Scientists are People, Too: Biographies of Astronomical Scientists as a Literary Introduction to the Heliocentric Theory

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INTRODUCTION

The Setting and Objectives

One of the teaching tools that teachers often use is to take advantage of their students' prior knowledge. This allows students to connect with the author or subject. Many students have had astronomical awareness or experiences as simple as Aristotle's in 320 BC – that the Earth must be round because it casts a crescent shape on the moon.

For me, it was an incidental thing that I sometimes noticed the moon out in the mornings and evenings when I walked my dogs. Almost as a type of entertainment, I started to anticipate where the moon would be positioned on my next walk. I found myself exhilarated as I could correctly anticipate its position. The key for me was that the moon was moving west, but because of the Earth's rotation, it appeared to be moving east. At that moment, I shared an icon of truth with the great masters.

Astronomy is very complex, to say the least. Some students, aware of their limitations, would not begin to broach the subject except from a non-threatening position. What if an introductory course were to be available that introduced the periphery of the subject? What if selected writings, biographies, autobiographies, theories and the like were a part of a curriculum to superimpose our literary devices of today on great works that were written hundreds of years ago?

Copernicus described himself somewhat as candid and clear enough that both the unlearned as well as the learned might see that he was not seeking to flee from the judgment of any man, even if someone provided a guard against the bites of slanderers, the proverb holds that there is no medicine for the bite of a sycophant. A student might suppose that a sycophant might be an insect of some kind seeing the quote uses "bite" with "medicine." The simple act of using the dictionary to clarify the meaning of sycophant could offer a lesson on inferences and metaphor.

Students could explore the sanctity of the priesthood and its ability to protect Copernicus' writings, as was his expectation – being a priest himself, and do a comparative analysis of a later time when the priesthood might be seen as being fervently against those people like Galileo who espoused the heliocentric position.

Students could have a curriculum that includes terms associated with the church at that time: "Your Holiness," "Ecclesiastical Commonwealth," "Lateran Council," etc. Additionally, students could do research papers on why the church's influence was pivotal in the acceptance of this theory. For example, they could study why Copernicus lectured on the principles of his planetary theory before Pope Clement VII, who approved his works; why the word "hypotheses" (believed to have been added by Andrew Osiander) appeared in the title when the findings were presented to Pope Paul III, the one to whom Copernicus dedicated his work; and why Galileo was put under house arrest for espousing the same theory.

Because the curriculum would be considered introductory in design and focused on the literary aspects, rather than science or math, it would give some marginal students the confidence to peer into the window of great works in a different time period. This would allow a larger group of students to participate, as it will be written in such a way to gain knowledge of the period while incorporating the TAKS standards that our students are required to learn.

At Welch, our students range from remedial to gifted. A program of this caliber would create an opportunity for greater exposure to the astronomical masters of the sixteenth century on a level that is comprehensible to a wider range of students through this introductory curriculum. Students would be able to get an insight into why it was so difficult to oppose longstanding scientific theories and consider why religious posturing on social and legal issues was quite different from what it is today. When the opportunity came to study the Copernican theory as part of the curriculum of the philosophy seminar of Dr. James Garson at the University of Houston, I was sure that using Galileo and also Copernicus and other astronomers to a lesser extent could be an opportunity to encourage students to explore further the lives of persons who made significant contributions to physics, advanced math, and astronomy.

Copernicus expected some "idle talkers" and "unlearned" to oppose his theory. We can reduce the amount of this type of present-day opposition by introducing him as a man with superior intellect who fought for a cause that made the world a better place. Some of the students will surely want to explore that place even now as they look up at the heavens and again later after they have met the great astronomers.

Looking at Scientists in Down-to-Earth Terms

Famous people who contribute to society on such a grand scale as Galileo Galilei (1564-1642) – a physician, astronomer, and theologian – are often not everyday people, and perhaps rightly so. We mostly approach their history on the basis of their contribution to society, but do not always look at their personal lives. Yet moral and social aspects permeate their lives just as they do the lives of other people. It is easy to be in awe of their tremendous contributions, thinking that such study is reserved for the most advanced students when it actually can be the domain of all students. Generally, we have the idea that Galileo and other scientists embracing the heliocentric system are so different from the vast majority of society that we seldom look at events in their lives that might be shared by a great number of ordinary people.

