STEM Activities Inspired by *Da Vinci's Tiger*

"Principles for the Development of a Complete Mind: Study the science of art. Study the art of science. Develop your senses- especially learn how to see. Realize that everything connects to everything else."—**Leonardo da Vinci**

Da Vinci's Tiger is an ideal novel to model the integration of sciences, technology, literature, and art. Within this historical fiction novel, readers are exposed to early advances in biology, geometry, engineering, invention, mathematics, anatomy—and art (including poetry, painting, and sculpture.) In Renaissance Florence, artists and engineers were synonymous—the same people were hired to both build and design elaborate churches and then decorate the interior with art. Most of the characters in *Da Vinci's Tiger* embody this ideal of the Renaissance—to be multi-talented and well-rounded.

Inspired by such incredible thinkers such as Ginevra de' Benci, Leonardo da Vinci, and Lorenzo de Medici, this guide is designed to inspire collaboration between educational departments, and encourage a transition from "STEM" to "STEAM" education.

This guide includes several sample lesson plans in physics, math, biology, geometry, art, engineering, and technology—all inspired by events in *Da Vinci's Tiger*.

Physics Problem Set

Topic: Physics

Goal: To use a fun storyline to help students understand the concepts of displacement, velocity, time, and acceleration.

Review the core equations for Velocity, Acceleration, Kinematics and movement in a straight line.

Break students into small groups to work through the following problem set:
Giuliano de'Medici is competing for honor and glory in a joust! Use your knowledge of displacement, velocity, time, and acceleration to help him win the day!

1. Giuliano easily defeated his first opponent and his new horse, Orso, showed off his speed! He galloped from one end of the 100 m jousting arena to the other in 6.25 seconds. What was his average speed?

2. In the second round, Orso didn't move quite as quickly. He averaged 14.5 m/s as he galloped the full length of the 100 m jousting arena. Determine the time it took Giuliano and Orso to gallop from one end of the arena to the other.

3. In a joust, the opponents start standing still at opposite ends of the arena and quickly accelerate to a steady, quick pace. Giuliano's horse Orso can accelerate from 0 to 14 m/s in a time of 2 seconds. Find Orso's acceleration.

4. During Giuliano's fourth match, he is worried that the collision with his opponent injured Orso. Giuliano quickly reins in his steed to check on him. Orso abruptly decelerates from 12 m/s to 3 m/s in 2 seconds. Determine Orso's acceleration rate and the distance he moved during this period.

5. Giuliano's fifth match is against a skilled and dangerous member of the Strozzi family. Not wanting to miss his target, Giuliano keeps Orso steadily accelerating at a pace of .5 m/s/s. How far from their starting place are they after 4 seconds?

6. During Giuliano's sixth match, a strong wind blows up. If Giuliano's horse is galloping at a speed of 30 miles/hour directly into a wind blowing at 50 miles/hour, what will be the resultant velocity of Giuliano's horse, Orso?

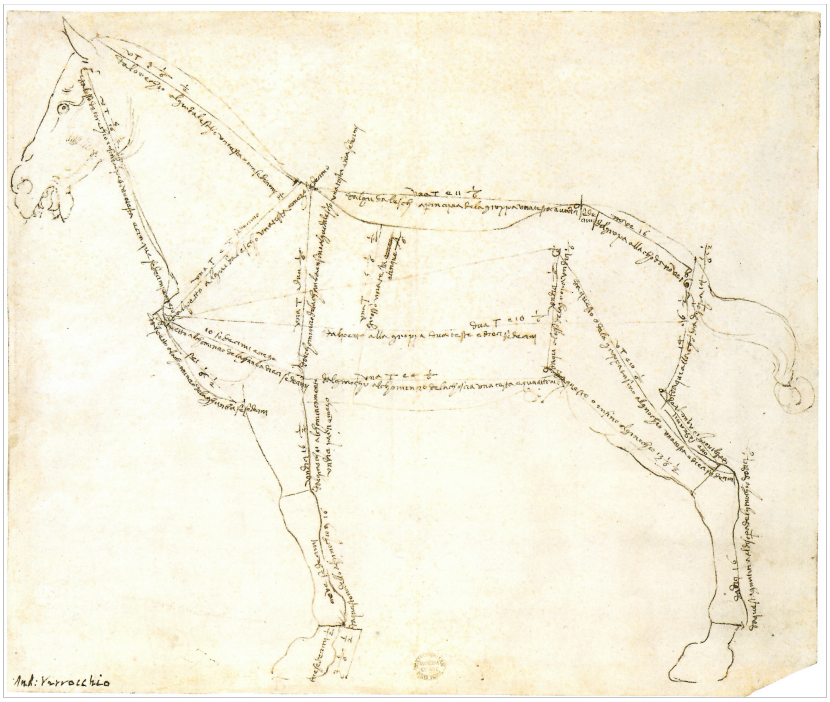
7. Giuliano and his final opponent, Sir Ulrich, face off 100 m away from each other at opposite ends of the jousting arena. Sir Ulrich's horse moves at a constant velocity of 11 m/s. Giuliano's horse, Orso, gallops at a faster velocity of 14 m/s.
    a. Assuming both Giuliano and his opponent start galloping their horses at the same time, after how many seconds will they collide?
    b. Where in the arena will they collide?

