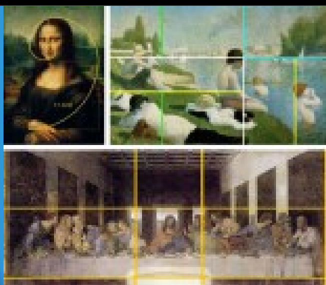
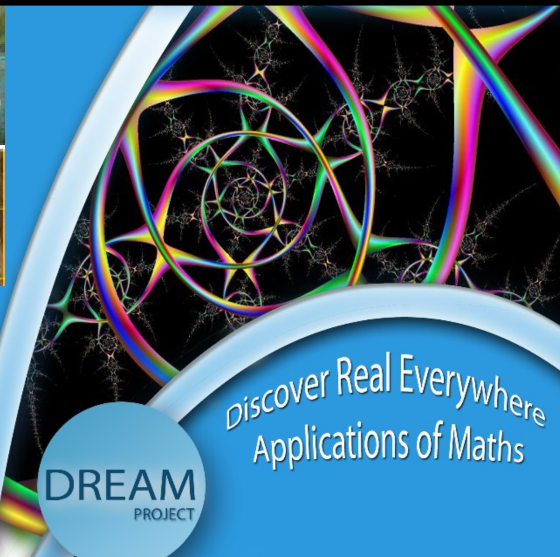
Erasmus+

Material selected by
Fuioagă Gizela

O4 - Open on-line course topic "Maths in Art"



TOGETHER MATHEMATICAL DREAM COME TRUE



Discover Real Everywhere Applications of Maths

DREAM PROJECT

Co-funded by ERASMUS+ Program of the European Union, Key Action 2
Project: 2016-1-RO01-KA201-024518"Discover Real Everywhere Applications of Maths – DREAM"
Beneficiary: Colegiul National "Constantin Diaconovici Loga", Timisoara

Timişoara
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Maths in Art

Contents

Foreword

This intellectual output was create in the Erasmus project " DREAM - Discover Real Everywhere Applications of Maths", identification number: 2016-1-RO01-KA201-024518, through the collaboration of students and teachers from Colegiul Național "Constantin Diaconovici Loga" Timișoara, Romania, 1o Geniko Lykeio, Aigiou, Greece, Agrupamento de Escolas Soares Basto, Oliveira de Azeméis Norte, Portugalia and "TIBISCUS" University of Timișoara, Computers and Applied Computer Science Faculty.

The project main objective was to build up a new maths teaching/learning methodology based on real-life problems and investigations (open-ended math situations), designed by students and teachers together. The activities involved experimentations, hands-on approach, outdoor activities and virtual and mobile software applications. The developed material was transform into on-line courses and is freely available to all interested communities, in order to produce collaborative learning activities.

O4 - Maths in Art has the purpose to facilitate the understanding of the usefulness of some mathematical chapters that are applicable in different domain of art.

The activities in this pack feed into the Skills and Capability Framework by providing contexts for the development of Thinking, Problem Solving and Decision Making Skills and Managing Information. Open-ended questions facilitate pupils to use Mathematics. ICT opportunities are provided through using Moodle platform and additional tasks researching information using the internet.

This intellectual output comprises five lesson scenarios and guides the teacher in creating interactive and exciting lessons.

Introduction

The importance of Aesthetic competence

Mathematics and art are related in a variety of ways. Mathematics has itself been described as an art motivated by beauty. Mathematics can be discerned in arts such as music, dance, painting, architecture, sculpture, and textiles. [Source: https://en.wikipedia.org/wiki/Mathematics_and_art]

Mathematics is the study of number, structure, pattern, and shape; although abstract, it has influenced art for centuries. Today, mathematics and art explore new bold domains. The power of their insights and effects on each other provides opportunities to be delighted by seeing new connections hiding in plain sight. Mathematics is a fresh lens to understand art: reckoning with chaos, algorithms, equivalence, topology, geometry and other mathematics tools to help us see art and the world with more depth.

Knowledge about form, color and composition is vital for the creation of products that function, and to successfully communicate through visual messages. This knowledge can contribute to personal development, which is a requirement for resolute creative idea development, visual communication and production. Such knowledge can improve the opportunity to participate in democratic decision-making processes in a society where more and more information is communicated visually. The subject has as one of its aims, to help to develop entrepreneurship and cooperation with business and industry, institutions and specialists. In interdisciplinary cooperation on design and technology, the subject particularly contributes to the practical-aesthetic aspects of design.

Aesthetic competence is a source of development on several levels, from personal growth, via influence on one's personal surroundings, to creative innovation in a larger social perspective.

The particular contribution of the arts to the acquisition of Key Competencies:

- Collecting, analyzing and organizing information
- Communicating ideas and information
- Planning and organizing activities
- Working with others and in teams
- Using mathematical ideas and techniques
- Solving problems

• Using technology
• Cultural understandings

Methodology

Learning and teaching in mathematics can be made more effective where a balance of practical, oral and written tasks is provided. This pack provides information and scenarios to assist in this task. The intention is to provide young people five activities that are related to their age and attainment. One aspect of the pack is the use of the PowerPoint presentations or educational videos in order to stimulate whole-class discussions before and after the activities have been completed. The emphasis should be on helping young people understand what the problems are and to become aware of the technical vocabulary surrounding the issues..

General Pedagogical Recommendations:

- Watching a power point presentation or a film which introduces the theme of real-life lesson
- Discovering the link between real life and the mathematical concept that governs the given situation
- Recall theoretical mathematical concepts
- Frontal discussion of the real situation in the matter
- Solving some parts of the problem by group of students using mathematical tools: minicomputers, Geogebra, Excel, internet
- Discussing solutions, looking for the optimal option
- Student's task: loads the optimal solution found on the MOODLE platform
- Teacher's task: controls the homework of the student and provides a feedback.