Galileo shared one of our modern-day problems – that of out-of-wedlock children. The implications of this act were much more intense during that time, as indicated by the events in the lives of Galileo's family. Even compared with one hundred years ago when hospitals stamped "Illegitimate" across the face of the birth certificate, the act has been viewed at various levels of disdain. Galileo's son, Vincenzio Gamba Galilei, to whom he gave his name, received a scholarly position with a pension. He later received a Doctorate degree from the University of Pisa. Afterward, he became engaged to Sestilia Bocchiner, a socialite from a prestigious family who brought with her a significant dowry. However, consider the plight of the daughters of Galileo. Their lives were spent in a nunnery, being considered unworthy of marriage due to their illegitimate status. This is an amazing comparison of brother and sisters with the same mother and father, where the only noticeable differences were their sexes. The son had the father's name; the daughters did not.

Students need to see the results of Galileo's choices on his significant other, his children, and himself. The impact of these actions can be compared with the same actions of people today, and the resulting consequences, where applicable. Students can look at welfare, subsidized housing, food stamps, drop-out rates, crime, health issues, and other social problems that often plague broken families, one-parent families, and/or poor families.

Modern-day workers strive to reach the glass ceiling in their fields of endeavor, as did the men of Galileo's day. This curriculum allows students to look at how wealth and property was transferred for posterity. Students can also compare how men obtained work. Education was and is a factor, but generally, people could live a lifetime in the same class to which they were born. Today, people in America are able to obtain education and advance in their careers. However, men at the top of the hierocracy still make most of the decisions if one looks at the Food and Drug Administration, Supreme Court and lower courts, Congress, institutions of learning, the Church, etc.

What is significant about Galileo's day is that there were two world systems: Ptolemaic and Copernican. Galileo addressed this in his writing the *Dialogues Concerning the Two Chief World Systems*. In his day, Galileo could present his scientific findings, provided they did not clash with the church/scriptures. Students will see how breaking this rule became his undoing. Because the Church and the institutions of learning, along with groups in the upper society, seem to have had the greatest impact on the acceptance or rejection of his theories, Galileo dedicated his work to many religious leaders and nobility.

The personal lives of other scientists working on astronomy related to Galileo and Copernicus will also play a role in this curriculum. Here are some examples:

Johannes Kepler experienced poor health during his early years and he was also nearsighted. In school, the other boys bullied him and beat him up. As an adult, he published astrological calendars and horoscopes to support himself. Yet he was still able to make a dynamic contribution to society.

Isaac Newton never knew his father – also named Isaac. When he was two years old, his mother remarried. According to his journal entries, he despised his stepfather because he threatened to burn his father and mother and the house with them. Sir Isaac Newton had a mental breakdown in later life supposedly stemming from altercations with Leibniz regarding the Calculus Priority Dispute, with the Jesuits over God and the Universe, and the grief from his mother's death.

Albert Einstein was the greatest scientist in recent history. Yet he started off slow in school and was even considered dyslexic. Many children have similar problems, but all are not able to overcome them and mix with and succeed in the mainstream. We probably can find other scientists in this curriculum that had ordinary problems as well as success.

This curriculum embraces these and some of the other ordinary aspects of the scientists' lives so that more students will be attracted to the idea of looking at a multi-leveled view of scientists, and will make connections to our present-day society and even to their own lives. The curriculum will show with examples and illustrations from life – yesterday or today – that "Scientists are People, Too."

BACKGROUND

A Look at Galileo's Family, Associates, Cohorts, and Religion

Galileo was born on February 15, 1564 in Pisa and given the name of the brother of his great-grandfather Galileo Galilei. His father was Vincenzio Galilei, who married the Pisan Giulia Ammannati, who used part of her dowry to get her husband started as a merchant. He also used his chosen profession, as a musician, to raise additional money for the family. He used his financial status to get Galileo started in school. When Galileo's father died, his uncle was able to secure him a place in the church in one of the novice positions. Also, after his father died, Galileo took on the care of his mother and sister. From there, he went to the University of Pisa, and in 1580, he was put into the arts faculty as a student of medicine. He found himself interested in math and physics. Because of his interest in physics, he studied Aristotle's treatment of how bodies moved in the universe. Galileo was not the first to question on of Aristotle's theories. John Philoponus had pointed out more than a thousand years before that the speed of falling bodies was not proportionate to their weight as Aristotle had thought.

