

A Backward Planet — Retrograde Motion

Introduction	2
Constructa-Vision.....	3
Finished Project.....	4
Blueprints	5
Core Concepts	6
Actual Project/Task	7
Learning Strategies	8
Site Work.....	9
Foundation	10
Scaffolding.....	11
Inspection.....	12
Additional Resources	14
Sample Lesson Review and Analysis	15

Introduction

From the time of Aristotle (384-322 B.C.) until the 1500s, mankind tried to come up with a model explaining the motions of the planets. Although the heliocentric theory seems so plausible to today's students, they often cannot easily use evidence to prove it. Ask them what they believe, and none will believe in a geocentric solar system. But ask them to prove it with scientific evidence, and suddenly you see many blank stares!

We shouldn't be so surprised. For several hundred years, astronomers watched the heavens, plotted the courses of planets, and still struggled to come up with a model to explain the motion of the planets. One of the most interesting phenomenon was the apparent retrograde motion of planets like Mars and Jupiter. They seemed to slow down and begin to move backwards in space for a few months, and then slow down and begin to move forward again. Trying to explain this proved difficult because scientists were thinking from only one perspective — Earth!

Using a computer planetarium program, students can simulate and observe in minutes what took scientists decades to see.

This short project makes use of the simulation of star and planet movement that can be modeled by planetarium programs. By observing both from Earth and from above the solar system in a "hover" mode, students can usually construct the reasons for retrograde motion — something the greatest minds of early astronomy could not do! In the process, students come away with a true conceptual understanding of the motion of planets.

Constructa-Vision

Teaching is a lot like building a house. Most of us generally know what we want the house to look like in the end, but we often need to sit down with several plans of finished houses in order to identify the specific house design we will want in the Finished Project.

Just like contractors, we need to have Blueprints drawn up that identify specifications for how to proceed.

Then the actual Site Work is done, which includes foundational work and temporary structures. And of course, during the course of construction, site inspectors check to see if the work is done correctly.

Check out the lesson to see how the Challenging Question unit to the right was put together using Constructa-Vision.

Challenging Question

What causes the retrograde motion of the planet Mars?

Time Frame

Single Block: 1-2 days

Double Block: 1 day

Finished Project

What will our science students "look like" after this unit? We hope they will be able to do the following:

1. Correctly set up and run a planetarium program on a computer to observe stellar and planetary motion over time.
2. Plot the motion of a planet over time, using the stars as a background grid.
3. Accurately relate the motion of Earth and Mars from two points of reference ... from Earth and from a point above the solar system ecliptic plane.
4. Summarize the development of the heliocentric theory, relating the works of Aristotle, Ptolomy, Copernicus, and Galileo.

How does this project relate to the Ohio Science Benchmarks?

Scientific Inquiry: Benchmarks 9-10

- A. Participate in and apply the processes of scientific investigation to create models and to design, conduct, evaluate and communicate the results of these investigations.

Scientific Ways of Knowing: Benchmarks 9-10

- A. Explain that scientific knowledge must be based on evidence, be predictive, logical, subject to modification and limited to the natural world.
- B. Explain how scientific inquiry is guided by knowledge, observations, ideas and questions.

Physical Science: Benchmarks 9-10

- A. Explain the movement of objects by applying Newton's three laws of motion.

Earth Science: Benchmarks 9-10

- A. Explain how evidence from stars and other celestial objects provides information about the processes that cause changes in the composition and scale of the physical universe.
- F. Summarize the historical development of scientific theories and ideas, and describe emerging issues in the study of Earth and space sciences.

Blueprints

Looking at a model home may help you choose the type of finished house you would like. But in order for the house to actually be built, the contractors must use a set of blueprints, which lay out the specific plans for the house.

In the same way, teachers planning a unit around a challenging question or problem need to lay out blueprints — specific plans for getting to their finished product!

Teachers need to define the Core Content or Concepts that students will be expected to master once the project is complete. What is it that you are trying to teach? Content-driven projects can be used to teach rigorous concepts in new and exciting ways. On the other hand, you should closely analyze a project that has no important underlying concept before doing it!

Teachers need to specifically define and design the Actual Project/Task itself. What is it specifically that the students be doing? How many days will the entire project take? What types of artifacts will be produced to show understanding? What resources will be needed?

Finally, what types of Learning Strategies will be used? Will students discover or construct principles during their project? Will cooperative or collaborative strategies be used? How will data be analyzed and displayed? Does research support these methods?

Core Concepts

A goal of a good teacher is to be sure that students learn core concepts — those practical concepts that will be important in the lives of all students. It is important for teachers planning lessons using technology not to forget that technology can be used to enhance content learning and make it more practical for everyday life.

Below is a list of basic objectives and content for this project.