Each group presents the correct answer for a problem you assign them. Review and discuss their results.

Proportions and Ratios

Topic: Biology and Math

Goal: To recognize the crossover between biology, math, and art.



Show the above picture and explain the following To more accurately understand nature and biology, Leonardo da Vinci and his teacher, Andrea del Verrocchio, paid special attention to proportions, fractions, and ratios. They would study the anatomy of people, horses, dogs, cats, etc. to better understand how creatures fit together and their limbs worked.

Assignment: Take a series of measurements of a friend, a family member, or a pet. Find the proportion of each important body part—head, arms, legs, torso, etc.—and calculate the ratio of the parts to each other and to the whole body. Then use these calculations to create a mathematically accurate sketch. (Don't worry! You are not being graded on your artistic talents!)

Conversions

Subject: Math

Goal: To help students apply conversion to real-life scenarios.

Work through the following problems: *You are a very busy merchant in Florence during Renaissance Italy. During this time, items were often traded instead of bought or sold. During your day, you complete a series of complicated transactions that involves doing quick conversions in your head.*

1. You start your day with a pocket full of coins—5 florins (gold coins) and 50 soldi (silver coin). A florin is worth 140 soldi. How much money do you have, in terms of soldi?

2. Your first stop of the day is at a jeweler. You purchase a ring worth 140 soldi, a simpler ring worth 11 soldi, and a gemstone for 70 soldi. Approximately how much do you pay the jeweler in florins?

3. When you return, a customer comes to your shop. They need 3 meters of fine velvet, valued at 225 soldi a meter. They don't have much cash, but they make glasses, valued at 20 soldi each. How many glasses could they trade you for 3 meters of fine velvet?

4. Your wife stops by your shop. She is angry because your family has commissioned a frescoed scene for your home, and you have not yet paid the artist. He is demanding 25 florins by the end of the week. A colleague of yours is planning to purchase a bulk order of taffeta from you. You sell taffeta at a rate of 15 soldi for 2 feet of taffeta. How many yards of taffeta would you have to sell per day to have 25 florins to pay the artist by the end of the week (assume today is Monday and the artist wants his payment on Sunday)?

5. Your most impressive and expensive good in the store is a bolt of velvet brocade with gold thread spun by the nuns of Le Murate. 2 feet of this brocade is worth 15 florins. A bank manager who makes 150 florins a year wants to buy 4 yards of the brocade. What percentage of his yearly salary would he have to give you for the brocade?

6. A noblewoman comes to your shop, looking to purchase your finest brocade for her daughter's wedding dress. During the Renaissance, parts of dresses were often made out of different materials. A full formal wedding gown requires 18 yards of brocade. An underskirt only requires 10 yards of brocade, and a pair of sleeves requires 4 yards of brocade. You charge 17 florins for 2 feet of this brocade. The noblewoman is willing to spend up to 300 florins on this wedding gown. Would she be able to purchase a full gown? If not, what could she afford to buy?

7. Your friend Marco wants some of that fine velvet. He offers you a horse from his farm, valued at 6 florins, in exchange for your velvet, valued at 225 soldi a meter (reminder: 1 florin = 140 soldi). How many yards of velvet is a fair trade for Marco's horse?

8. You and your wife are considering buying a small property outside Florence valued at 100 florins. On an average day, you earn 6 florins. You want to save a third, spend a third, and put a third away for this property. Assuming you work 5 days a week, approximately how many months will it take you to save up the necessary money to buy the Tuscan property?

Geometry: The Golden Rectangle

Subject: Math

Goal: To teach students how to apply important math principles to art.

Introduce the idea of the golden rectangle: a golden rectangle is a rectangle whose side lengths are in the golden ratio, $1 : \frac{1+\sqrt{5}}{2}$ or $1 : \varphi$

Teach how to construct a golden rectangle (using a straight edge and a compass):

1. Construct a simple square
2. Draw a line from the midpoint of one side of the square to an opposite corner.
3. Use that line as the radius to draw an arc that defines the height of the rectangle.
4. Complete the golden rectangle.