In 1604 Galileo observed a comet in the night sky above Padua. This single event may have precipitated his reexamination of Aristotle's unchanging heavens. Galileo had a workshop in his home for building instruments. One of the instruments he is credited with developing and improving (to some extent) is the refracting telescope. News of the spyglass (invented to see faraway objects in 1608 by Hans Lipperty) gave Galileo just the pivotal point he needed to get started on an improved version of it. In 1610, Galileo built a nine-power telescope, three times more powerful than Lipperty's. With it, he saw mountains and craters on the moon. He concluded that the moon was not perfectly round, as had been thought. He observed satellites of Jupiter – disproving Aristotle's idea that Earth was the only center of motion. He was also able to see the phases of Venus, full at farthest point from us, crescent when closest to us. In 1613, Galileo published "Letters on Sunspots." The church praised the discovery but did not agree with his interpretation.

With the telescope, Galileo was able to prove more of his positions on the heliocentric (sun-centered) system. During this ride of popularity, he was appointed to a position in the court of the Grand Duke of Tuscany. With his new and improved position, he was able to devote time to an instrument he called "the geometrical and military compass." He gave courses and lectures in cosmology, astronomy, and geography at the university. He realized that he could not embrace the Ptolemaic system, and he studied problems with the Copernican view. He considered the idea that if the Earth spins on its axis, why aren't we thrown off; and if an object is dropped, shouldn't it fall sideways rather than straight down? Also shouldn't the positions of a star be different at different times of the year illustrating parallax?

One could suppose that if a person has a different belief, and they find errors in some part, it is reasonable that they might try to investigate the entire theory. Galileo used his time as a mathematics professor to question some of Aristotle's theories even more. He also decided to challenge Ptolemy's theory. He published a commentary to show the shoddy method of philosophy Ptolemy had used in his famous work *Almagest* (Sharratt, 1996). Each advance towards truth engaged Galileo in more and more discussions. Galileo borrowed some important ideas from Aristotle, but when he considered the tides, he developed original ideas about the motion of the Earth.

In the meantime, Galileo started his own family. His family included two daughters and one son, but he was not married to their mother. Galileo had used a lot of money to position his sister for a socially accepted level that would help her to become married, leaving little for himself. Young ladies at that time were expected to have dowries, and without money, there was usually no dowry. This was the case for Galileo's daughters Virginia and Livia. They were born out of wedlock and had no dowries, so they were sent to convents when they became a certain age. Galileo placed his daughters in the convent of San Matteo in Arcetri near Florence with the help of Cardinal Bandini. Virginia did well, but Livia was almost always unhappy. This positioning of the daughters would later play a tremendous role in Galileo's life. His son, however, had quite a different fate; Galileo gave him his name, legitimizing him, and he became a member of aristocratic society, obtained a good position, and married well.

The correspondence between Virginia and Galileo will form a part of the curriculum. It started with simple things like notes sent with things she knitted for him. By the time of Galileo's inquisition, there was an active correspondence. Virginia was taking care of his property and making some decisions for him. The series of letters from Galileo's daughter during his in-house imprisonment will be used to show the relationship that developed between father and daughter (Sobel, 1999). Galileo and his daughter discussed events they shared, e. g. the death his sister. The letters are very religious in content and show a loving relationship between Galileo and his daughter. Some literary examples can be taken from the correspondence regarding their relationship.

Politics

The political arena is sometimes the domain of revolutionary ideas that affect a whole way of thinking of the masses of society. Copernicus had provided information to the Lateran Council at the request of Leo X when they considered the question of reforming the Ecclesiastical Calendar. Copernicus felt that more work needed to be done as it relates to measuring the sun and moon with accuracy. After he was encouraged by Paul, Bishop of Fossombrone, he devoted himself the making exact observations concerning the heavens. He wrote his findings in a manuscript called *De Revolutionibus* in 1543, which was not published until he was on his death-bed. Being incapacitated, he was not aware that the introduction of the book had been changed and was not presented as an absolute truth, but as a theory.

At this time, astronomy, which for us is a science, was at that time still loosely attached to mathematics, and the geocentric (Earth-centered) view had been a part of the church's position since the Egyptian astronomer Ptolemy's time, hundreds of years before Copernicus and Galileo, in the second century. The church also used Aristotle (384-322 C.C.E.) to uphold their view. It is quite different from Copernicus' theory of all the planetary motions in a natural model with a common unit of measure. Ptolemy sought to explain his theory using the Earth as a base and then specifying the order of other planets' distance from the Earth. Prior to Galileo's presenting the heliocentric system, it had already been presented by Copernicus some years earlier. Not only had Copernicus presented the heliocentric system view, but Johannes Kepler, a contemporary of Galileo, had also presented that view with mathematical equations thought by some to be more convincing than Galileo's. In 1597, Galileo told Kepler that he was a believer in Copernicus' theory of the heliocentric system. Kepler urged Galileo to openly admit that he was a supporter of the Copernican theory.