Examples from O4 - Maths in Art use the notions and the properties of following chapters:
- The similarity of triangles;
- Geometrical transformations: rotations, translations, and reflections;
- Graph of elementary function.
- The golden ratio

Theoretical background

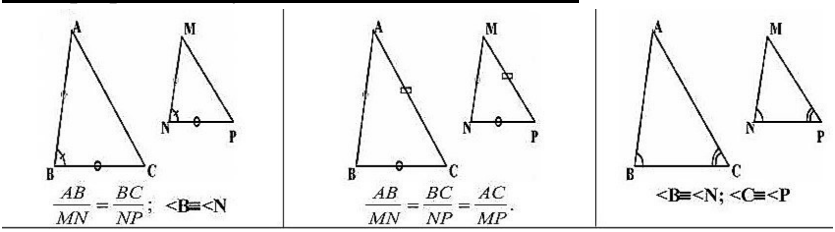
The similarity of triangles

Two triangles are said to be similar when they have two corresponding angles congruent and the sides proportional.

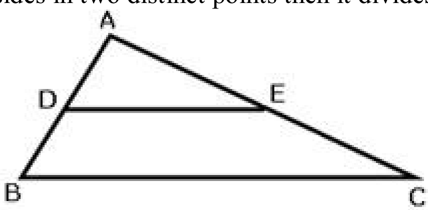
Similarity Postulates and Theorems

1. Angle-Angle (AA) Similarity Postulate - If two angles of one triangle are congruent to two angles of another, then the triangles must be similar.
2. Side-Side-Side (SSS) Similarity Theorem - If the lengths of the corresponding sides of two triangles are proportional, then the triangles must be similar. (This is like SSS congruency)
3. Side-Angle-Side (SAS) Similarity Theorem - If an angle of one triangle is congruent to an angle of a second triangle and the lengths of the sides including these angles are proportional, then the triangles must be similar. (This is like SAS congruency)

Basic proportionality theorem or Thales' theorem:



If a line is drawn parallel to one side of a triangle and it intersects the other two sides in two distinct points then it divides the two sides in the same ratio.

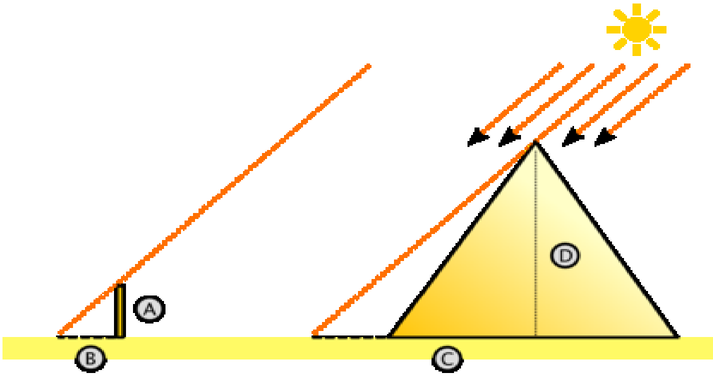


Basic Proportionality theorem, BPT, Thales Theorem, line parallel to one side, sides in same ratio

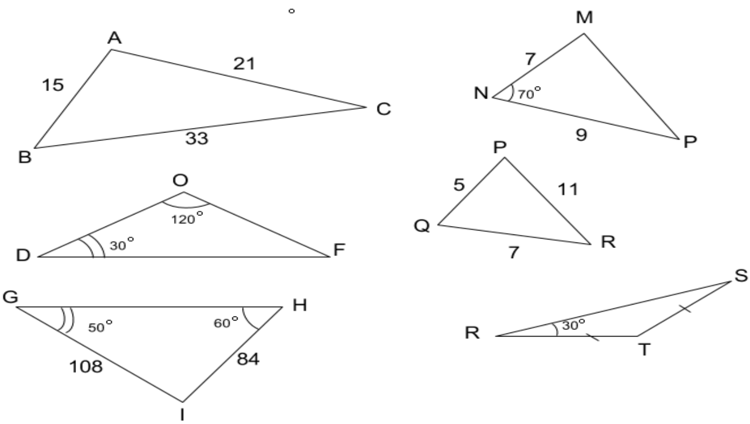
In the ΔABC , if $DE \parallel BC$, then $AD / DB = AE / EC$.

Reciprocal of the theorem: If a line divides any two sides of a triangle in the same ratio, then the line is parallel to the third side.

Applying Thales' Theorem to Real Life:



Areas of Similar Triangles
The ratio of the areas of two similar triangles is equal to the square of the ratio of their corresponding sides.
Exemple:



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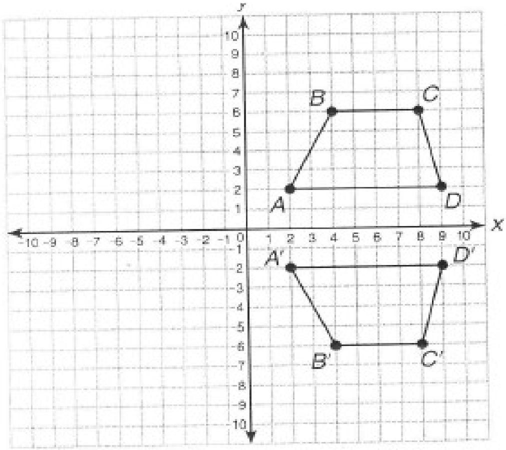
Geometrical transformations: rotations, translations, and reflections

Transformations: Geometric figures can change position using translations, reflections, rotations, and dilations.

Reflections: Over the x-axis and y-axis.



A reflection occurs when you flip a figure over a given line and its mirror image is created. A reflected figure has the same size and shape as the original figure. Therefore it is CONGRUENT to the original.

Example: The following coordinate plane shows the reflection over the x-axis of trapezoid ABCD to form trapezoid A'B'C'D'.

Reflecting with graph paper: Simply flip the figure over the x-axis or y-axis (whichever is directed).

