Poetry of the Universe

"What men are poets who can speak of Jupiter if he were a man, but if he is an immense spinning sphere of methane and ammonia must be silent?"

-Richard Feynman

"The effort to understand the universe is one of the very few things that lifts human life above the level of farce and gives it some of the grace of tragedy."

-Steven Weinberg

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Program Overview

Introduction

Who hasn't looked into the night sky and wondered what was going on out there? This unit encourages students to see the creativity and relevance of science while meeting basic performance standards. It also pushes students to look for unexpected answers in the abstract world of our universe and provides a balance to experiments that measure the concrete natural surroundings.

The purpose of this unit is to prepare students for the graduation portfolio in the areas of physical science. The portfolio is a collection of student work that includes demonstrating an understanding of physics (motion, forces, cosmology, the structure and evolution of the universe) as well as the scientific process (supporting hypotheses with evidence and evaluating the impact of science on society). Since this is one of the rare science topics that cannot be explored with direct experimentation, the unit uses many different approaches to achieve an understanding of these concepts. To avoid getting bogged down in the language of cosmology, many graphic organizers and visual examples are used to place emphasis on the big ideas. Cosmology sites along with popular books and videotapes on the universe allow students to access these abstract ideas visually. It is also important to make these questions as concrete as possible by drawing upon personal experience and historical advances in science.

Major Goals

This unit was designed to help students meet portfolio standards that are consistent with the New York City science standards. The science portfolio is a collection of work that students present in order to graduate and is evaluated with a rubric that is based on accepted science standards. Performance is the key to the portfolio and students must demonstrate an understanding of basic scientific concepts in their work in addition to larger questions about how science functions and how it relates to society. The unit prepares students for three major assessment pieces that can be included in their portfolio. It meets graduation portfolio standards as noted on the Science Portfolio Rubric (see *Sample Worksheets and Handouts* section):

- The structure and properties of matter, including atoms and molecules
- The interactions between matter and energy
- Motion and forces
- The natural history of our Earth system
- The structure and evolution of the universe
- Answering scientific questions using evidence
- How science affects individuals and communities
- Representing data in multiple ways
- How to argue by supporting hypotheses using evidence

It also addresses the following New York City performance standards:

- S1d -Demonstrates an understanding of motions and forces
- S3d -Demonstrates an understanding of the origin and evolution of the universe
- S4a -Demonstrates an understanding of big ideas and unifying concepts
- S5d -Uses evidence from reliable sources to develop descriptions, explanations and models; and makes appropriate adjustments and improvements
- S5f -Works individually and in teams to collect and share information and ideas
- S7b -Argues from evidence
- S7e -Communicates in a form suited to the purpose and the audience
- S8d -Demonstrates scientific competence by completing secondary research

Target Students

Approximately seventy-five seniors participated in this unit and another eighty have taken part in previous incarnations of this unit before this year. I also used elements of this unit with a total of 100 9th grade students last year. Students generally have had Internet experience but have little exposure to simulation applications such as the one used here to model gravitational interactions. This year's classes had between 20-25 students and met every day for 55-minute periods. Time was spent almost exclusively in the classroom, although the work with the gravity simulation was done in the computer lab. Internet research was done mostly independently. Interpreting these articles tends to take more time and assistance than finding them. This might be difficult to adapt to non-secondary school classes, but similar work with 9th and 11th grade physics students has been successful. The classes I taught contained a fair number of ESL/ELL students that required various forms of instruction and assessment. Various forms of communicating these understandings were always options and because the program was mostly conceptual, we were dealing with ideas that were best represented visually. As often as possible, graphic organizers were used to help direct learning in a structured manner. The major assessments for the unit included different facets from creative writing to group work to visual art (collage, drawing, etc.) to accommodate different learning styles. For these reasons, the program was accessible to the wide range of students in the class and the lack of sophisticated math skills presents the opportunity to adapt this to lower grades as well.

Assessment

Students will complete three major pieces of work to be included in the science portfolio.

1. *Creation Myth: How Did the Universe Begin…and Why?*

This is a story about the universe. You will be able to tell this story through words and pictures. We know a great deal about the structure of the universe and how it evolved. You must include these facts in your story. However, we still have no good idea about what caused the Big Bang or why the universe was created, why gravity exists, etc. These are the questions that you can answer any way you like in your story.

2. *Time Travel Debate*

You will be arguing one side of the question "Will humans travel through time?" We think it is theoretically possibly, but will it ever happen? That is for you to decide. There will be judges and there will be a winner. Let's go!

3. *Poetry of the Universe Poster*

Poetry is art. Our study of the universe is science. How can we connect these two things? Both are beautiful and have some sort of organization. You will show what you know about the universe and its elegance for all to see.

Unit Outline

Note: Each day and lesson plan is designed for a 55-minute period.