Several other scientists in Galileo's time supported the Copernican Theory.

Tycho Brahe, 1546-1601, was a Danish astronomer who, even while using defective tables, correctly predicted the eclipse of the sun. On that success, Brahe reformed the techniques of observation. When the first new star in1, 600 years appeared, Brahe correctly identified it as a star. The king of Denmark allowed Brahe to study on the island of Hven. Brahe was able to show that the comet of 1577 did not originate in the Earth's atmosphere, but rather was a comet moving through outer space. Kepler used Brahe's accumulated information and observations to support the Copernican system even though Brahe, himself, had rejected the Copernican theory. Christoph Claves thought a whole new system was needed because of differences between Galileo and Brahe.

Francis Bacon, 1561-1626, another contemporary of Galileo, also believed in the sun-centered universe. Bacon was an influential supporter of the scientific method. He believed that even though one had to start out with a preliminary hypothesis, one should use inductive reasoning when investigating a phenomenon.

Another contemporary of Galileo who believed in the sun-centered universe was Rene Descartes, 1596-1650. Descartes believed in reasoning to solve problems. He believed that the world consisted of two materials: thinking substance – the mind – and extended substance – matter. Through his struggles of how mind and matter integrated, he developed what came to be thought of as the Cartesian philosophy. His most famous philosophical work was *Discourse on the Method of Rightly Conducting the Reason and Seeking for Truth in Sciences*.

It may seem odd that although the focus of this curriculum is on the Copernican theory, the principal figure to be studied is Galileo. Copernicus' story is equally intriguing, but although his theory was correct, he was unable to change the thinking of the scientists and the church and gain acceptance for what he believed. Galileo's work had a more profound impact.

Although the Copernican theory had some support in Galileo's day, it was also a dangerous view to hold. On August 13, 1600, Dominican Friar Giordano Bruno was burned at the stake for heresy because he insisted that the Earth traveled around the sun. Fortunately Galileo did not succumb to the same fate as a punishment for being an enemy of the church, and in the long run his work did eventually gain acceptance.

The Church

In Galileo's time, the church was very powerful and was able to sanction or disapprove almost everything. Being excommunicated from the church was not a small matter. It was perceived to mean the difference between heaven and hell since the Pope, as an intermediary to the kingdom in the Anglican and Catholic faith, held the key to everyone's salvation. Even if a person sincerely believed a thing, he would be less likely to publish that belief if he thought that it would offend the Pope. Perhaps that is why *De Revolutionibus* is symbolic in its presentation of a heliocentric universe and why Galileo sought to befriend and get the approval of many in the church. A study of his life reveals that he dedicated some of his writings and papers to high-ranking members of the church.

The church had a myopic view about the rotation of the universe. It subscribed to Aristotle's view that the Earth was a motionless body at the center of the universe. Other heavenly bodies were supposedly moving around the Earth. In 1572 a comet was observed by Danish astronomer Tycho Brahe that proved that heavenly motions were not perfectly circular as previously thought, but that comets, specifically, could crash through the spheres of planetary orbit. Yet he still perceived the Earth as motionless, but other planets as revolving around the sun.

When Galileo's new telescope revealed the satellites of Jupiter, it clearly disproved Aristotle's theory of the Earth being the center of motion. Following this extraordinary information, Galileo would have the task of proving to society and the church that the heliocentric system is correct.

A controversy took place during the time of the Jesuit General Claudio Aquaviva who wanted more caution exercised. The Lynceans, a scientific society, had used Galileo's ideas as a new way of philosophizing (which in those days meant doing science). This means that they wanted to publish new ideas without controversy. The sunspots controversy threatened to reopen old wounds between the Jesuits and the Lyceans. Galileo thought the discovery of the suns spots was a credit to his theory. That position was one of his more controversial ones and did nothing to help him. At that time, Galileo published the *Sidereal Messenger*, which meant to discredit an attack on the Copernican theory presented before the telescope was invented. Now that his "Discourse of Floating Bodies" and the "Letters on Sunspots" had been well received in public reading, it was a good time to request sensory observations and conclusive proofs of the theory. Galileo had the support of some people: Prince Cesi, the leader of the Lyncean academy and Castinelli. But when the Grand Duchess questioned Castinelli about the agreement of scripture and the controversies, Castinelli decided to avoid those topics unless he was allowed to speak out by an administrator.