Reflecting without graph paper:

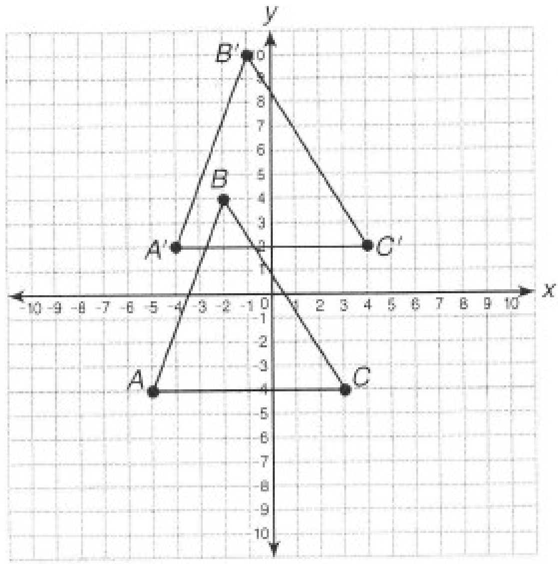
To reflect over the x-axis, keep the x ordinate the same and make the y ordinate its opposite. $(x, y)\rightarrow(x, -y)$. Example: $(3, 5)\rightarrow(3, -5)$

To reflect over the y-axis, keep the y ordinate the same and make the x ordinate to its opposite $(x, y)\rightarrow(-x, y)$. Example: $(4, 7)\rightarrow(-4, 7)$

Translations:

A translation occurs when you slide a figure without changing anything other than its position. A translated figure has the same size and shape as the original figure. Therefore it is CONGRUENT to the original.

Example: The following coordinate plane shows the translation 1 unit to the right and 6 units up of ΔABC to form ΔA'B'C '.



Translating with graph paper: Simply take each point and move it as directed.
Translation without graph paper: To find the new position of a coordinate, ADD the translation to the original (x, y) pair. For example, to translate the point A(-5, -4) 1 unit right and 6 units up, A (-5, -4) + (1, 6) = A' (-4, 2)

Rotations: Clockwise and Counterclockwise
A rotation occurs when you turn a figure around a given point. Figures can be rotated in clockwise or counterclockwise direction. A rotated figure has the same size and shape as the original figure. Therefore it is CONGRUENT to the original.
Example: The following coordinate plane shows the 180° rotation around the origin of ΔEFG to form ΔEFG

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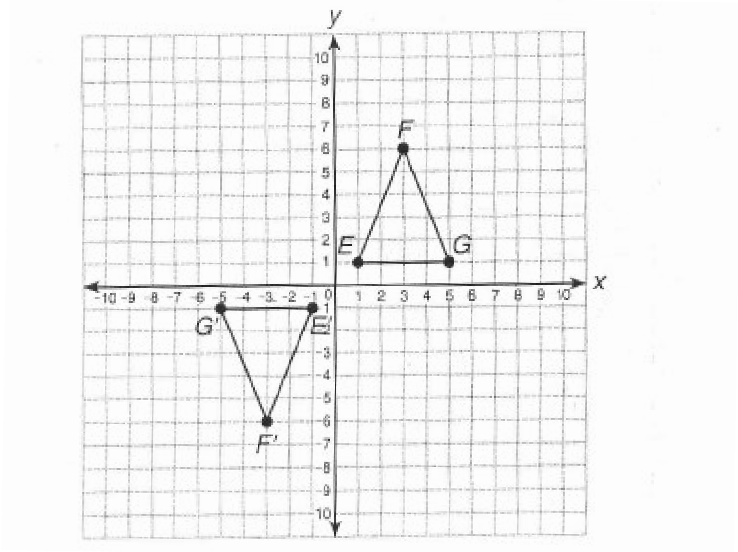


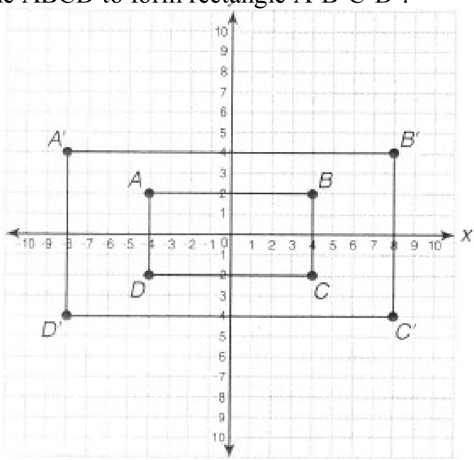
Rotating with graph paper AND Rotating without graph paper:
The steps are the same:
1) Determine which quadrant the rotated image will move to.
90 degrees moves 1 quadrant
180 degrees moves 2 quadrants
270 degrees moves 3 quadrants
360 degrees stays in the same quadrant
2) Determine the signs of the (x, y) image in the new quadrant.
(See the diagram to the right to assist you in remembering the signs in each quadrant).
3) Write a list of the new image coordinates using the signs you have decided on with these additional directions.
a) For 90° and 270° the x and y reverse positions in the coordinate pair.
b) For 180° and 360° the x and y stay in the same position in the coordinate pair.
4) DRAW the new image using your new coordinate list.

Dilations:

A dilation occurs when you enlarge or reduce a figure.
Figures will be dilated from a point called the center of dilation.

Unless specified otherwise, the center of dilation is usually the origin (0,0).
To perform a dilation on a figure you MULTIPLY the coordinates of each vertex by a positive scale factor.
If a scale factor is less than 1, the dilations will be a reduction.
If a scale factor is greater than 1, the dilations will be a enlargement.
In a dilation the image is SIMILAR to the original figure, because it is the same shape, but usually a different size.
The image is only congruent if the scale factor is exactly 1.

Example: The following coordinate plane shows a dilation, using a scale factor of 2 of rectangle ABCD to form rectangle A'B'C'D'.



Dilating with graph paper AND without graph paper:

The steps are the same:
MULTIPLY each x and y in the original coordinate pairs by the scale factor to form the image coordinates.
DRAW the new images coordinates you have created.
For example: A(-4,2) is multiplied by 2 and becomes A' (-8, 4)

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Property Preservation:

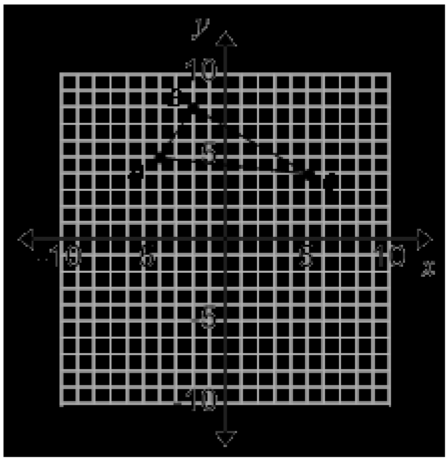
In transformation geometry, if a characteristic about a an image remains the same after a transformation occurs on the image, that "property" is said to be "preserved".