Day	Topic	Class Work/Guiding Questions	Assigned Homework
1	Our Solar System	What do we know about it? How did we find out about it?	Explain how the early experiments were elegant and simple.
2	Stars and Galaxies	Where did the sun come from? Where does its energy come from?	Explain the structure and evolution of stars and galaxies. Balance nuclear reactions and show how energy comes from converting mass
3	Newton's Physics	How do objects move? Why do they move?	Explain five common examples of motion using Newton's Laws
4	Gravity	How can we simulate the motion in our solar system?	Create three questions/hypotheses about how changing the mass or velocity of planets/our sun would change the overall motion.
5	Gravity	What determines the motion of our solar system?	Show how the solar system would change with different planets, masses and velocities. Use evidence from simulation.
6	Einstein's Relativity	Can we travel faster than the speed of light? How does gravity affect space?	
7	Shape of the Universe	Is the universe flat? Is it a sphere? How do we know?	Compare the shape of the universe to the shape of the earth. Where can this map take us?
8	Big Bang	How did the universe begin? How do we know?	Why did Stephen Hawking say if we know what happened before the Big Bang we would know the mind of God?
9	Big Bang	How is our universe changing? How do we know?	What is the fate of our universe? Should we worry about it?
10	Big Bang	Stephen Hawking's Universe	Answer questions about the video.
11	Creation Myth	How have people explained what they do not know?	**Write a story about the creation of the universe that is scientifically correct to help others understand the structure and evolution of the universe.**
12	Time Travel	How could we travel through time?	Read article on time travel.
13	Time Travel	How will time travel affect the future?	Finish interview with great-grandchild.
14	Time Travel	What is your hypothesis?	What are the main arguments for and against time travel?
15	Time Travel	What is your evidence? How can you argue this persuasively?	
15	Time Travel	**Time Travel Debate**	List what you know about the universe for poster project.
16	What Is the Poetry of the Universe?	What Is the Poetry of the Universe? What is poetry? What do we know about our universe? How can we describe it?	List what you want to put on your poster.
17	What is the Poetry of the Universe?	What Is the Poetry of the Universe?	Sketch the poster. How does it show the poetry of the universe?
18	What is the Poetry of the Universe?	How can we show this poetry?	Finish poster.
19	What is the Poetry of the Universe?	**Presentations**	**Hand in Poster.** Work on your portfolio over the vacation!

Lesson 1

Aim:
To understand basic facts about the solar system as a model for the larger universe. Explain how these facts are supported by scientific experiments. Appreciate the elegance and creativity of these experiments.

Standards:
Demonstrates an understanding of the structure of the solar system and of the scientific process

Vocabulary:
Revolution, rotation, heliocentric, hypothesis, elegant

Motivation:
What do we know about our solar system? How do we know these things?

Materials:
KWL Chart for *Our Solar System*

Procedure:
1. Do now: What do you know about our solar system?
2. Have students fill in first column of *Our Solar System* KWL chart (prior knowledge is listed on the board).
3. How do we know these things?
   Hopefully, students will know that the earth is a sphere, that the sun is the center of the solar system, that planets orbit the sun, how long a day and a year is on earth, etc. If not, direct them toward these basic facts with simple questions such as "What is the shape of the earth?" and "What does the solar system look like?"
   Explain that we will look at various experiments. For each experiment, focus on the questions:
   - What is the hypothesis?
   - What is the evidence?
   - What is the simplest way to show this?
   - What is elegant about this experiment?

   Examples follow.
4. Shape of the Earth
   There are several simple ways to prove that the earth is not flat.
   - Place two sticks vertically in two different places on the earth's surface. The shadows of these sticks will be different if the earth is flat versus if it is curved. Draw both options with the sun and they will see how they differ.
   - The shadow of the earth on the moon in a lunar eclipse shows a curve, not a straight line. This can be demonstrated with a flashlight, a globe and piece of cardboard if needed.
   - The horizon disappears with sunset, sunrise and receding objects (ships at sea) that correspond to a curved shape.
5. Center of the Solar System
   Copernicus and Arab astronomers showed this conclusively by showing that smaller object orbit larger ones. Examples include Jupiter's moons as well as ours. Ultimate proof lies in the motion of the stars. This is a little bit tricky, although clear explanations can be found in *Conceptual Physics*.

6. Length of Earth's Year
   There are plenty of ways to show this but an interesting method would be to think about the cycle of seasons and to measure the length of the day, the sunrise and sunset, etc. These things cycle in 365 24-hour (day) increments.
7. Length of Earth's Day
   This is similar to the previous example and is not that important to discuss. Again, there are 24-hour cycles that include the sun and the moon.
8. Finish KWL chart to determine what we need to know to complete the assessments. Give students a guide to the unit that includes the outline and the assessments. Direct the final two columns to focus on the activities planned to support the assessments.

Homework:
Choose two experiments discussed in class. For each one, explain the experiment and the results, how it could have been done a much more sophisticated way given different technology, and what makes the experiment "elegant."

Our Solar System

What do we know about the solar system?	
What do we want to know?	
How will we learn these things?	

Lesson 2

Aim:

Describe the chemical processes that produce energy in stars; balance nuclear reactions

Standards:
Demonstrate the relationship between matter and energy; understand the role of stars and galaxies in the structure and evolution of the universe.

Vocabulary:
Galaxies, clusters, neutrons, protons, electrons, nucleus, nuclear mass

Motivation:
Where does our energy come from?

Materials:
Handout for guided discussion, table of nuclear masses.

Procedure:
1. Do now: Where does the energy in our solar system come from?
2. Explain how our sun is not unique as a star. Introduce the idea of the Big Bang and that hotter matter of a certain composition (hydrogen) collected as the temperature decreased. Have students answer the first question about where energy comes from on their guided note handout.
3. What an atom? Students should be familiar with this, so review the basic particles and structure of the atom. Have students write definitions of particles on the guided note handout.
4. Review the rules for balancing nuclear reactions. If students are familiar with chemical reactions, emphasize that, although we balance chemical reactions to conserve mass, nuclear reactions are different.
5. Go over examples on the board in a step-by-step fashion. Any example will do. Some good ones include the alpha decay of uranium-238 and the decay of carbon-14, which students may be familiar with in terms of carbon dating.
6. Have students work individually or in groups to complete the practice reactions. Give students the nucleosynthesis reactions that take place in stars.
7. Introduce the idea of $E = mc^2$ and how mass can be converted to energy. This should be the answer to how nuclear reactions produce energy.
8. Using the practice reactions, show how elements become heavier and that they increase the density and force of gravity. Briefly explain the life cycle of stars. This is not that important and will be brought up again when discussing gravity and mass.

