SCIENTIFIC REVOLUTION (16TH/ 17TH CENTURIES): HELIOCENTRIC MODEL: COPERNICUS AND GALILEO

LINK
Lesson Plans
by passports educational group travel

SCIENTIFIC REVOLUTION (16TH/17TH CENTURIES): HELIOCENTRIC MODEL: COPERNICUS AND GALILEO

Description
Through the investigation of selected primary and secondary sources, students in this lesson will identify, understand and be able to explain the basics of the Copernican or Heliocentric model of the universe, how Galileo picked up the idea and expanded upon it, and how heliocentrism challenged the established scientific and religious authorities of the time.

Subjects
Science, World History, European History

Grade Level
11-12

Duration
90 minutes

Tour Links
- Basilica, Frombork, Poland
- Copernicus Monument, Warsaw
- Basilica di Santa Croce, Florence
- Museo Galileo, Florence

Essential Questions
- Who was Nicholas Copernicus?
- Who was Galileo Galilei?
- How did Copernicus develop the Heliocentric Model of the Universe?
- How did Galileo expand on this idea?
- How did Copernican ideas run afoul of 16th century established models of the universe?
- Why did the Catholic church take issue with Copernicus and Galileo?
- What happened to Galileo as a result of his writings?

Academic Summary

Let no one untrained in geometry enter here...
... That the earth is also spherical is therefore beyond question, because it presses from all sides upon its center. Although by reason of the elevations of the mountains and the depressions of the valleys a perfect circle cannot be understood, yet this does not affect the general spherical nature of the earth. This appears in the following manner. To those who journey towards the North Pole of the daily revolution of the heavenly sphere seems gradually to rise, while the opposite seems to sink. Most of the stars in the region of the Bear seem not to set, while some of the Southern stars seem not to rise at all. So Italy does not see Canopus which is visible to the Egyptians. And Italy sees the outermost star of the Stream, which our region of a colder zone does not know. On the other hand to those who go towards the South the others seem to rise and those to sink which are high in our region. Moreover, the inclination of the poles to the diameter of the earth bears always the same relation, which could happen only in the case of a sphere. So it is evident that the earth is included between the two poles, and is therefore spherical in form … It is clear that the water also according to its nature continually presses like the earth downward, and does not rise above its banks higher than its convexity permits.
… As it has been already shown that the earth has the form of a sphere, we must consider whether a movement also coincides with this form, and what place the earth holds in the universe. Without this there will be no secure results to be obtained in regard to the heavenly phenomena. The great majority of authors of course agree that the earth stands still in the center of the universe, and consider it inconceivable and ridiculous to suppose the opposite. But if the matter is carefully weighed it will be seen that the question is not yet settled and therefore by no means to be regarded lightly. Every change of place which is observed is due, namely, to a movement of the observed object or of the observer, or to movements of both, naturally in different directions, for if the observed object and the observer move in the same manner and in the same direction no movement will be seen. Now it is from the earth that the revolution of the heavens is observed and it is produced for our eyes. Therefore if the earth undergoes no movement this movement must take place in everything outside of the earth, but in the opposite direction than if everything on the earth moved, and of this kind is the daily revolution. So this appears to affect the whole universe, that is, everything outside the earth with the single exception of the earth itself. If, however, one should admit that this movement was not peculiar to the heavens, but that the earth revolved from west to east, and if this was carefully considered in regard to the apparent rising and setting of the sun, the moon and the stars, it would be discovered that this was the real situation. Since the sky, which contains and shelters all things, is the common seat of all things, it is not easy to understand why motion should not be ascribed rather to the thing contained than to the containing, to the located rather than to the location. From this supposition follows another question of no less importance,

> concerning the place of the earth, although it has been accepted and believed by almost all, that the earth occupies the middle of the universe. But if one should suppose that the earth is not at the center of the universe, that, however, the distance between the two is not great enough to be measured on the orbits of the fixed stars, but would be noticeable and perceptible on the orbit of the sun or of the planets: and if one was further of the opinion that the movements of the planets appeared to be irregular as if they were governed by a center other than the earth, then such an one could perhaps have given the true reasons for the apparently irregular movement. For since the planets appear now nearer and now farther from the earth, this shows necessarily that the center of their revolutions is not the center of the earth: although it does not settle whether the earth increases and decreases the distance from them or they their distance from the earth.
> *Nicholas Copernicus, On the Revolutions of the Heavenly Spheres, (excerpts) 1543*