***For example**: Size is preserved in a reflection, because the new image is still the same size as the pre-image (original image). In a dilation, size is NOT preserved, because the image changes size.*

TEST

1. A student graphed triangle ABC on a coordinate plane, as shown to the right. After a translation, the location of vertex A is $(-7, -1)$. What ordered pair describes the location of point B after the triangle is translated?

A (-8, -5) ; B(-8, 5) ; C(-5, -2) ;



2. If a figure is reflected over the x-axis and then reflected over the y-axis, what one transformation would accomplish the same end resulting figure?

   (A) Dilation

   (B) Reflection

(C) Translation

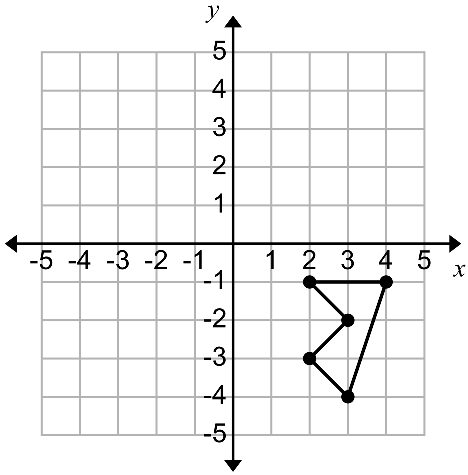
(D) Rotation

3. Which transformations will create CONGRUENT figures? Circle all that can apply.
(A) Rotation and Translation
(B) Reflection and Rotation
(C) Reflection and Dilation
(D) Reflection and Translation

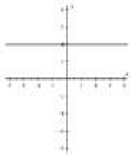
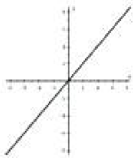
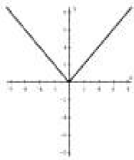
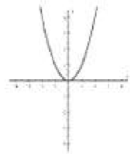
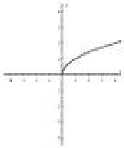
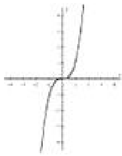
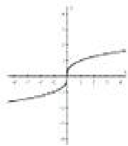
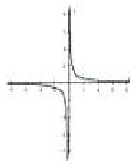
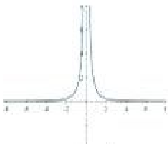
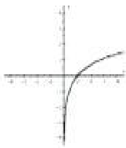
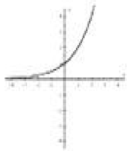
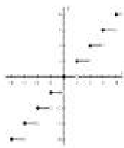
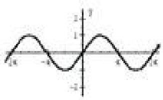
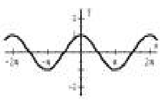
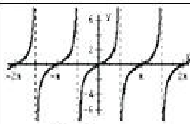
4. Two lines intersect to form a $34°$ angle. The lines are rotated $90°$ about the origin. What is the measure of the angle after the transformation?
(A) $56°$
(B) $146°$
(C) $34°$
(D) $68°$

5. Draw the image of the figure after the following transformations:

- a reflection over the *x*-axis
- a horizontal translation 5 units to the left



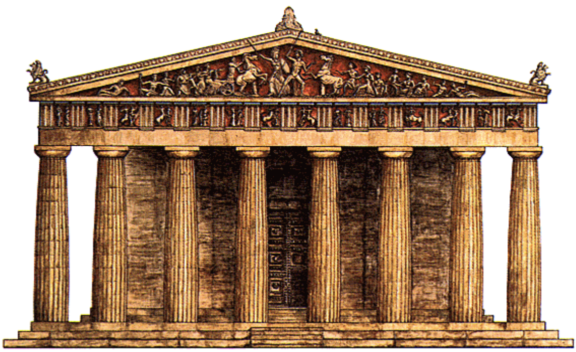
Graph of elementary function

Constant  $f(x) = c$	Linear  $f(x) = x$	Absolute Value  $f(x) = \|x\|$	Quadratic  $f(x) = x^2$
Square Root  $f(x)=\sqrt{x}$	Cubic  $f(x) = x^3$	Cube Root  $f(x) = \sqrt[3]{x}$	Reciprocal/Inverse/ Rational  $f(x) = \frac{1}{x}$
Rational  $f(x) = \frac{1}{x^2}$	Logarithmic  $f(x) = \ln(x)$	Exponential  $f(x) = e^x$	Greatest Integer (Step Function)  $f(x) = [[x]]$
Trigonometric Functions →	 $f(x) = \sin(x)$	 $f(x) = \cos(x)$	 $f(x) = \tan(x)$

The Golden ratio

Introductory concepts

In the 13th century, an Italian mathematician named Leonardo Da Pisa (also known as Fibonacci -- son of Bonacci) described an interesting pattern of numbers. The sequence was this; 1, 1, 2, 3, 5, 8, 13, 21, 34, 55, ... Notice that given the first two numbers, the remaining sequence is the sum of the two previous elements. This pattern has been found to be in growth structures, plant branchings, musical chords, and many other surprising realms. As the Fibonacci sequence progresses, the ratio of one number to its proceeding number is about 1.6. Actually, the further along the sequence that one continues, this ratio approaches 1.618033988749895 and more. This is a very interesting number called by the Greek letter phi φ. Early Greek artists and philosophers judged that a desirable proportion in Greek buildings should be width = φ times height. The Parthenon is one example of buildings that exhibit this proportion.



The Greeks thought that this was a pleasing dimension for a building or any structure. It was not too stocky and not too thin. They called this proportion the Golden proportion. Actually they wanted the ratio of the length to the height to be the same as the ratio of the (length plus height) to the length.

That is $\frac{y}{x} = \frac{x+y}{y}$

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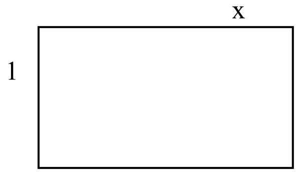
This pleasing proportion is still used. Product marketing often exhibits the φ ratio

In an algebra class you could do the following. Let's let the height of a golden rectangle be 1 unit. Then our picture would look like this.