Homework:
Calculate the energy lost/produced in the stellar nuclear reactions.
Explain how stars change over time.

What's up with these stars?

Where does the energy in the universe come from?

What is a nucleus?

Proton =

Neutron =

Electron =

How do we balance nuclear reactions?

1. The top numbers (total # of protons + neutrons) must be equal on both sides.
2. The bottom numbers (total charge) must be equal on both sides.

Examples

Practice Reactions

Where does the energy in nuclear reactions come from?

What happens to stars over time?

Lesson 3

Aim:
Explain motion in our solar system according to Newton's Laws of motion

Standards:
Describing motion in nature

Vocabulary:
Velocity, acceleration, force, action, reaction.

Motivation:
How do objects move the way they do?

Materials:
Newton's Laws handout, paper, other objects: books, balls, etc.

Procedure:
1. Do now: Are you moving?
2. Students will probably respond by saying that their hands, hearts, etc. are moving. Push them to think about the motion of the earth as it revolves and rotates.
3. How do we explain motion?
   Give students the handout with the definitions of Newton's Laws. For each one, go through an example/demonstration. There are many to be found in *Conceptual Physics*. Here are some ideas:
   - 1st Law: A book will not move unless you push it. A ball will roll until you (or friction) stop it. Be sure that they understand force as a push or pull.
   - 2nd Law: A car is harder to move than a bike. It is also harder to stop. It will also hurt more if you are hit by a car. If you push a shopping cart harder, it goes faster. Be sure to define acceleration and to emphasize that it can be a change in speed or direction.
   - 3rd Law: You punch a wall and then your hand hurts. The wall pushes back. Why don't you float away? Gravity pulls us down. But what keeps us from falling down to the earth? The force of the floor balances the force of gravity. The gravity is the action force of you on the floor and the floor pushes back. Be sure to avoid the idea that action force is you pushing and the reaction is that something moves.

   Students should summarize these in their handouts.
4. Have each student draw an example of one law.
5. Ask students to display and explain their examples. Correct any misconceptions.

Homework:
For each example, choose which of Newton's Laws best describe it and <u>explain your reasons</u>. Indicate what is in motion, what the force is, etc.

1. You pound your foot to the floor to knock snow off your boots.
2. You have to push harder to make a door open faster.
3. Dropping a hammer on your foot hurts more than dropping a nail.
4. When you are in a car making a turn, you move to the side of the car.
5. You are able to push a bike up a hill but cannot push a car.
6. The earth revolves around the sun.

Newton's Laws of Motion

1st Law	2nd Law	3rd Law
An object in motion will remain in motion and an object at rest remains at rest unless acted on by a force	F = m x a	For every action force there is an equal and opposite reaction force

Lesson 4

Aim:
Explain how Newton's Laws of Motion apply to the structure of the solar system

Standards:
Understanding forces and motion; structure and dynamics of our solar system

Vocabulary:
Inertia, equilibrium, tension.

Motivation:
What would happen if the earth stopped moving?

Materials:
String, tape, an object to tie to the string, computer for demonstration, gravity simulation program (see *Resource List)* Note: You will need to practice with this program before to make sure that you can quickly show examples using earth.

Procedure:
1. Do Now: What would if the Earth stopped orbiting the sun?
2. Solicit hypotheses. Explain that since gravity is pulling it toward the Sun, it would crash into it.
3. Demo: Is there a balance between gravity and motion force? Have a student spin an object on a string. Is there a force on the string? Yes, there is tension. You can feel it. What happens if we let go of the string? Motion (inertia) pulls it out of orbit. This is explained with Newton's 1st Law. An object in motion tends to remain in motion happen in the same direction unless there is a force.
4. Planets in orbit
   Normally, there is a balance of the gravity and the motion that keeps the orbit stable.
   Draw it. Note that one is the force of gravity and the other is really inertia, which is not a force. What is this called? Equilibrium. Is the Net Force zero? Is there acceleration? Yes. The direction changes. Remember that the object flew off in a straight line without the force of the string. Newton's 1st Law. Acceleration is also a change in direction, so there is force. Also, since inertia isn't really a force, there cannot be a balance that cancels forces to zero.
5. Check understanding with a few questions for group. Wait for a minute or so before taking answers. Ask students to really think about their answers.

   - *What would happen to the Earth if the velocity increased dramatically?*
     It would fly out of orbit, or at least change the orbit to a larger distance.
   - *What would happen if the mass of the Earth were decreased?*
     The force of gravity depends on mass, so the force would decrease.
     Again, this would give inertia the upper hand and Earth would fly out of orbit.
   - *What would happen if the mass of the Earth were increased?*
     The force of gravity would increase.
     This gives gravity the upper hand and the Earth would move closer to the Sun, possibly crashing into it. (Someone may ask how this could happen. You might ask back where in outer space mass could come from, such as asteroids, comets, etc. We also might be able to launch objects into

space, like garbage. Still the Earth is so massive that either would have to involve a huge mass to make a difference.)