On 24 May 1543, after being in a coma for almost six months, seventy-year-old astronomer and mathematician Nicholas Copernicus died in Frombork, Poland of complications related to what was then called apoplexy (now called a stroke). A few weeks earlier, his life's work, a short 40-page book called On the Revolutions of the Heavenly Spheres, appeared in print. It had been secretly published by Lutheran printers in Nuremberg. Tradition says that as he lay dying, Copernicus woke from his coma to kiss a copy of his revolutionary book. The work immediately caused controversy across Europe. For decades, Copernicus had undertaken a secret scientific, philosophical and mathematical examination of the heavens. His observations led him to the conclusion that the entire European community was wrong about the position of the Earth in relation to the rest of the universe.

The ancient Greeks had revolutionized scientific theories and observations regarding the universe over 2000 years earlier. Men like Anaximander, a 6th century BCE pre-Socratic philosopher, tried instead to use observation and human reason to explain what they saw. As Anaximander peered into the sky from his home off the coast of Ionia (today's modern Turkey – then settled by Greeks), he noticed that bodies such as the Sun, Moon and stars appeared to move across the sky in a circular motion. Priests before this time had attributed this motion to the activities of the gods themselves. Anaximander, while still believing that the objects he observed were gods, came up with the radical idea that those objects revolved around a free-floating Earth on a set of concentric wheels. Zeus himself had created this system to establish order in the chaos of the universe. Since the gods created the Sun and the Moon in different sizes, those bodies must in turn be at different distances from the Earth (a revolutionary idea at the time). Anaximander even theorized on the existence of multiple worlds, although he couldn't see them in his observations (he failed to understand that some of the "stars" he saw were actually planets). Later Greek and Roman astronomers like Ptolemy expanded on Anaximander's work. This ancient model became known as the "geocentric" model of the universe.

Early Christian fathers made the idea of the geocentric universe part of Christian dogma. The ancient ones, they said, had been divinely inspired, even if they themselves did not realize it. Biblical passages throughout the Old Testament put the Earth as an unmovable object surrounded by the heavens, all of which had been created according to God's plan for humanity. New Testament writings on the subject in the early Church simply confirmed what was already known — the Earth lay at the center of the universe. To go against geocentrism was to go against the Church, and therefore against God. Ideas like that put one's eternal soul in jeopardy. That was blasphemy, a crime punishable by burning at the stake. As the Church gained power in Europe following the fall of the Roman Empire, even whisperings or accusations of blasphemy could warrant an investigation, torture, prison and death. Copernicus himself refused to make his work public before his death because he worried someone would report him to papal authorities. And yet, his observations led him to believe that the 2000-year-old idea of a geocentric model was wrong. It all stemmed from a false premise.

That foundation of geocentrism lay in a belief that the Earth itself was stationary. Although he couldn't feel it or see it, Copernicus theorized that the Earth rotated around a central axis. The Sun's movement across the sky, therefore, was a result of this rotation. If he was right, the observations from the Earth would show that it could not be at the center of the cosmos. Instead, he came up with the idea that the Earth revolved around another, much larger, object (which itself was also rotating): the Sun. That put the Sun at the center of the universe (he did not conceptualize anything outside of our solar system), giving rise to the idea of the heliocentric model. Today this realization is seen as the spark that opened the Scientific Revolution in Europe.

When word of Copernicus and his theory reached Rome, the Catholic Church condemned it as heresy and banned its publication, but it was too late. On the Revolutions of Heavenly Spheres continued to be published in areas far from Church control. Eventually his teachings reached Florence, a hotbed of learning and Renaissance thought, where an Italian physicist and astronomer named Galileo Galilei picked them up. In 1610, Galileo pointed his newly invented telescope at Jupiter, a planet known to people since the Hellenistic Age (3rd / 4th century BCE). He observed four objects crossing the planet's face. Over the course of a few days, he found that the objects moved, and that one had even disappeared, only to return on the opposite side of the planet days later. Galileo quickly realized he had discovered objects revolving around the huge planet (now known as the moons of Io, Europa, Ganymede and Callisto). After he published his findings, Galileo was subsequently arrested and tried for heresy by the Church. With the help of powerful friends (especially the Medici family), he escaped execution after recanting his views under the threat of torture, but he was convicted of heresy and sentenced by Church officials to house arrest for the remainder of his life.