Galileo later wrote "A Letter to Castinelli" and expanded the contents in "A Letter to the Grand Duchess," Christina, mother of the Duke of Tuscany. (Galileo was mathematician and philosopher at the court of the Duke at this time.) Galileo's "Letter" sounds as if he has or expects to have a demonstration of the Copernican theory. These letters concerned the proper use of scripture in philosophical disputes. From this point on, Galileo found himself in a position to write many letters to may people explaining his theories and trying to get people to see his way of thinking.

He tried to win over Paul V. Orsini with his argument on the tides, but this effort provoked the Pope and eventually lead to Galileo's inquisition. Galileo continued to write, first the "Assayer" and later "Discourses." He later wrote "Balance" to dismantle an opponent's case.

In 1616, Galileo went to Rome to prevent a condemnation of Copernicanism and to present to Cardinal Bellamine his theory of what causes the tides. (His view was erroneous as it turns out.) On February 16, 1616, Pope Paul formed a standing committee of theological consultants to render judgments on two Copernican propositions:

1. The sun is the center of the world and completely immobile by local motion.
2. The Earth is not the center of the world, nor immobile, but moves according to the whole of itself, and also with a diurnal rotation.

It was found that item 1 was at least erroneous in the faith, and that proposition 2 was both foolish and absurd in philosophy. Both positions were judged to be formally heretical.

Copernicus' book was withdrawn temporarily, pending correction of some passages. (Galileo crossed out those passages in his own copy of the book, but very lightly.) No action was taken against Galileo, but Bellamine instructed him not to hold or defend the Copernican theory, although he was free to discuss it as mathematical hypothesis. Galileo met with Pope Paul V, and not being officially condemned by him, continued to lecture under his protection until the Pope's death in 1623.

In 1623, Cardinal Maffeo Barberini was elected Pope and took the name Urban VIII. His nephew, Francesco was a member of the Lynceans along with Galileo. Urban VIII permitted Galileo to write about Copernicus, as a hypothesis (that is, as something known to be untrue, but useful).

In 1632, when Galileo published his major work on the Copernican theory: *Dialogues Concerning the Two Chief World Systems*, he found himself in a position not unlike the one Copernicus had been in. The Pope appointed a special commission to examine it and the events preceding its publication. It was thought that Galileo made fun of Urban VIII, especially with the character Simplico. Additionally, the Church felt he disobeyed the rule to not publish anything that was averse to bible teachings. The Pope felt that he had been deceived by Galileo. In April, 1633, Galileo was brought before the Jesuits who wanted to destroy him. Inchofer made the strongest case he could against him, but his lack of knowledge prevented his being successful. By the end of June, the Pope had received the final report including complaints against "The Letter to Castelli." Galileo was called again on June 21 to see if he would still deny that he embraced Copernicanism. Galileo insisted that he was there to obey, and he had not held on to Copernicanism since 1616.

The opinion of the Inquisition was that he was vehemently suspect of heresy: holding and believing a doctrine which was false and contrary to scripture and maintaining that one may hold and defend an opinion as probable after is has been declared and defined as contrary to scripture. Galileo knelt and received his sentence: life in prison. To silence him, however, real prison was not necessary. He went to serve his sentence in Rome on July 6 and later stayed with Archbishop Ascanio Piccolomini in Sienna. The tranquil surroundings there saved his sanity, and he began to study again. Later Galileo moved from Sienna to Florence where he was near his daughter, Virginia. She lived only a short time after his sentence was commuted to house arrest. At the end, he still tried to be active, using students who came to stay with him and learn. Students apparently appreciated the opportunity to be his assistant. This allowed him to continue working while under house arrest.

Church Figures and Ideas

A number of church figures and their ideas will be included in the curriculum unit. Here some examples:

- Cardinal Baronius is quoted by Galileo as saying that the Bible as meant to teach us how one goes to heaven, not how the heavens go.
- Jesuit astronomers of the Catholic Church liked Tycho Brahe's idea of the Earth as motionless in the center pf the universe.
- Saint Augustine said that whatever the sages of this world have demonstrated concerning physical matters is no way contrary to our Bible…. every truth must agree with every other truth. Holy Writ cannot be contrary to the solid reasons and experiences of human knowledge.
- Saint Thomas Aquinas built his great work on a combination of Aristotle's thought and Christian revelation. He felt there is no conflict between faith and reason; philosophy is based on reason and theology on the revealed word of God. As God cannot err, any differences between the conclusions of philosophy and the truths of revelation must come from faulty reasoning.