Introduce the golden spiral and draw on the board:

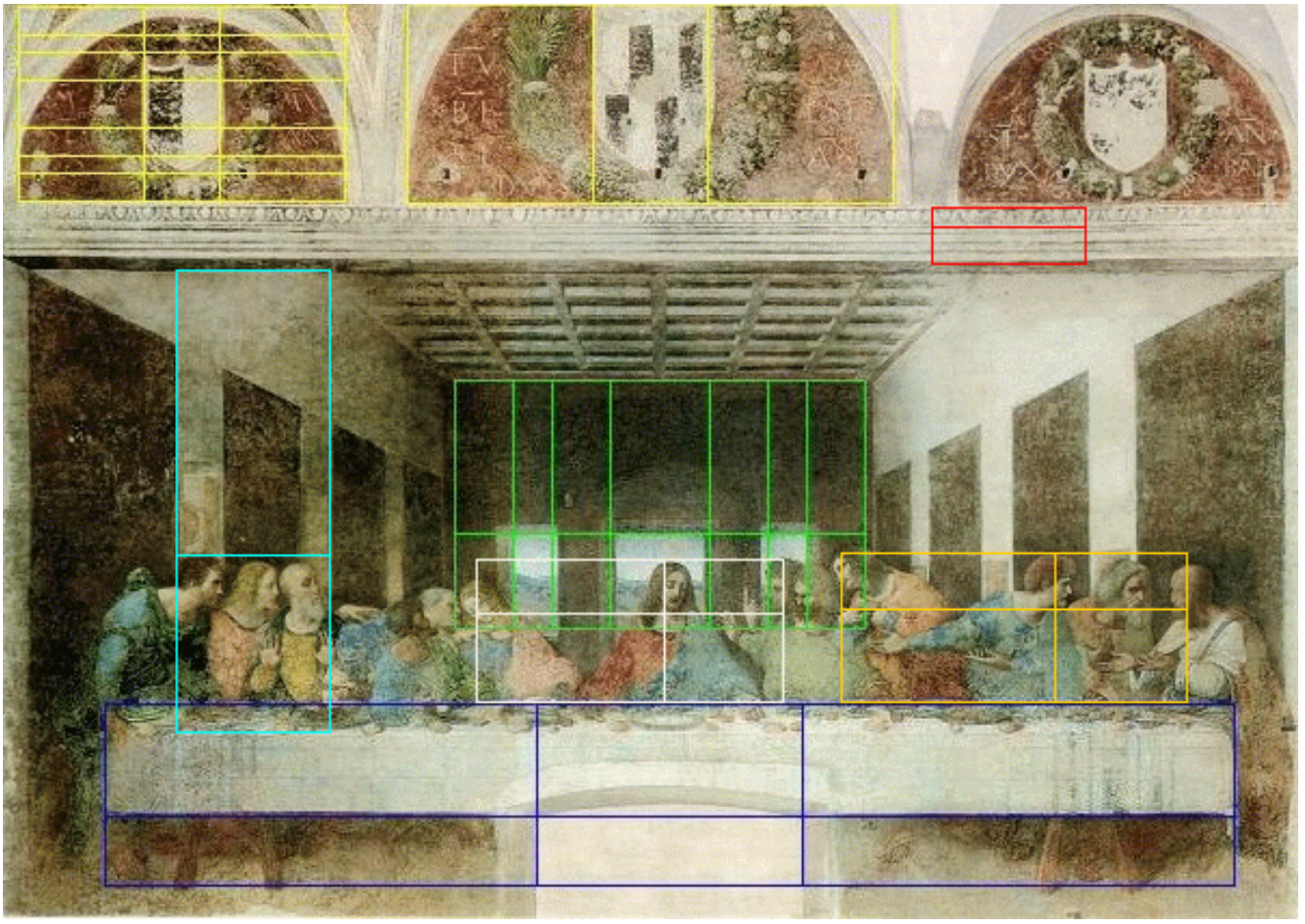
A distinctive feature of the golden rectangle is that when a square section is removed, the remainder is another golden rectangle. Square removal can be repeated infinitely, in which case corresponding corners of the squares form an infinite sequence of points on the golden spiral.

Have students construct their own golden spiral.