- What would happen to Earth if it were moved farther away from the Sun?
  Since gravity also depends on distance, the farther away two objects are, the less gravity there is. Inertia would be winning again, so the Earth would move even farther away from the Sun, possibly flying out of orbit.
- What would happen to Earth if it were moved closer to the Sun?
  The closer two object are, the more force there is, so gravity would be winning again. The Earth would be pulled closer to the Sun, possibly falling into it.
  (This could also happen if an asteroid or comet hit Earth with enough force. Although this would also likely change the velocity.)

After each question, test the hypothesis using the gravity simulation to check answers. Only use Earth as the example.

6. Why do we care?
   The universe started with the Big Bang. There was a big explosion and lots of rock and gas spewed everywhere. Initially, we probably didn't have only 9 planets near our sun. What happened to the rest? Allow students to answer using the examples. Some may have crashed into the sun and some flew away. Some may have become moons.

7. Ask students why these objects might have gone away and been eliminated from our solar system.

Homework

Create three questions and hypotheses about how changing a part of our solar system would change the overall motion we see.

Things you can change:

- Velocity of a star
- Mass of any planet or star
- Distances between planets and stars
- Direction of motion for any planet or star
- Adding or removing a planet or star

Note to teachers: The variables that you can change depend on the specific software you are using. See *Resource List* for more information.

Lesson 5

Aim:
Describe dynamics of the entire solar system using computer simulations

Standards:
Forces and motion; structure and evolution of the universe

Vocabulary:
Hypothesis, conclusion

Motivation:
What could happen to our solar system as it changes?

Materials:
Computer lab, gravity simulation software (Students can pair up if not enough computers are available)

Procedure:
1. Ask students to share some of their hypotheses from the previous homework.
2. Distribute *Simulation Questions* handout. Have them choose one of their hypotheses and write it in the last empty box. Explain that before they test the questions that they need to have a hypothesis.
3. Demonstrate and explain the gravity simulation program.
4. Students work to answer their questions
5. Review conclusions to make sure everyone is on the same page.
6. What are some of the big ideas you learned? Answers should include ideas about balancing mass, velocity and direction. You might also ask them how this explains why we don't see fast moving planets at the perimeter of the solar system or massive planets at the interior.

Homework:
1. If planets in our solar system moved faster, what would happen to them?
2. If planets in our solar system moved slower, what would happen to them?
3. How does mass affect the motion of planets?
   Draw a diagram of the solar system. Show how the motion of the planets depends on mass, gravity and velocity. Use Newton's Laws and examples from the gravity simulations.

Simulation Questions

Question	Hypothesis	Conclusion
What would happen to Mercury if it moved much faster?		
What would happen to Venus if it moved slower?		
What would happen to earth if it had a larger mass?		
How would changing the sun's density affect the motion of the planets?		
What do you think would happen to a planet close to the sun but moved faster than Mercury?		
What do you think would happen to a planet that was not very close to the sun, but was very massive?		

Aim:
Explain the differences between Newton's physics and relativity

Standards:
Students will describe the structure and evolution of the universe

Vocabulary:
Relative, space-time

Motivation:
How can we travel through time?

Materials:
Diagrams from *Conceptual Physics* showing relative motion in a spaceship and the twin trip; diagrams of *An Illustrated Brief History of Time* showing space-time; Handout comparing Einstein's and Newton's Physics.

Procedure:
1. Discuss with students that Newton got most of the natural world right, but that in extreme cases of large and small, he failed. Touch on quantum mechanics but emphasize Einstein as a revolutionary thinker. He had imagination. He was one of the first to think about how to explain the universe in a way different from Newton. He still used science, but thought about a different way of explaining the universe.
2. Relative motion
   Use the examples from *Conceptual Physics* to show that, even in Newton's world, motion could be described as relative to position of viewing. When you drop a soda on an airplane. it looks like it is falling straight down, but from an outside observer it looks like it is "falling forward". Ask students which is correct. The answer is that both are correct and that is what Einstein hoped to explain. Have students summarize this difference in their charts
3. Light
   Using diagrams from *Conceptual Physics*, students can see that in the same circumstance of being in an accelerating spaceship that light is bent. If the spaceship accelerates at 9.8 m/s^2, then it is really the same as gravity. Einstein predicted that gravity would bend light, which was later proven to be true. Stars that appear in a certain spot change appearance if some of that light travels close to the gravitational field of the sun. This is a good time to introduce space-time and to think about gravity not as a force (Newton) but as a property of mass so that two objects are not needed for gravity. Add these two things to the chart as well.
4. Time
   Since how we move through space also affects time, Einstein thought that we actually live in four dimensions. He showed that the faster we move through space, the slower time goes. Use the classic twin trip example to show that this is true. So if we can change time by moving through space, why can't we also travel through time?

5. Einstein showed that we can essentially go forward in time by moving fast, but can we go back as well.
   Students can offer opinions but the question will be answered later when discussing Black Holes.
6. How did Einstein prove this?
   He certainly didn't do an experiment! This is a great time to talk about the balance between theory and experiment and how the two compliment each other. Mention how controversial and revolutionary this was when Einstein proposed it.

Note to teachers: This may seem like a short presentation, but students always have questions about this because it is so counterintuitive. Read up yourself and be ready to answer questions.

Homework:

1. How does gravity affect space?
2. How does gravity affect light?
3. What did Einstein prove about time that was different?
4. What did he prove about gravity that was different?