In the arguments concerning Copernicanism, reference was made to the Bible:

> Joshua 10, where Joshua prays for the sun to stand still and day to lengthen. The problem is that Aristotle says fixed stars rotate from east to west and the sun from east to west, but slower. Galileo contended that not only does the sun rotate on its axis, but its rotation caused the revolution of the planets, giving light and motion to them. If the sun stopped, so would the planets.
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> Council of Trent met between 1545 and 1563 to formulate rules to govern the response of the Catholic Church to the Protestant Reformation. Matters would be settled by whatever the Church Fathers agreed on; one result was that Copernican interpretations were excluded.
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> Cardinal Robert Francis Roulus Bellarmine (1542–1621), a Jesuit theologian, defended the church against growing absolutism of kings. He wrote letter saying that the church would insist on a literal interpretation of the anti-Copernican texts unless the Copernicus doctrine were demonstrated to be true. (Hawking, 2002)
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> Protestant reformers believed individuals should be free to interpret the biblical passage as their own best judgment as directed and guided by the Holy Spirit.
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> Galileo pointed out that the testimony of the Bible was restricted to faith and moral issues, not astronomy. Bellamine agreed with the idea that any statement in the Bible is a matter of Faith and Morals.

TEACHING STRATEGIES

Acquiring Information: Analyzing, Classifying, and Evaluating

This curriculum will focus on biographies, letters, historical records and illustrations to form a narrative curriculum for students to look at the lives of astronomers, especially Galileo. The goal is to enhance students' reading, writing, historical, and scientific knowledge. Acquiring this knowledge can include some research on and evaluation of the information presented. For this reason, narrative curricula are dynamic. Although an outline is given, the curriculum is guided to some extent by the evaluations, questions and answers, analyzing and classifying. The scope can be largely identified from the following outline, but is not limited to the outline. The outline suggests a list of considerations that would be helpful in understanding the curriculum.

Outline

I. Definition of Astronomy
What is astronomy? Astronomy is the study of the sun, moon, plants and stars. It includes learning about the Earth itself because the Earth too is a planet. Astronomy explains what makes the sun rise and set, causing day and night. Through astronomy, men also learn how the stars and planets move, and about the vast distances in space.

II. History of Astronomy

A. Aristarchus of Samos (350-320 B.C.)
Aristarchus proposed a heliocentric (sun-centered) system.

B. Aristotle (384-322 B.C.)
Aristotle proposed a geocentric system with a nested set of spherical shells, - one for each of the moon, sun, and known planets. The shells and heavenly bodies attached to them were composed of crystalline substance, æther or quintessence, which was different from earth or its atmosphere.

C. Ptolemy: Second Century Hellenistic Astronomer, (87- 150 A. D.) Egyptian name: Claudius Ptolemaeus. Author of "The Geography" and "Almagest."

Ptolemy created a model of uniform circles called epicycles. He placed Earth slightly off-center, and by custom-designing the circles, was able to predict the motions of the heavenly bodies. Ptolemy could consider planets individually but could not construct a single natural system as a whole. His model showed all cycles taking exactly one year. The Church adopted Ptolemy's model as truth. Aristotle and Ptolemy's model lasted for over a thousand years.

D. Nicolaus Copernicas (Poland) (1473-1543 A.D.)
Copernicus observed a lunar eclipse in Rome in November of 1500. Although he spent most of his time in service to the poor, he built an observation tower in Frauenburg in March of 1513. The following year he wrote a brief *Commentary on the Theories of the Motions of Heavenly Objects from Their Arrangements* but circulated the manuscript only among his closest friends. He believed the Earth was not the center of the universe, only the center of the moon's orbit. He believed that the Earth and the other planets revolved around the sun. He wrote *De Revolutionis* in 1543 describing a single system with the sun at its center. Computations were used to measure the Earth's distance from sun. The fact that things seem to rotate around the Earth was really the Earth's rotation. The one-year cycle was the time the Earth needed to rotate around the sun. Copernicus accurately identified the position of Venus and Mercury as being closer to the sun and revolving at a faster rate. His work was published while he was on his death-bed. He entrusted the manuscript to George Rheticus, but when Rheticus was forced to leave Nuremberg, the task of publishing fell to Andreas Osiander (Hawking, 2002). Osiander gained possession of to Copernicus' book without permission, and changed the foreword of it to mention hypotheses instead of theory (Armitage, 1957).