For this rectangle to exhibit the Golden Ratio, this proportion must be true,

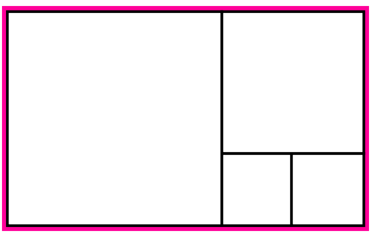
$$\frac{x}{1} = \frac{x+1}{x}.$$

To solve this solution for x we might solve the proportion by cross-multiplying.

$$x^2 = x + 1 \quad \text{or} \quad x^2 - x - 1 = 0$$

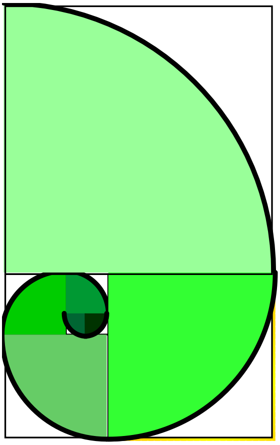
Solving this equation with the quadratic formula, students would find that x must equal $\frac{1 \pm \sqrt{5}}{2}$.

Now $\frac{1-\sqrt{5}}{2}$ is a negative number because $\sqrt{5}$ is larger than 1. So $\frac{1-\sqrt{5}}{2}$ is meaningless as the side of a rectangle. Therefore, the only possible solution must be $\frac{1+\sqrt{5}}{2}$. This is the Golden ratio which is called φ. Students can evaluate this ratio with their calculators and get about 1.618033989.



These rectangles have a length to width ratio that approaches the Golden Ratio just as we saw in the list of Fibonacci ratios on the previous page.

If within each square, a quarter circle is drawn with the circle's center being the corner of the square closest to the center of the pattern, a spiral is created. This is called the Golden Spiral.

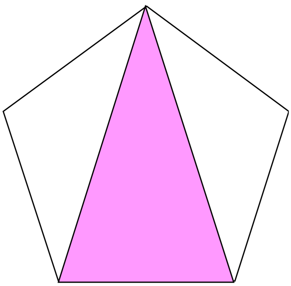


The Fibonacci pattern can also be used to create interesting images that seem to be distortions of space. Here's another representation of the Fibonacci pattern.

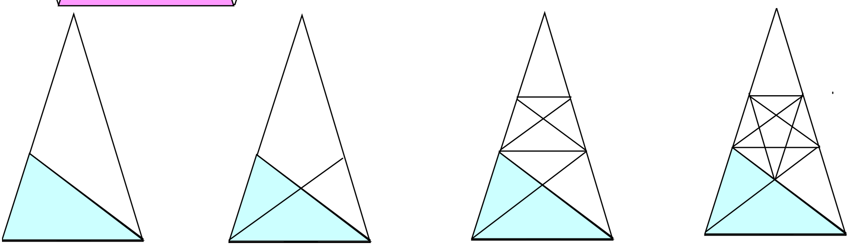
Golden Triangles

As you would expect, the base of a Golden Triangle multiplied by φ will equal the sides of this isosceles triangle. This exact triangle can be found inscribed in a regular pentagon

Compass and straight edge will allow students to create wonderful iterative designs with these two images. The diagonal of a pentagon is φ times the length of one side.

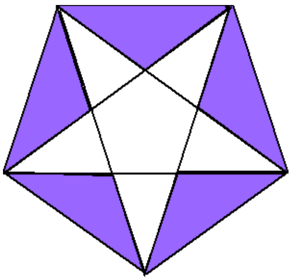


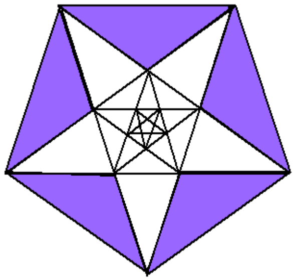
Lute of Pythagoras



The basis of this design is the Golden Triangle. A triangle is created with the ratio of isosceles sides to the base of phi. In other words, the length of the triangle sides is about 1.618 times larger than the length of the base. One can create an enclosed Golden Triangle by duplicating the base length and rotating it clockwise 36 degrees. Using a compass helps students do this base size duplication easily. Other Golden Triangles can be formed by rotating the base length in a counter clockwise rotation and by drawing lines that are parallel to the base. By continuing to connect vertices, one begins to find pentagrams (five pointed stars) and pentagons throughout the figure.

The Golden Ratio, phi, can be found repeatedly in pentagons and pentagrams. Any diagonal of a pentagon is phi times larger than the side of the pentagon. The length of one star point of a pentagram is phi times the interior pentagon's side or the base of the Golden Triangle that is the star's point.





Other fabulous φ facts;

φ is about 1.618033988749895

$1/\varphi$ is about 0.618033988749895

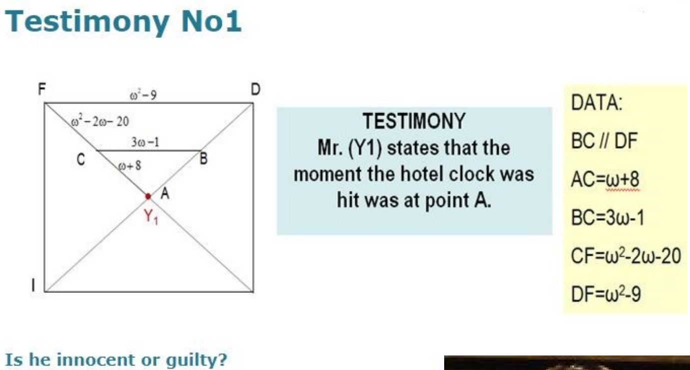
Do you notice anything cool with the two values above?

$$\varphi - 1 = \frac{1}{\varphi}$$

Since $\varphi = 1 + \frac{1}{\varphi}$ then $\varphi = 1 + \frac{1}{\varphi} = 1 + \frac{1}{1+\frac{1}{\varphi}} = 1 + \frac{1}{1+\frac{1}{1+\frac{1}{\varphi}}}$ *etcetera*

1. Detecting a crime by an inspector mathematician!

Field of application: Math in Art (cinematographic art)
Required knowledge: Geometry, Similarity, Pitagora's theorem
Project: Who killed Mr. X?
Moodle: http://srv-1lyk-aigiou.ach.sch.gr/moodle/course/view.php?id=7&sesskey=283VD7oyl3#section-1
Authors: Ioannis Papadopoulous, Antonia Grekioutou, students from 1o Geniko Lykeio Aigiou, Greece
Coordinator: Nikolaos Diamantopoulos
The assignment of this lesson is to solve 10 problems of geometry and logic that lead to finding the "crime scene". These problems are testimonials of witnesses in the little scenario created in the game of Sherlock Holms.