Physics Comparison Chart

	Newton's Laws	Einstein's Relativity
Time		
Space		
Motion		
Light		
Gravity		

Lesson 7

Aim:
Describe/show how time travel is possible; compare the shape of the universe to the shape of the Earth

Standards:
Demonstrates an understanding of matter and energy; demonstrates an understanding of the universe; represents information in several ways

Vocabulary:
Curve, flat, plane, sphere, dimension, hypersphere, wormhole, black hole, energy, relativistic

Motivation:
How do we get to Los Angeles? How can we get to another universe?

Materials:
Globe, 2-D US map, graph paper, handout of drawings of universe from *Poetry of the Universe*, time travel article (http://freespace.virgin.net/steve.preston/Time.html)

Procedure:
1. Students show how we get to Los Angeles on the map. Show again on globe. How are they different?
2. Students describe geometry of plane vs. sphere.
3. What is the shape of the universe? We used to think the Earth was flat!
4. What do we know about the universe? Refer to KWL chart. List evidence for Big Bang from chart.
5. We can see the Big Bang? What shape allows for an expanding universe where we can see the past?
6. What happens when we put graph paper on a sphere? It gets distorted.
7. We need to do the same thing with the shape of our universe. It is finite but boundless, how?
8. Examine pictures of geometry of universe.
9. How can we get to the Big Bang from Earth? Have students work in groups to draw this on the map.
10. Fill out Venn diagram for Earth vs. Universe.
11. Why is the space curved? Gravity.
12. Look at five-minute segment of Stephen Hawking's Universe on Black Holes. What are the similarities between a black hole and the curved space of the universe?
13. How can we get to another universe? Another point in time?

Homework:
Draw a map of the universe and show how we could get back to the Big Bang and to other universes? What do you think about the time travel article? Is it going to happen?

Lesson 8

Aim:
Describe the events of and the evidence for the Big Bang.

Standards:
Demonstrate an understanding of the structure and evolution of the universe.

Vocabulary:
Big Bang, galaxies, clusters

Motivation:
How did the universe begin?

Materials:
Paper for timelines, articles on the Big Bang (See *Resources*)

Procedure:
1. Do now: How did the universe begin?
2. Hopefully some students will say that is started with the Big Bang while some will say that God created the universe. This is an excellent opportunity to talk about the idea of scientific evidence and how it is not exclusive to religious views. Both are ways to explain the world. Science uses experiments and measurements. These cannot answer questions about why we are here. This should be of some comfort for those who hold stricter religious beliefs. Be sure to emphasize that since this is science class that we are interested in learning about scientific facts.
3. Briefly outline some of the ideas about the Big Bang. That all of matter and energy were created in a tremendous expansion of space and time. As the universe expanded, matter cooled and formed galaxies, stars, planets, etc.
4. Give students the evidence sheet and briefly summarize the evidence for the Big Bang that includes the ongoing expansion, background radiation/energy that cannot be explained in another way, and the fact that heavier elements found in planets are not found in stars and take more energy to form than stars actually produce. Have students organize this in their charts.
5. Give students handouts from the Internet on the Big Bang (see *Resources)* and have them create a timeline. Depending on your students, you may need to go over the idea of a timeline and how to create a proper scale. This is analogous to graphing so they might be able to make that connection. Not every little thing needs to be in the timeline, but main ideas about what happened to the matter and the energy must be in there! This will be a guide for the creation myth.

Homework:
Why did Stephen Hawking say that to know what happened before the Big Bang would be to know the mind of God?

The Big Bang!

What the heck happened?	What is the evidence?	What else do you know?

Lesson 9

Aim:
Explain ideas about the possible future of our universe.

Standard:
Demonstrate an understanding of the structure and evolution of the universe.

Vocabulary:
Expansion, contraction, equilibrium

Motivation:
Should we worry about the end of our universe?

Procedure:
1. Review answers to students' homework questions. Students often respond to this more poetic sort of statement. You might emphasize how Hawking recognizes the unknown and perhaps discuss why he implies that the time before the Big Bang is unknowable. Also think about how there is some poetic sense to his statement. This may lay the groundwork for the final project.
2. Ask students how the universe is changing now. You should include ideas about expansion and the changing composition of stars, but also allow them to bring in ideas about human influence on nature. This will lead into the idea of should we care.
3. Focus on the idea of expansion. Ask students to take a few minutes to create a hypothesis about what will happen to the universe in the future. The options are that it will keep expanding, eventually stop expanding and stay the same, or stop expanding and then contract.
4. How can we prove this?
   The key is to understand the balance between the residual energy of the Big Bang that causes the inertia of expansion and the force of gravity that pulls everything back together. How do we know which is stronger? It all depends on the mass. If the mass is large enough, gravity wins. If not, expansion wins.
5. What should we do about it?
   This is a really interesting question about how science interfaces with society. Obviously, measuring the mass of the universe is an expensive proposition. Ask students to write on their own if they think that it would be worth spending that money and if the millions of years that we have to live as a society before anything happens should prevent us from acting now. Although this may seem simple, the discussion will wrap up the class. You can bring in general ideas about if it is worth spending any money answering these narrow questions when we have so many social problems to solve right now. Play the devil's advocate and get students to really defend their ideas with evidence.

Homework:
How will humans react to the different possibilities for the future of our universe?

Lesson 10

Aim:
Review the Big Bang process

Standards:
Structure and evolution of the universe

Materials:
Stephen Hawking's Universe video, Episode 2; television and VCR

Procedure:
1. Give students questions for the video. Watch it while stopping to explain things that you think might be confusing.
2. The video is one hour long, so if you have time, have students ask questions.