E. Tycho Brahe (Danish) (exact dates not known)
Tycho Brahe observed the supernova of 1572 and discovered that comets are celestial rather than atmospheric. Their irregular motions disprove Ptolemy's theory of perfectly

circular motions. Jesuit astronomers of the Catholic Church liked Tycho Brahe's idea of the Earth as motionless in the center of the universe (Ferguson, 2002).

F. Jesuit Clavius, (Christoph Clau of Germany 1538-1612 A.D.)
Clavius was dissatisfied with Ptolematic astronomers. He wished to improve the teaching of Aristotelian philosophy by encouraging sensible modifications; he did not want to accept Copernicanism as the true system of the universe. He was a friend and contemporary of Galileo's. Two other Jesuit mathematicians agreed with Clavius. Bellarmine told Galileo in 1616 that Copernicanism could not be held as true. Ignatius of Layola, (1491 -1556 A.D.), who founded the Society of Jesuits published the book Ration Studiorum in 1585 for all Jesuit schools and colleges to help the priests with a principal question of the philosophy of science: how does one chose between rival scientific opinions? Jesuits decided to follow St. Thomas Aquinas in theology and Aristotle in philosophy. Later, Galileo developed arguments used by Clavius to support the truth of Copernicanism, but the Catholic Church took refuge in the instrumentalism which Clavius attacked. Clavius' philosophy of science was opened to serious criticism, as was Galileo's (Sharratt, 1994).

G. Galileo Galilei (1543-1642 A.D.)

H. Johannes Kepler (German). (1571-1630 A.D.)
Kepler was in poor health during his early years, and he was also nearsighted. Yet, he produced the most accurate tables of his time, which lead to the eventual acceptance of the heliocentric system. He published astrological calendars and horoscopes to support himself. He did not hold this out as a true science, but a means of income. In his time, the difference between astrology and astronomy was vague. One day he experienced a revelation while teaching geometry: he drew an equilateral triangle with a circle, and another circle drawn within the triangle. It occurred to him that the ratio of the circles was indicative of the ratio of the orbits of Saturn and Jupiter. He assumed that all the known planets of that day were arranged in such a way that the geometric figures would fit perfectly between them. After testing his theory using two-dimensional plane figures such as the pentagon, the square, and the triangle, he dedicated his life to measuring celestial bodies (Hawking, 2002). Based on his geometric theory regarding planetary orbits and distances, Kepler wrote *Mystery of the Cosmos* published in 1596. (Ferguson, 2002). After further studies, Kepler published *Harmonies of the World* in May of 1618 (Hawking, 2002).

I. Sir Isaac Newton (1642-1727 A.D.)
Newton is most noted for formulating gravitational force and defining the laws of motion. His work, *Mathematical Principles of Natural Philosophy*, generally known as *Principia*, was published fusing the contributions of Copernicus, Galileo, Kepler and others into a dynamic compilation of scientific foundation. Newton also began his prism experiments in light refraction and dispersion. He set out to prove that white light was composed of a mixture of various types of light, each producing a different color of the spectrum when refracted by a prism. After his death, his interest in chemical experiments was correlated to his later research in celestial mechanics and gravitation (Hawking, 2002).

J. Albert Einstein (1879 -1955 A.D.)
Einstein was born in Germany and is the most recent of the scientists to be covered in this curriculum. Children's parents and grandparents may be able to talk about him to them. Films and newspaper articles are available. We can hear him speak and see him smile and ride a bicycle. We probably feel closest to him. It is said that he carried a notepad in the baby's stroller and jotted down notes to himself. Some of them are said to have lead to

the theory of relativity and the development of the atom bomb. As he pondered the workings of the universe, he is said to have had flashes of understanding that were too deep for words. Oddly enough, he was thought to have suffered from dyslexia. In 1907, he published four epochal scientific papers, including his work on the theory of relativity. One consequence of relativity is the relation between energy and mass, expressed mathematically by $E=mc^2$. He helped develop the foundation of quantum mechanics with the Danish physicist Niels Bohr. He settled in Princeton, New Jersey as a professor of mathematics and theoretical physics at the Institute for Advanced Study (Hawking, 2002).