Resources: Information sheet – Theatrical Scenario, Testimonials - work sheets.
Generalization: Worksheets can change, clues problems can change, they can be organized by degrees of difficulty.

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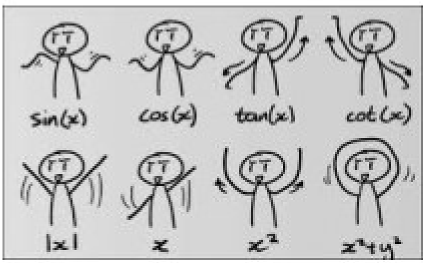
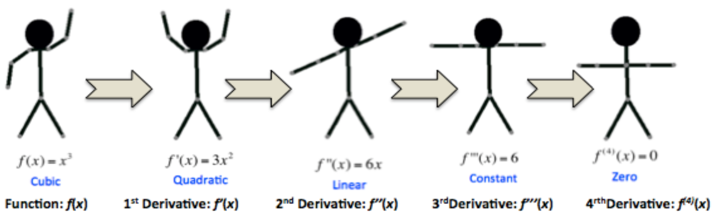
2. Math is dance

Field of application: Math in Art (Dance)
Required knowledge: Graph of functions: linear, square, module, exponential, logarithmic, trigonometric, derivate of functions
Project: Math is dance
Moodle: http://srv-1lyk-aigiou.ach.sch.gr/moodle/course/view.php?id=7&sesskey=283VD7oyl3#section-2
Authors: Ilianna Sakellari, Ioannis Papadopoulous, Efrosyni-Maria Bouzou, Panagiotis Panagopoulos, 1o Geniko Lykeio Aigiou, Greece
Coordinator: Nikolaos Diamantopoulos, Ilias Spanos, Spyridon Potamitis
The assignment: Students must recognize the function according to the graph.
Resources: video: https://www.youtube.com/watch?v=OFzqDatEvCo, work sheets.
Generalization: Students can be challenged to create their own graphics for functions and the similar movements.





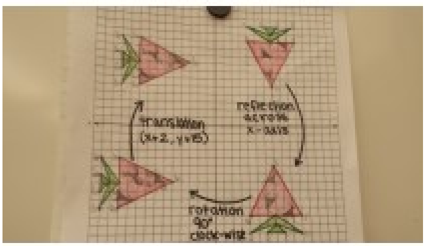
The Derivative Dance

3. How can I use math concepts in art making?

Field of application: Math in Art
Required knowledge: Geometrical transformations
Project: Create art work with transformations
Moodle http://srv-1lyk-aigiou.ach.sch.gr/moodle/course/view.php?id=7&sesskey=GbNiHyEUG3#section-3
Authors: Ilianna Sakellari, Efrosyni-Maria Bouzou, 1o Geniko Lykeio Aigiou, Greece
Coordinator: Nikolaos Diamantopoulos, Ilias Spanos
The assignment: Students will observe and describe examples of rotations, translations, and reflections in various works of art. Students will then create a work of art using these mathematical concepts. Finally, students will describe the transformations from their artwork using ordered pairs.
Math Objectives:

- Verify experimentally the properties of rotations, reflections and translations
- 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 congruence between them
- Describe the effect of dilations, translations, rotations and reflections on two-dimensional figures using coordinates

Resources: www.youtube.com/watch?v=uVrh3frrC38, Kahoot, work sheets.
Generalization: Create art work with new and diferent geometrical tansformation



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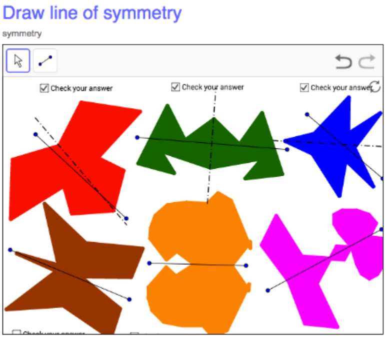
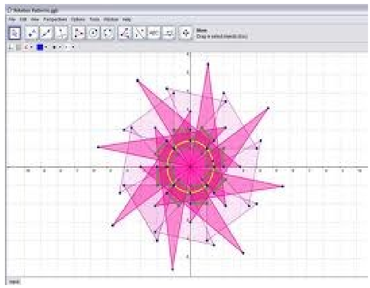
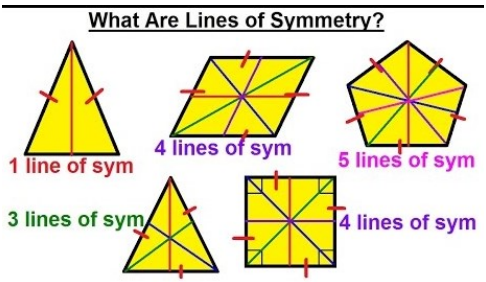
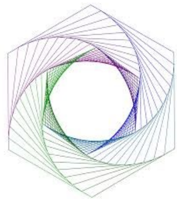
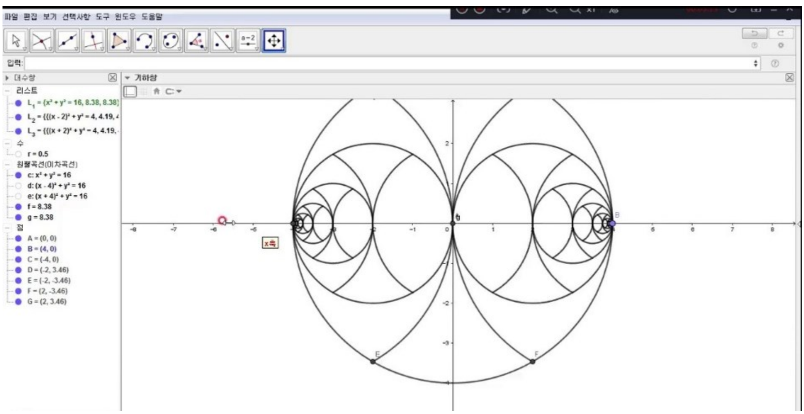
Art created with Geogebra:











