by defining 2D and 3D shapes. The book survived at first by being copied by hand.

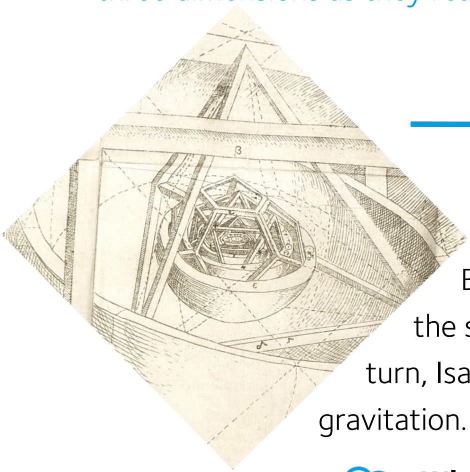
Find a Greek version made in 888CE by a scribe called Stephanus. He illustrated the text with simple pen and ink diagrams.

Find the first English translation of Euclid's *Elements*. Published in 1570, and printed rather than hand-written, the translation let people who didn't speak Greek study this key mathematical text.

What else did the author do to make his illustrations clearer, and help students understand geometry?

Henry Billingsley was inspired by anatomical and astronomical multi-layered paper flap illustrations and models. He included this type of model in the pages of his book, allowing his readers to construct the polyhedra in three dimensions as they read the text.





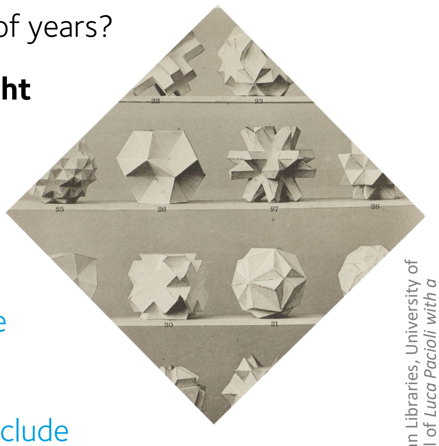
Johann Kepler used the astronomical data gathered by astronomer Tycho Brahe to create his three laws of planetary motion. Kepler's theories built on the sun-centred model of Copernicus by defining the planets' elliptical orbits. In turn, Isaac Newton used Kepler's ideas to come up with his law of universal gravitation.

Why do you think Kepler also created this strange diagram, where the orbits of the six known planets are overlaid with the five Platonic solids?

Students will have their own suggestions about this and, to some extent, only Kepler himself could answer this question. He had discovered that the proportional distance between each heavenly body was roughly equal to the proportions of the five Platonic solids (tetrahedron, cube, octahedron, dodecahedron, icosahedron). He believed that there was an underlying order to the structure of the universe and his diagram is an attempt to use geometry to explain the spacing and motion of the planets.

The categorisation of page after page of polyhedra in Max Brückner's work might seem pointless to some. Why do you think humans have been fascinated by geometry for thousands of years?

Look around the exhibition and list some reasons why people might study geometry.



Students are likely to produce a wide variety of suggestions here, but reasons apparent from the exhibition are the study of mathematics; the use of geometry to convey perspective in art and graphic design; architectural drawing and modelling; crafts and trades such as carpentry, joinery and stone masonry.

Themes that are less apparent from the exhibition but might be suggested include engineering, computer graphics, origami, and packaging design. In biology and chemistry, many molecules and materials have a geometric structure.