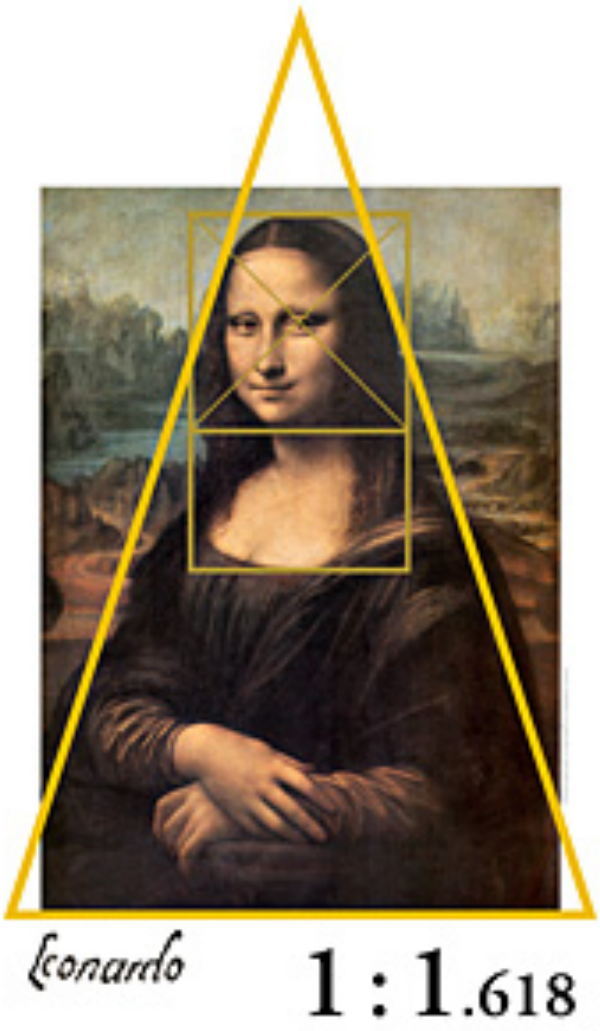
Applying the Golden rectangle to art:

Leonardo da Vinci extensively used the Golden Rectangle in his art. He believed matching up his paintings to the golden ratio created a more balanced and aesthetically pleasing composition. During the Renaissance, this ratio was known as “The Divine Proportion.”

Use *The Last Supper* to show how much Leonardo used the Golden Rectangle:



Next, show the students the Mona Lisa and have them try to find as many golden rectangles as they can. Point out that the golden rectangle framing her head, neck, and bodice. Point out that her head fits within a square. Draw a line straight through the portrait and point out it passes right through her left eye.



Finally, hand them an image of *Ginevra de'Benci* by Leonardo da Vinci and see how many golden rectangles they can find:

Models from Da Vinci's Notebook

Subject: Engineering/Technology

Goal: To synthesize historical images of machines with student's modern knowledge and innovation

Introduction: While his notebooks are packed with doodles and some rather far-fetched ideas, Leonardo da Vinci created many drafts and sketches of imaginative and practical machinery. In particular, he developed many models for cranes and hoists that helped with the construction of huge buildings and cathedrals.

Visit this website to learn about Leonardo's inventions and view models based on sketches done by him or his contemporaries, paying particular attention to anything used for construction:

Le Macchine di Leonardo da Vinci:
http://www.macchinedileonardo.com/index.php?machines-mechanics#2

In a group of 4-5 students, pick a machine from Leonardo's sketches (a crane, a hoist, or other building machinery) and research its design.

Create your own sketches and then build a small model of whatever machine you built.

Building a Model: The Duomo

Subject: Technology/Engineering

Goal: To develop a deeper understanding of Renaissance art and architecture through scientific exploration.

Introduction: Explain the following using pictures, drawings, or video of the Duomo. The huge cathedral at the center of Florence is commonly called "The Duomo" in honor of its enormous, 10-story-high dome. No matter where you go in Florence, the Duomo dominates the skyline—and would have been even more impressive in Renaissance Italy. The Duomo is also a marvel of engineering, still the world's largest masonry dome—built entirely without modern technology or any kind of supporting scaffolding as its bricks rose row by row over 16 years of work.

By the beginning of the 15th century, the cathedral was complete—except for its dome. The original design called for an octagonal dome higher and wider than any that had ever been built, with no external flying buttresses (like Paris' famed Notre Dame) to keep it from falling under its own weight. It would instead need to be supported from the inside.

Brunelleschi, a goldsmith who finally came up with a plan for the dome, after carefully analyzing Rome's Pantheon, used a double shell design. The heavier inner dome was supported by four rigid, octagon shaped frames made of stone chains. These chains were built like an octagonal railroad track. The inner dome was also supported by vertical "ribs" set on the corners of the octagon curving up and inward to the center point at the top of the dome. Brunelleschi then used a herringbone brick pattern in slightly inverted arches to transfer the weight of the bricks (ultimately 40,000 tons!) down and out to the nearest rib. The outer dome was supported by nine masonry rings. The Duomo was then topped with a lantern and a gleaming bronze ball—designed by Andrea del Verrocchio and perhaps assisted by his apprentice Leonardo da Vinci.

Assignment: On a team of 4-5 students, using simple materials (Styrofoam, dowel rods, etc), build a small model of the Duomo. Watch this National Geographic film to see how modern bricklayers and scholars do it: https://www.youtube.com/watch?v=kkBaxFuh40E