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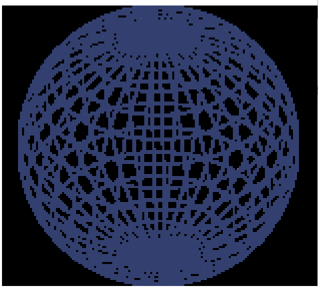
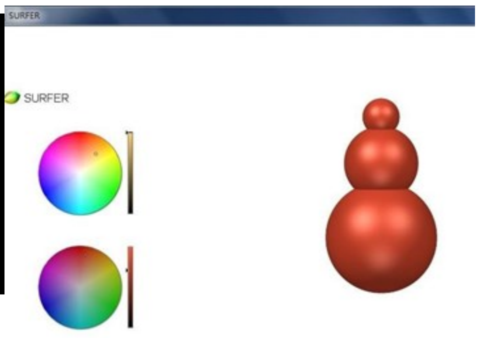
4. Using Maths to make Art

Field of application: Math in Art
Required knowledge: Equation for circle and sphere
Project: Using Maths to make Art
Moodle http://srv-1lyk-aigiou.ach.sch.gr/moodle/course/view.php?id=7&sesskey=HNGbci2Ghr#section-5
Authors: Ilianna Sakellari, Panagiotis Panagopoulos Efrosyni-Maria Bouzou, student from 1o Geniko Lykeio Aigiou, Greece
Coordinator: Nikolaos Diamantopoulos, Ilias Spanos
The assignment: This is a mathematics lesson for learning new knowledge, such as the equation of circle (2D) and cylinder (3D) and the equation of sphere (3D), as well as applying this knowledge in order to facilitate the goal of achieving "Symbolic - graphic Combination".
Resources: Forum, chat, Required software: SURFER, work sheets, Snowman project





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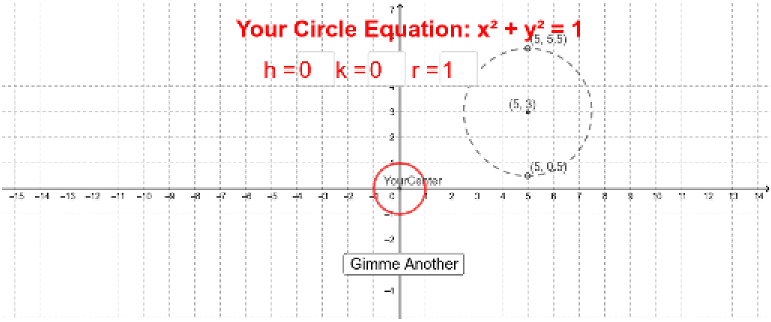