III. Church Figures and Events

A. Fifth Lateran Council: Copernicus took part in writing the calendar in 1515 and also wrote a treatise on money in 1517.

B. Dominican friar Giordano Bruno burned at the stake in 1600 for insisting the sun was the center of the universe.

C. The Jesuit Priest Christoph Scheiner plots sunspots in 1626 and 1627 supporting Aristotle (Caprara, 2003).

D. Galileo forced by church to recant the heliocentric theory in 1633 (Strathern, 1996; Feldhay, 1995)

IV. The Dialogue and Galileo's Condemnation (Sharratt, 1996, Ch. 8.)

V. Galileo's Family Members

A. Marina Gamba of Venice, Significant Other

B. Suor Maria Celeste (Christened Virginia)

C. Suor Arcangela (Called Livia)

D. Vincenzio (Son)

CURRICULUM

Objectives

Evaluate

Through the comparison of photographs and illustrations students will make a reasonable evaluation of how instruments may have been used.

Analyze

Students will examine heliocentric and geocentric systems to analyze contributors to each school of thought regarding the systems.

Compare/Contrast

Students will look at the relationship of Galileo with his significant other and his out-of-wedlock children and compare it to practices of today.

Research

Students will research information to support and clarify this study.

Application

Students will use standard writing methods and rewrite some of the letters from the study using today's language and expressing today's feelings.

Literary Support

Students will create a number of charts, timelines, illustrations, etc. to support the assignments and writings.

Genre

Students will create a dialogue to represent court proceedings relating to the inquisition of Galileo.

LESSON PLANS

Lesson 1

Students find illustrations of as many of the instruments used up until the time of Galileo. They will discuss how those instruments may have been used. They will find illustrations by Galileo and other astronomers. (They will not do math calculations but will simply refer to illustrations). Students will imagine and try to explain how those instruments may have been used in creating the illustrations. Students will draw the geocentric model for planets and also draw the heliocentric model for planets. They will discuss retrograde motion (the backward motions of Mars, Jupiter and Saturn) and try to figure how it may have been explained. Students will write their explanations and compare them with the geocentric explanation by Medieval Cosmology: each planet revolved on the edge of a circle called the epicycle, and the center of each epicycle revolved around the Earth on a path called the deferent. (See the Ptolemaic system for clarification.) Students will then draw the heliocentric system and create an explanation for the revolutions of the planets. They will discuss why the heliocentric system (in retrospect) is so much easier to explain.

Lesson 2

Students will list eight (or more) events from the outline and list them in chronological order. Students will find some world event correlating with that same time. For instance, in 1632, the Black Death swept across Italy. Explain how one of those major events would have impacted the lives of the principle persons in this curriculum. Students will have time to research the events before evaluating the impact. Students may correlate events with each other and discuss them.

Lesson 3

Students are assigned parts as officials of the church (some were favorably disposed to the work of Galileo and some were not). They will create a debate among the members that conceivably could have led up to the inquisition of Galileo. Students will take the roles of church figures, dignitaries, friends, and the defendant. The events of the inquisition will be studied for authenticity.

Lesson 4

Students will read a number of the letters from Suor Maria Celeste (Virginia). (See Sobel, 1999.) They will choose one of the letters and rewrite it using today's language. They will be asked to explain what they think Suor Maria Celeste may have been feeling, and to use their imaginations to construct a response from Galileo.

Lesson 5

Students will choose two astronomers and create a compare/contrast chart. From the chart, the students will use the correct format to write a compare/contrast essay. The same astronomers can be used to write a cause/effect essay as well as a problem/solution essay.

Lesson 6

Students will choose some of the events in the scientists' lives that are similar to problems that families have today. Students may have a discussion using various Kagan strategies. Students must produce a written product at the end of discussion. The product should include an analysis of the scenarios discussed.

Lesson 7

Students will choose some of the colorful illustrations of daily and social lives, types of dress, architectural designs, maps, etc., from *The Story of Philosophy from Antiquity to the Present* (Delius et. al., 2005). Students will discuss how they think the clothing was made, cared for, and the level of comfort. Students will compare their ideas with the clothing we wear today.

ANNOTATED BIBLIOGRAPHY

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Supplemental Sources

Krupp, E. C. *Echoes of the Ancient Skies: The Astronomy of Lost Civilizations*. New York: Harper and Row, 1983.
This book chronicles impressions of the heavens by various people at various times. Some were surprisingly correct, but not organized for presenting a world-view that could be defended in a reluctant society.