By the end of this project, students should be able to do the following:

Content

1. Distinguish between the geocentric and heliocentric theories describing our solar system.
2. Summarize the work of Aristotle and Ptolemy and describe how their models were developed to explain observed data.
3. Summarize the work of Copernicus and Galileo and describe how their models better described the observed data of solar system planetary movement.

Thinking/Problem-Solving Skills

1. Look at observational data from two different spatial perspectives in order to further understanding.
2. Graph data over time in order to see patterns not readily apparent in real time.

Technology Skills

1. Use a planetarium program to observe planetary movement over time.
2. Use an orrery view in a planetarium program to analyze the rate of revolution of different planets.
3. Use an electronic database of star fields to use as reference points for planetary motion.
4. Use screen capture techniques to prepare images to use in a report.

Actual Project/Task

Students will do the following tasks during this unit:

1. Set up a planetarium program in a sky view and use it to plot the movement of Mars over a period of several months. This movement will be plotted on a star chart produced from the planetarium.
2. Students will analyze the movement of Mars, and discover that it appears to move backwards for a short period of time, and then move forward again, forming what appears to be a "loop" (Ptolomy's epicycles).
3. Students then compare the month-by-month sky view with a view from outside the solar system (hover/orrery view) and analyze both for related patterns.
4. Students devise a hypothesis/model that explains the cause of this apparent backwards movement and then use screen captured images to prepare a short report demonstrating their model.

The principle task of the students is to study the retrograde motion of Mars from two different spatial perspectives and come up with a logical explanation for that motion.

Learning Strategies

Good teachers make it a point to vary their strategies so that all students are able to learn effectively in their classes.

Below is a list of some of the strategies used in this project to help students learn.

1. **Discovery** - Students will plot the motion of the planet Mars over several months and discover that it actually appears to move backwards for a time (retrograde revolution). Since this cannot actually happen, students must develop a hypothesis/model to explain this motion. This is essentially what Copernicus and Galileo did to come up with the heliocentric theory of the solar system.
2. **Research** - Students will explore several sites on the Internet to discover the work of Aristotle, Ptolemy, Copernicus, and Galileo. (See Additional Resources for links.)
3. **Data Analysis** - Students will plot the position of Mars over several months on a star chart generated by a planetarium and then relate that motion to the motion of Mars and Earth observed on the orrery (hover) view in the planetarium.
4. **Summarizing** - Students will use screen captures to prepare a short report and use those images to show how retrograde motion is due to the "lapping" of planets.

Site Work

Foundation

Most lessons have some basic skills that are required before you are able to begin. These are sometimes called "foundational" or "prerequisite" skills. As in the building of a house, ensuring an adequate foundation is very important in learning.

Scaffolding

You just can't build a structure without introducing some temporary structures — temporary roads, scaffolding, or false walls. In a similar way, most complex tasks in learning require some type of leading activities or temporary bridges that enable students to go from what they know to what they need to know.

Inspection

A house has several inspections along the way, as well as a final inspection after it is completed. Those initial inspections don't cause the whole project to stop — they ensure that each step is done correctly. If an electrical circuit fails inspection, the electrician is recalled and the problem is corrected. If the initial inspections are done well, the rigorous final inspection usually goes without a hitch. In fact, that is the goal!

Learning needs to involve "along the way" inspections (formative evaluations) that ensure correctness as well as a final (summative) evaluation that is rigorous, yet is one which students are well prepared.

Foundation

The following skills need to be in place in order for students to be successful on this project.

Graphing/Plotting Skills

1. Students should have some knowledge of the Right Ascension/Declination system of plotting stars in the sky.

Astronomy

1. Students should have a basic conceptual understanding of Newton's First Law of Motion — that objects travel in straight lines and continue that way unless acted on by another force.
2. Students should know basic solar system mechanics — that planets circle the sun in circular/elliptical orbits.

Computers

1. Students should be comfortable in an icon-based computer environment and be able to locate and open files.
2. Students should be comfortable using a browser and search engine to locate information on the Internet.
3. Students should be able to open a basic planetarium program and set it so that a planet can be tracked over several months, both from a sky view and from a hover/orrery view.

Scaffolding

The following activities will prepare students for the Retrograde Motion project.

1. **Planetarium Program** — Students will be given several stars and planets to locate using the finder portion of the program. They will also be asked to find the Moon and track it over the course of several days.
2. **Heliocentric vs. Geocentric Theory** — Students will be asked to give evidence that the sun is the center of the solar system. The instructor will play devil's advocate by giving reasons why the Earth must be the center.

Can a planet actually move backwards? If not, why does Mars exhibit that trait?

Do your students know the right questions to ask to try to explain this phenomenon?