Follow up:
Have students go to the PBS website for the series and find one article on the Big Bang. Have them read and summarize the article.

Students may also watch other episodes, answering questions for those parts as well.

Questions

- What is cosmology?
- If the earth is constantly rotating, why aren't we flung or feel any force in that direction?
- Why don't you see the earth being pulled toward a falling apple despite the fact that the apple does exert a gravitational force on the earth?
- Both Copernicus and Galileo felt pressure from the church and state to alter their scientific conclusions to avoid contradicting religious texts. Are there current conflicts between science and religion?
- The quality of a telescope is often determined by the quality of the mirror. Why is the mirror so important?
- How did we discover that the universe is constantly changing? Why was this important?
- What are these nebulae? What are galaxies?
- How does the Doppler Effect tell us about the motion of objects?
- Our sun is remarkably similar to other stars in the universe. What implications does this fact raise?
- What is the universe? Is there anything else?

Web Sites

Stephen Hawking Homepage
http://www.damtp.cam.ac.uk/user/hawking/home.html
NASA's Space Science Page
http://spacescience.nasa.gov/
Imagine the Universe:
http://imagine.gsfc.nasa.gov/

Questions

- What was the problem with Einstein's cosmological constant? Why did he put it in his equations? (This was Einstein's one major mistake in his lifetime!) Who challenged Einstein on this issue?
- How can science and religion agree on the theory of the Big Bang? How can these two coexist in other areas of natural life?
- How would proof of a static universe negate the idea of the Big Bang?
- Why was Hubble's conjecture that nebulae in the night sky were not part of our own galaxy so important?
- How did Hubble determine how far away the Andromeda galaxy was from earth?
- What was Hubble's proof that the universe was expanding?
- Have you ever heard the phrase "the world according to Hoyle"?
- How did Hoyle explain that the universe was expanding but was staying the same in the larger sense with his steady-state theory? What was a major problem with this explanation?
- Why were heavier elements an important part of the theory of the creation of the universe?
- How do stars die? How is gravity an important force in this process?
- Stars start with hydrogen. Where did the original hydrogen come from?
- What was the evidence that the Big Bang began with an explosion? If there were no initial explosion, what radiation would scientists see in space?
- What is a paradigm shift?
- What is a singularity? What are the conditions for the creation of a black hole? How is this related to the Big Bang?
- Why would you expect the Big Bang to produce a non-uniform radiation signal from outer space? Why would cool spots produce galaxies?

Web Sites

Introduction to Cosmology

http://map.gsfc.nasa.gov/html/web_site.html

The Big Bang

http://cfpa.berkeley.edu/Education/IUP/Big_Bang_Primer.html

Questions

- Why do you think the alchemists chose earth, water, fire, and air as their four basic elements? Could you convince yourself that everything you see is a combination of these "elements"?
- How was the alchemist idea that a primal matter existed actually true?
- What was the ultimate goal of alchemy? What motivated them?
- How does the weight of each atom determine the properties of these elements?
- Was Mendelev's original periodic table perfect? What was altered since his time?
- Why was Rutherford so surprised to find that radium gave off helium?
- What are some ideas about how the original matter of the universe was created?
- What is anti-matter? How does it compare to matter?
- How was this mythical anti-matter proven to exist?
- What's up with those cosmic rays? How were they discovered?
- How were cloud chambers used to see anti-matter?
- Is there proof of energy being converted to matter?
- Where is the anti-matter?
- Why is it a good thing that we have more matter than anti-matter?
- How do you think philosophers and theologians would view the idea that our universe exists because of an imperfection in the symmetry of the universe?
- Why were the majority of the atoms produced from energy hydrogen atoms? How does this connect with the stars of the universe?
- Can you outline the evolution of the universe, our universe, in terms of why we ended up living on earth?

Web Sites

WebElements
http://www.shef.ac.uk/uni/academic/A-C/chem/web-elements/web-elements-home.html

Periodic Table
http://edie.cproust.sfu.ca/~rhlogan/periodic.html

A Little Nut
http://www.xmission.com/~dparker/nucleus.html

The Day the Universe Went All Funny
http://www2.ncsu.edu/unity/lockers/users/f/felder/public/kenny/papers/relativity.html

Questions

- What holds the universe together? What pulls it apart?
- What do galaxies contain?
- How is the motion of stars in galaxies different from the motion of planets in a solar system?
- What does this difference imply about dark matter?
- More specifically, how could you show that over 90% of the matter in a galaxy is dark matter?
- Why is the amount of dark matter important to cosmologists?
- What is a macho and where are they? Even though they don't reflect light, how can they be "seen"?
- How does light refracted by gravity appear different to us on earth?
- What is a neutrino? How are they produced?
- What variables need to be included in models of the universe that study dark matter? Why are computers so important?
- Why are neutrinos so difficult to measure?
- Why is important to measure the mass of neutrinos?
- What are cosmic rays and how do scientists prevent them from interfering with neutrino measurement?
- What evidence was there that neutrinos were not the entire answer to the dark matter question?
- What is cold dark matter? What is the support for its existence?
- What are wimps and how might they be detected?
- Could all the matter in the universe eventually become dark matter?