The debate would rage for centuries. The Catholic Church put Copernicus' book on its list of banned works in 1616 (along with Galileo's writings on the subject), where it would remain for over two centuries. Debates on the issue of heliocentrism festered in Europe until the 19th century. Catholic and Protestant theologians (including Calvin and Luther) condemned the idea as blasphemous and against the teachings of scripture.

Yet it continued to spread nonetheless. Eventually, as more observations were made with better telescopes, the heliocentric model became the accepted theory of the scientific community. In 1835, the Catholic Church left Copernicus and Galileo's books off its banned list. It took until 1992, however, for the Pontifical Academy of Sciences to official clear Galileo of heresy, saying that the Italian astronomer had indeed been right in adopting the Copernican theory. Today, Copernicus and Galileo are seen as national heroes in Poland and Italy and their writings are freely available on the Internet. Through the investigation of selected primary and secondary sources, students in this lesson will identify, understand and be able to explain the basics of the Copernican or Heliocentric model of the universe, how Galileo picked up the idea and expanded upon it, and how heliocentrism challenged the established scientific and religious authorities of the time.

Objectives

1. Students will identify, understand and be able to explain the basic scientific ideas behind the Copernican or Heliocentric model of the universe.
2. Students will identify, understand and be able to explain how Galileo picked up heliocentrism and expanded upon it.
3. Students will identify, understand and be able to explain how the development of heliocentrism in the 16th century challenged the established scientific and religious authorities of the time.

Procedure

I. Anticipatory Set

- Writing / Question: If you've never been to space, how do you know the sun is at the center of the solar system? (5 min)
- Handouts – Copies of documents and readings from the websites listed. (5 min)

II. Body of Lesson

- Lecture / PPT – Geocentric Theory vs. Heliocentric Theory (20 min)
- Video – Copernicus and the Scientific Revolution (15 min)
- Independent Activity – Students read the articles and sources on Copernicus, Galileo and the Heliocentric Model of the Universe, taking notes as appropriate. (30 min)
- Suggestion: AP / Advanced students should focus on primary sources.
- Group Activity – Socratic Seminar: Discussion on Copernicus, Galileo and the Heliocentric Model. (15 min)

III. Closure

- Assessment / DBQ – Essay: Explain in detail the basics of the Copernican or Heliocentric model of the universe, how Galileo picked up the idea and expanded upon it, and how heliocentrism challenged the established scientific and religious authorities of the time.
- Alternative Assessment / Homework: Using any and all of their artistic skills, have students draw modern versions of the solar system, using both geocentric and heliocentric models. Since observation and the collection of data is part of the scientific method, can students design an experiment that uses science to defend the geocentric model?

Extension

On tour: Frombork Cathedral, Poland

While on tour, students in Poland can visit the Archcathedral Basilica of the Assumption of the Blessed Virgin Mary and Saint Andrew in Frombork (about an hour east of Gdansk along the Baltic Sea in Northern Poland) where they can see for themselves the burial place of Nicholas Copernicus. The polish astronomer lived in Frombork and wrote *On Revolutions* there. When he died in 1543, he was buried in the cathedral. Starting in the 19th century, when his theories gained acceptance, teams of forensic archeologists searched the grounds in vain for his burial plot, but in August 2005 they found him. DNA taken from the skeleton matched that from hair found in one of Copernicus' books. In 2010, he was reburied with full national honors back at the cathedral and a new monument was erected by the Polish government to honor their national hero.

On tour: Museo Galileo, Florence

While on tour in Florence, students can visit the Museo Galileo in the Piazza dei Guidici, down the street from the Ponte Vecchio and Piazza della Signoria, where they can see for themselves the history of science in the city and around the world. Galileo's work, of course, occupies a significant and obvious place in the museum. The Museo Galileo conducts educational worksheets and group tours. Groups are asked to call ahead to reserve tours. In 2012, the museum opened a new interactive area where students can interact with innovative exhibits designed to explain science through hands-on activities. Admission for groups of 15 or more is €5.50 per person. Regular admission is €9 per adult and €5.50 per child (ages 6-18). The museum is open every day (including Sundays) except 25 Dec and 01 Jan. For visitors who choose to go on their own, video guides are available at the assistance desk for €5 each.