Inspection

Have your students presented you with enough information and artifacts to prove they understand?

Formative (nongraded) Assessments

1. **Synthesis of General Principles** — Students will be asked to give a general comparison of the terms *geocentric* and *heliocentric* before they begin the planetarium portion of the project.
2. **Correct Use of Technology** — Students will be asked to show their sky in both a sky view and a hover/orrery view. They also must show that they can set the animation clock to check the sky over a period of time.
3. **Screen Captures** — Students should show that they can capture a screen and paste it into a Word document.

Summative Assessment

1. **Word Document** — Students will turn in a document that includes the following:
 - An explanation of why Mars appears to travel backward in the sky.
 - A set of several images from both the sky view and the hover view of the planetarium, supporting their explanation or model.
2. **Extended Investigation** — Using the planetarium program, students determine the next time Jupiter exhibits retrograde motion.

Rubric for A Backward Planet — Retrograde Motion

Components	Exemplary	Acceptable	Needs Improvement
Communication	Clear, insightful	Generally clear, logical	Unclear, poor idea progression
	Extensive use of topic-specific vocabulary	Appropriate topic-specific vocabulary	Lack of topic-specific vocabulary
	Few Errors	Some Errors	Many Errors
Research	Numerous appropriate resources	Adequate appropriate resources	Few or inappropriate resources
	Wide variety	Some variety	Lack of variety
	Reliability well-documented	Reliability somewhat well-documented	Reliability not documented
Problem Solving	Detailed description of problem	General description of problem	Vague description of problem
	Abundant evidence of Higher-Order Thinking Skills (HOTS)	Demonstrates HOTS (analysis, synthesis, prediction)	Little evidence of HOTS
	Draws insightful conclusions	Draws appropriate conclusions	Draws inappropriate conclusions
Presentation	Clearly focused, richly developed	Generally focused and developed	Lacks focus and coherence
	Creative, engaging	Engaging	Does not engage the audience
	Abundant supporting evidence	Adequate supporting evidence	Little or no supporting evidence

Are you helping students by making sure they know the target you want them to hit?

Are you giving helpful feedback on how they are doing before you take grades?

Additional Resources

Planetarium Programs (Free Public Domain)

Home Planet

<http://fourmilab.ch/homeplanet/homeplanet.html>

WinStars

<http://www.winstars.net/english>

Educational Issues Links

Performance Assessment

http://www.weac.org/Professional_Resources/Testing/performance_assessment.aspx

Teaching for Understanding: Educating Students for Performance

http://www.weac.org/News_and_Publications/education_news/1996-1997/under.aspx

Other Useful Links

Copernican System

http://galileo.rice.edu/sci/theories/copernican_system.html

History and Philosophy of Western Astronomy

<http://www.astronomynotes.com/history/s3.htm>

History and Philosophy of Western Astronomy (Galileo)

<http://www.astronomynotes.com/history/s6.htm>

Ptolemaic System

http://galileo.rice.edu/sci/theories/ptolemaic_system.html

Sample Lesson Review and Analysis

Subject Area

Does this lesson meet the academic standards for the grade level and subject indicated?

This module incorporates many benchmarks for the Ohio Graduation Test that can easily be applied at the middle school level. This is a plus for districts because they can get a head start on preparing kids for their graduation requirements.

It is probably best fitted for helping kids use evidence to support ideas and helpful for explaining the historical development of our current heliocentric model of the solar system.

Scientific Ways of Knowing: 9-10

- A. Explain that scientific knowledge must be based on evidence, be predictive, logical, subject to modification and limited to the natural world.
- B. Explain how scientific inquiry is guided by knowledge, observations, ideas and questions.

Earth Science: 9-10

- A. Explain how evidence from stars and other celestial objects provides information about the processes that cause changes in the composition and scale of the physical universe.
- F. Summarize the historical development of scientific theories and ideas, and describe emerging issues in the study of Earth and space sciences.

Does it provide practical suggestions for integrating subject areas?

This lesson doesn't specifically include ways of integrating other subject areas, but several of the reference links to scientists or the "flat earth" pages provide teachers with several concepts that could be related to other areas.

It also provides "Core Concepts" broken down into content, thinking skills, and technology skills, and a summary of what the student who has mastered this activity should be able to do when it is all done.

Technology Use

Does the lesson suggest a variety of technologies to meet the learning outcomes?

No. This lesson basically uses simulation software to teach a concept. Supplemental work and assessment could be extended in a variety of learning styles, but this particular lesson essentially uses the software package to teach and demonstrate knowledge of the concept. Some screen capture and cutting and pasting can be used by students to demonstrate understanding.

Does this lesson specify the technology hardware, software, and support necessary for implementation?