Web Sites

Introduction to Dark Matter:
http://csep1.phy.ornl.gov/guidry/violence/darkmatter.html

Cosmic Hide and Seek:
http://www.gti.net/cmmiller/drkmttr.html

Particle Dark Matter:
http://www.astro.princeton.edu/~dns/MAP/Bahcall/final.html

NASA's Dark Matter
http://cossc.gsfc.nasa.gov/gamma/new_win/nw5.html

Questions

- Why would anyone look for extraterrestrial intelligence?
- No aliens, but what was found by SETI?
- What was causing the red shift of hydrogen in the spectrum of this particular "star" in Virgo?
- Quasars are what? How are they different from normal stars like our sun?
- What force would cause a star to collapse to a single point?
- Why did Einstein doubt his own theory?
- At what point does a collapsed star become a black hole?
- Did anything scientifically useful come out of the development of the atomic bomb?
- What was the predominant theory of what would happen to a dying star? What did new computer calculations show?
- Why was it important to show that matter falling into a black hole traveled close to the speed of light?
- Why would it make sense that black holes would grow larger and stronger?
- What did black holes imply about the theory of gravity in terms of creating a singularity?
- What is a singularity? Why is it so difficult to comprehend?
- How does the idea of a singularity help explain the Big Bang?
- Why do quasars give us important information?
- How can we "see" a black hole?
- How does a black star affect the light coming from a star that feels its gravitational pull?
- Could something else cause a star to move in such patterns and how would you know the difference between that and a black hole?
- What is the relationship between quasars, centers of galaxies, and black holes?
- Why might we think that a black hole is at the center of our galaxy?
- How can matter or energy escape a black hole? Will it be random or will there be information in what escapes?
- How might the idea of black holes be similar scientifically to the search for ET? How is it different?
- How does the idea of a black hole and wormholes tie into time travel?
- Might the physics of black holes allow us to work around the normal laws of physics? How?
- Why is the physics of black hole research important beyond pushing the limits of our imagination?

Web Sites

What Feeds the Monster?
http://zebu.oregon.edu/1996/ph123/qso.html

Hubble Surveys Quasars:
http://www.xs4all.nl/~calkop/quasars.html

Introduction to Black Holes:
http://bradley.bradley.edu/~dware/blkhole.html

Questions

- Why are the two options laid out by Hawking that are different laws for the beginning of our universe or that there is a theory that explains both the beginning and the development of the universe?
- Why should we worry about the science that occurs at the extremes?
- Why do you think that these extreme ideas seem so foreign to us?
- Why is that lady watching a movie on shelves of books?
- Why are Newton's Laws lost in the world of General Relativity and Quantum Mechanics?
- Why did Einstein believe that there was a theory that connected the two theories?
- Why did the expansion rate of the universe need to be so exactly what it was?
- We know that the universe grew symmetrically and evenly in all directions. How does an inflationary theory, of bubbles coming together, explain this observation?
- Why is it problematic?
- Probability is a key component of Quantum Mechanics. How might the element of chance be a method for explaining a singularity?
- How does imaginary time help explain a possible beginning? How does Quantum Mechanics help this idea along?
- Why is a no-boundary universe an elegant solution? What does it really assume about Quantum Mechanics and General Relativity?
- How could the universe choose what its parameters were? How is this related to biological evolution?
- You'd better know WBAI and Michio Kaku! They are both in New York.
- What is string theory?
- How does string theory look at the universe in a unifying way similar to Einstein's E=mc2?
- What is the main problem with the string theory?
- What is the ultimate test of any of these theories?

Web Sites

Quantum Mechanics
http://www.mtnmath.com/faq/meas-qm.html
Beyond the Big Bang:
http://www2.ari.net/home/odenwald/anthol/beyondbb.html
Mathematical Breakthroughs
http://www.surf.com/~westley/4q95faf/4q95dmsn.html
Superstring Theory:
http://www.lassp.cornell.edu/GraduateAdmissions/greene/greene.html
Stephen Hawking's Homepage
http://www.damtp.cam.ac.uk/user/hawking/home.html

Lesson 11

Aim:
To summarize and describe the creation and evolution of the universe in the form of a myth/folktale.

Standards:
Demonstrate an understanding of the structure and evolution of the universe; demonstrate an understanding of the origin and evolution of the Earth system; explains a scientific concept.

Vocabulary:
Big Bang, galaxy, star, planet, gravity

Motivation:
Why do you think people told their kids that the moon was made of green cheese?

Materials:
Creation Myth examples, story maps

Procedure:
1. Have students answer the motivation question. Focus on explaining observed features of nature. What do we know about the moon now? We know what it is made of, but do we know where it came from? Sort of, the Big Bang. Do we know why it is there? Sort of, we know that there is a balance between gravity and momentum due to the motion of the orbit. Why does anything exist?
2. Why do people have myths and folktales?
3. Read first creation myth (*The Origin of Light*) aloud. Student will fill in the story map as they go along.
4. Compare answers as a class after.
5. Creation myths help people understand the world around them. How can we help others understand what we know about the universe?
6. Refer to vertical timeline of evolution of the universe from previous class.
7. Can we prove that a magical frog did not burp the universe up? No, but we can explain what happened to the universe after.
8. So come up with your own story of how the universe began. Make sure that your story cannot be disproved by scientific evidence. Also make sure that you use events from your timeline in your story.
9. Fill out another story map but this time for a new creation myth of the universe.
10. Discuss story ideas as a class.
11. Start writing myth.