Web Links

Lesson Plan Websites

- www.fordham.edu/halsall/mod/1543copernicus2.asp
  Nicholas Copernicus: Excerpts from the Revolution of the Heavenly Bodies, 1543 (primary source) – from the Modern History Sourcebook at Fordham University
- www.webexhibits.org/calendars/year-text-Copernicus.html
  On the Revolutions of Heavenly Spheres (primary source) – full text version of Copernicus' book
- www.fordham.edu/halsall/mod/1630galileo.asp
  The Crime of Galileo (primary source) – from the Modern History Sourcebook at Fordham University
- www.fordham.edu/Halsall/mod/galileo-tuscany.asp
  Galileo: Letter to the Grand Duchess Christina, 1615 (primary source). This letter spells out Galileo's observations and the reasons he gives in support of the heliocentric model. This copy is from the Modern History Sourcebook at Fordham University.
- http://people.physics.carleton.ca/~watson/Physics/NSCI1000/Pseudo-science/Copernicus_vs_Ptolemy.html
  Copernicus vs. Ptolemy (class notes) – from Peter Watson, Professor Emeritus, Physics Department at Carleton University (Canada)
- www.umk.pl/en/university/patron/
  Nicholas Copernicus (website) – from Nicholas Copernicus University in Poland
- www.colorado.edu/physics/phys3000/phys3000_sp12/Lectures/L8.pdf
  Galileo, Heliocentrism and the Church (class notes) – from the Department of Physics at Colorado
- http://galileo.rice.edu/sci/theories/copernican_system.html
  Copernican system (website) – from the Galileo Project at Rice University
- http://galileo.rice.edu/index.html
  The Galileo Project (website) – main page for the project from Rice University
- www.geocities.ws/glhsscience/GeoTheoryvsHelioTheory.ppt
  Geocentric Theory vs. Heliocentric Theory (PowerPoint)
- www.teachingchannel.org/videos/choosing-primary-source-documents?fd=1
  Reading Like a Historian: Primary Source Documents (video). Great 2-minute video on how to incorporate primary sources into the Common Core and history classes. From Shilpa Duvoor of Summit Preparatory Charter High School in Redwood City, CA. Highly recommended for teachers.
- www.youtube.com/watch?v=zHUWP9zu4W8
  Copernicus and the Scientific Revolution (video). 17-minute video that is appropriate for in-class showings.
- www.youtube.com/watch?v=Lr_bQs4oXgU
  Galileo's Battle for the Heavens (video). This video, a biography of Galileo's life, is about 90 minutes long, and so is probably too long for most in-class showings, but is highly recommended for students to see on their own as an out-of-class assignment.

- www.learner.org/resources/series58.html?pop=yes&pid=853#
  The Western Tradition #25: The Renaissance and the Age of Discovery (video). This 25-minute video, although perhaps too long for most in-class showings, is well worth watching. It is part of a much larger (52-part) series produced by WGBH TV in Boston in 1989 and features Dr. Eugen Weber, former history professor at UCLA and one of the foremost experts in Western History before his death in 2007. The series, called "The Western Tradition" consists of 52 lectures of 30 minutes each, and covers subjects from the Dawn of History to the Twentieth Century. Highly recommended for students and teachers.

Background Information

- http://en.wikipedia.org/wiki/Nicolaus_Copernicus
  Nicholas Copernicus– Wikipedia article
- http://en.wikipedia.org/wiki/De_revolutionibus_orbium_coelestium
  On the Revolutions of the Heavenly Spheres (by Copernicus) – Wikipedia article
- http://en.wikipedia.org/wiki/Copernican_heliocentrism
  Copernican heliocentrism – Wikipedia article
- http://en.wikipedia.org/wiki/Copernican_Revolution
  Copernican Revolution – Wikipedia article
- http://en.wikipedia.org/wiki/Anaximander
  Anaximander – Wikipedia article
- http://en.wikipedia.org/wiki/Galileo_Galilei
  Galileo Galilei – Wikipedia article
- http://en.wikipedia.org/wiki/
  Dialogue_Concerning_the_Two_Chief_World_Systems
  Dialogue Concerning the Two Chief World Systems (by Galileo) – Wikipedia article
- www.passports.com/group_leaders/on_the_road/italy/country_profile
  On the Road: Italy – from Passports Educational Travel
- www.passports.com/group_leaders/on_the_road/italy/florence_sightseeing
  On the Road: Florence Sightseeing – from Passports Educational Travel
- www.passports.com/group_leaders/on_the_road/italy/florence
  On the Road: Florence – from Passports Educational Travel

Key Terms

- Copernicus
- Galileo
- Geocentric Model
- Heliocentric Model
- Observation
- Scientific Method
- Scientific Revolution
- Universe