Yes. Two links to free planetarium programs are provided, and each is well documented for ease of use. Both programs need limited power and typical machines found in classrooms today should be fine. However, the links provided are limited to Windows/PC machines. Other links or software programs for MAC should be included.

Links on the Web

Planetarium Programs (Free Public Domain)

Home Planet

<http://fourmilab.ch/homeplanet/homeplanet.html>

Does the lesson require the learner to use technology for learning that could not have been possible otherwise?

Although learning this concept certainly can be accomplished in other ways, using a simulation that shrinks months into minutes helps shrink learning that might take several months into just a few minutes. The ability to view where planets are over a period of several months in just a few mouse clicks is very empowering.

The other advantage of this software is that it allows students to look at our solar system from two different vantage points—one from earth and one from above our solar system. This enables students who may not be good at spatial thinking or constructing 3-D mental images to think about this problem in ways that they might not try.

Does the lesson require technology support resources that are readily available in most Ohio schools or in inservice and preservice educational settings.

Most schools operating on a PC environment should have machines that will support the software needed. There are also MAC planetarium programs available, but this lesson does not provide links to them.

Does the lesson suggest technologies to support students with special needs?

This type of activity takes something most science teachers teach on the blackboard and puts it into a spatial format in which poor students can succeed and perhaps even excel. In field tests of this lab, it is often the poor student who makes the logical leap in understanding because they often are skilled in spatial or three-dimensional thinking. This module centered around a simulation may truly help some with special needs.

Instructional Strategies

Does the lesson provide clear and specific explanation of the instructional strategies?

The module does provide the general framework for the instruction. It does not contained detailed lesson plans. This is due to the fact that different software packages might be used.

The lesson offers "foundational skills"—skills needed by learners before they should attempt this lab. Teachers can be sure that all are on the "same page" before beginning.

Does the lesson provide alternative strategies to meet the diverse needs of learners?

The main concept of this lab involves spatial reasoning. Students who struggle with this type of conceptualization may have a harder time, but the simulation is meant to help overcome that weakness.

Does the lesson use instructional strategies to engage students in deep, conceptual understanding of content and processes?

Yes. This is probably the greatest strength of this lab. Once students make the leap of understanding from two different spatial points of view, they will have this concept forever. Considering it took man thousands of years to figure out this concept, helping kids develop this type of understanding in less than an hour is truly amazing!

Does the lesson use instructional strategies to engage students as active participants, explorers and researchers?

This is another strength of this activity. Students are given some initial help with dates to plot and then are given the question and allowed to explore. They investigate and collect and plot the data. They interpret the data and come up with models explaining the resulting motions of the planets. This is an engaging activity. Students need to run the simulation, plot and interpret data, and then provide a document demonstrating understanding.

Does the lesson provide suggestions for supplemental resources on the instructional strategy?

Yes. Several links are included about the scientists involved in the heliocentric and geocentric historical debate, and those links lead to a number of other related sites.

Links on the Web

Copernican System

http://galileo.rice.edu/sci/theories/copernican_system.html

History and Philosophy of Western Astronomy (Galileo)

<http://www.astronomynotes.com/history/s6.htm>

Does the lesson use instructional strategies that promote personal meaning and reflection?

Yes. Students are asked to reflect on their data and then develop and document a model using screen saves and words. Because the module involves things they can see (stars, the planet Mars), many students do get personally involved. Also, because the module tends to be like a mystery, many students are intrigued and want to solve it the mystery.

Does the lesson use instructional strategies that relate students' knowledge to real-world contexts?

Yes and no. On any clear night, students can check out the concepts explored in this activity. Students tend to be "space friendly" and view this type of activity as "real" to them.

Assessment

Are the lesson assessments congruent with lesson learning goals and instructional strategies?

Yes. There are some formative assessments enabling the teacher to establish that students understand concepts as they go, as well as a summative assessment that involves using evidence to support a student-developed model. Even the assessments are somewhat engaging, so that students enjoy developing them.

Does the lesson provide clear and specific explanation of the assessment strategies?

The lesson provides a clear explanation of the major goals of the assessment but is written in a general way. This gives the instructors freedom to create their own assessments. However, it might be better to at least have an example of the student activity for newer teachers.

The lesson does provide some screen shots of possible evidence students might use in their documents.

Does the lesson assessment promote higher-order thinking and knowledge construction?

Yes. The simulation allows students to construct their own understanding. Since the module involves spatial and three-dimensional learning, it can be considered higher-order thinking.

Does the lesson provide both formative and summative assessments?

Yes, along with prerequisite skills needed before the activity is started.

Do lesson assessments require the application of new learning in a different context(s) (i.e. transfer of learning)?

No, although there is an extension exercise that would demonstrate transfer of learning.