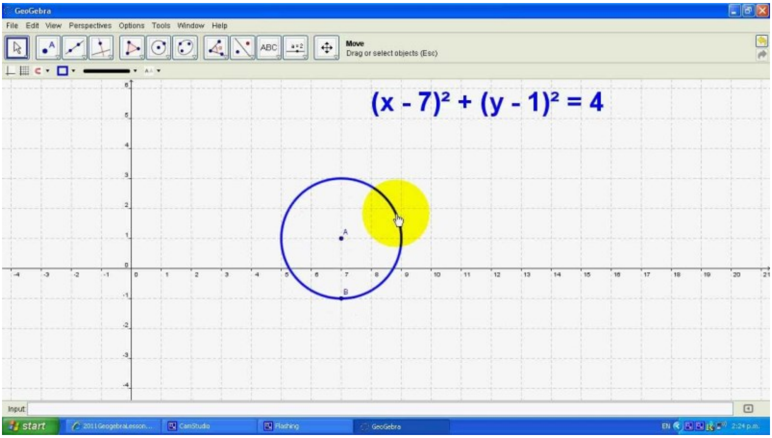

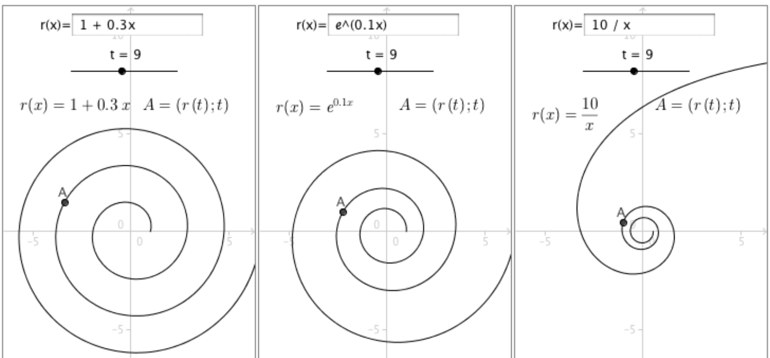

Archimedean spiral　Logarithmic spiral　Hyperbolic spiral

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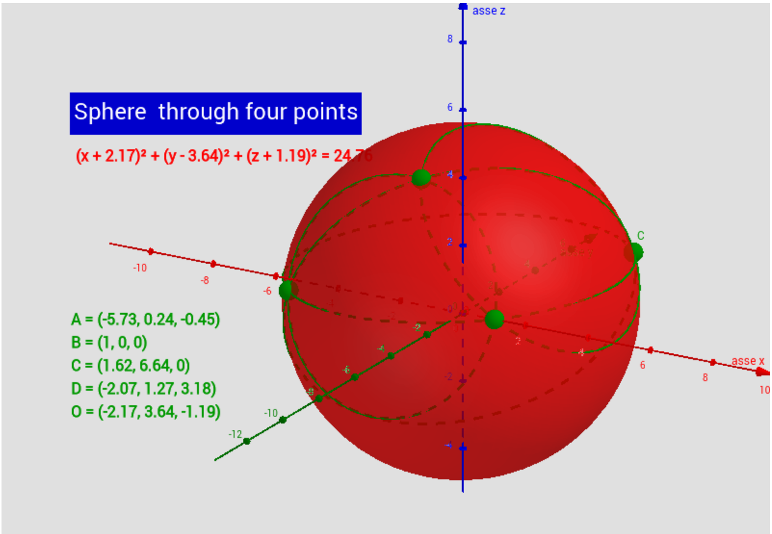
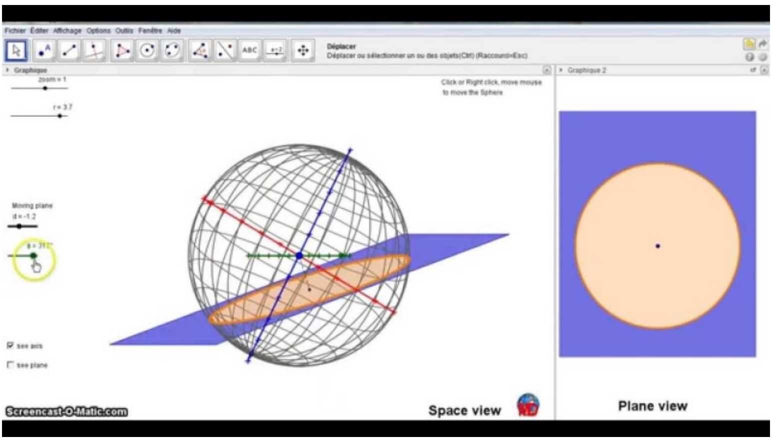
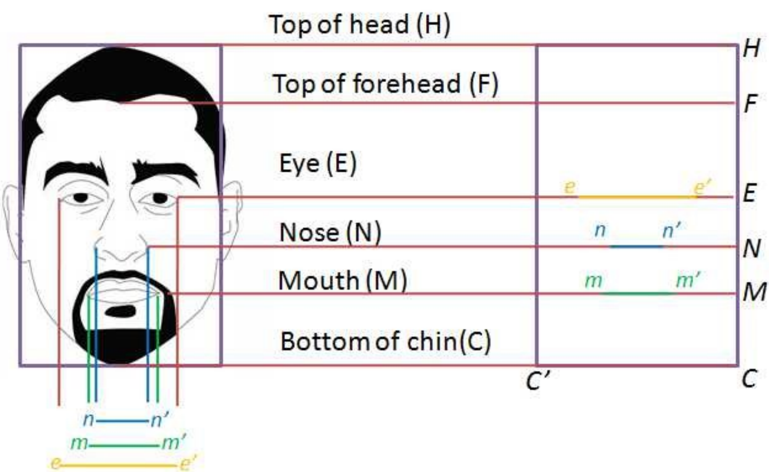




5. The Golden Ratio in Art

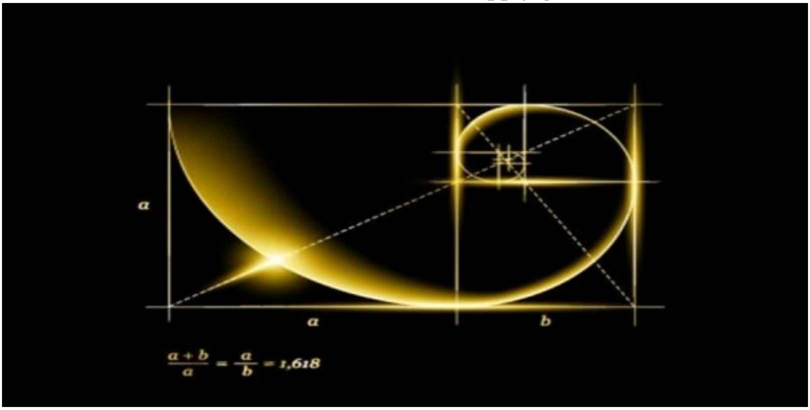
Field of application: Maths in Art
Required knowledge: Thales's theorem, ratio, series
Project: The Golden Ratio and Art
Moodle: http://srv-1lyk-aigiou.ach.sch.gr/moodle/course/view.php?id=7&sesskey=HNGbci2Ghr#section-5
Authors: Ioannis Papadopoulous Antonia Graikioutou students from 1o Geniko Lykeio Aigiou, Greece
Coordinator: Nikolaos Diamantopoulos, Spyridon Potamitis
The assignment: It is said that the closer the dimensions of the face fit to the Golden Ratio, the more beautiful the person will be perceived to be by others. Find some close up photos of famous people and determine their facial ratios. You may even want to take close up photos of yourself and your friends to determine your own ratio. Remember that 1.62 is considered golden when it comes to beauty.

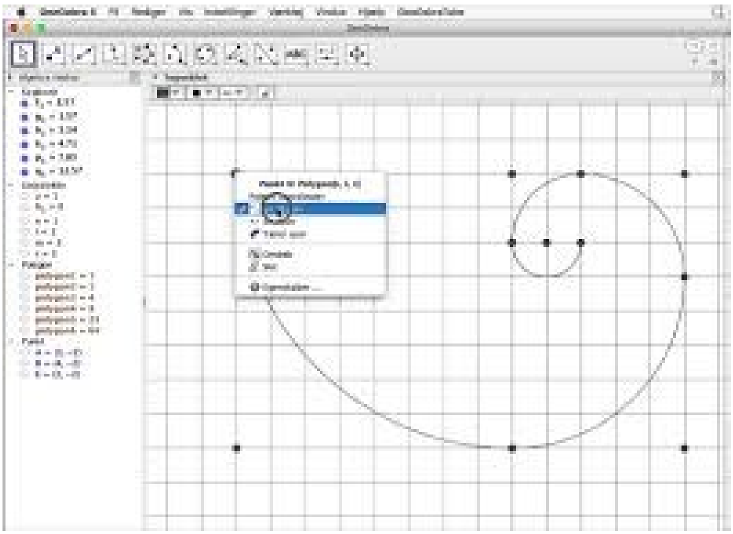


"The power of the golden section to create harmony arises from its unique capacity to unite different parts of a whole so that each preserves its own identity and yet blends into the greater pattern of a single whole." — György Dóczi, The Power of Limits

Resources: Story about the discovery of the gold section, Presentation, worksheet

Generalization: Discovers works of art that apply golden ratio on the internet.





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