Homework:
Finish myth for homework. These will be graded on the following criteria:
1. Were the parts of the story that you "made up" answering questions that science does not have answers to?
    2. Did you include what science does know about the life of our universe?
    3. How creative was your story?
    4. Does your story make it easier for other people to understand the history of the universe? (peer evaluation)

Creation Myths

You will be writing your own myth to help others understand how the universe evolved and how it is organized.
You must make what you write scientifically correct! Do not make up stories to explain what we already know to be true, but, instead, focus on what we don't know – primarily why the universe exists.

Here are some examples of myths from various cultures that have a scientific basis. They might give you some ideas.

The Origin of Light: An Alaskan Myth from the Inuit

In the early times, there was only darkness; there was no light at all. At the edge of the sea, a woman lived with her father. One time she went out to get some water. As she was scraping the snow, she saw a feather floating toward her. She opened her mouth and the feather floated in and she swallowed it. From that time she was pregnant.
Then she had a baby. Its mouth was a raven's bill. The woman tried hard to find toys for her child. In her father's house was hanging a bladder that was blown up. This belonged to the woman's father. Now the baby, whose name was tulugaak (Raven), pointed at it and cried for it. The woman did not wish to give it to him, but he cried and cried. At last she gave in and took the bladder down from the wall and let the baby play with it. But in playing with it, he broke it. Immediately, it began to get light. Now there was light in the world, and darkness, too.
When the woman's father came home, he scolded his daughter for taking the bladder down from the wall and giving it to the child. And when it was light, tulugaak had disappeared.

Boshongo Myth

The Boshongo are a Bantu tribe of Central Africa. In the beginning there was only darkness, water, and the great god Bumba. One day, Bumba, in pain from a stomachache, vomited up the sun. The sun dried up some of the water, leaving land. Still in pain, Bumba vomited up the moon, the stars, and then some animals: the leopard, the crocodile, the turtle, and, finally, some men, one of whom, Yoko Lima was white like Bumba.

Aztec Myth

The mother of the Aztec creation story was called Coatlique (the Lady of the Skirt of Snakes). She was created in the image of the unknown, decorated with skulls, snakes, and lacerated hands. There are no cracks in her body and she is a perfect monolith (a totality of intensity and self-containment, yet her features were square and decapitated).
Coatlique was first impregnated by an obsidian knife and gave birth to Coyolxanuhqui, goddess of the moon, and to a group of male offspring who became the stars. Then one day Coatlique found a ball of feathers, which she tucked into her bosom. When she looked for it later, it was gone, at which time she realized that she was again pregnant. Her children, the moon and stars, did not believe her story. Ashamed of their mother, they resolved to kill her. A goddess could only give birth once, to the original litter of divinity and no more. During the time that they were plotting her demise, Coatlique gave birth to the fiery god of war, Huitzilopochtli. With the help of a fire serpent, he destroyed his brothers and sister, murdering them in a rage. He beheaded Coyolxanuhqui and threw her body into a deep gorge in a mountain, where it lies dismembered forever. The natural cosmos of the Indians was born of catastrophe. The heavens literally crumbled to pieces. The earth mother fell and was fertilized, while her children were torn apart by fratricide and then scattered and disjointed throughout the universe.

Chinese Myth: Pangu Separates the Sky from the Earth

The sky and the earth were at first one blurred entity like an egg. Pangu was born into it. The separation of the sky and the earth took eighteen thousand years-the yang, which was light and pure rose to become the sky, and the yin, which was heavy and murky, sank to form the earth. Between them was Pangu, who went through nine changes every day, his wisdom greater than that of the sky and his ability greater than that of the earth. Every day, the sky rose ten feet higher, the earth became ten feet thicker, and Pangu grew ten feet taller. Another eighteen thousand years passed, and there was an extremely high sky, an extremely thick earth, and an extremely tall Pangu. Then came the Three Emperors (the Emperor of the Sky, the Emperor of the Earth, and the Emperor of Men.)

So these numbers came into existence and evolve like this. The number begins with one, becomes established at three, is completed at five, prospers at seven, and ends in nine. So the sky is ninety thousand li (a unit of measurement) from the earth.

Story Map

Title:_____

Setting:

Characters: _____ _____

_____ _____

_____ _____

Reason
For
Creation

Event 1: _____

Event 2: _____

Event 3: _____

Event 4: _____

Event 5: _____

Ending/
Moral

Modern Folktale: The Creation of the Universe

You will be writing a story about the creation of the universe. Cultures often came up with folktales to help explain things that were complex or things that they didn't understand. You are going to do both!

Right now, we are not 100% sure that the Big Bang theory explains the beginning of the universe, but there are several important pieces of evidence that point in this direction. Even if the Big Bang theory is not perfect, there is little doubt that it is very close to the truth of what happened many billion years ago. We do know what happened after the "moment of creation" and you should not stray from these scientific facts!

Make sure that you use your timeline to chart the events of the tale as well as the story maps that we worked with in class.

Folktale Outline

1. **What happened before the Big Bang? 30 points** (i.e., questions we have no answers for!)
   - Why was the universe created? Why is there not just empty space? Why does anything exist?
   - Did something create the universe or did it happen as a result of something else?
   - Why did matter and energy come into existence? Why do we need both? How are they different or similar?
   - Why does gravity exist? What causes it?

Note: There are some theories about what happened before the Big Bang, such as the inflationary theory. You will earn extra credit if you base this section on one of these ideas.

2. **What happened after the Big Bang? 60 points**
   - What was going on with the matter and energy?
   - How did protons, nuclei, atoms, galaxies, stars, and planets form?
   - What does the universe look like right now?
   - Where does the energy come from?

3. **What is the future of our universe? 10 points** (some serious speculation and hypothesizing!)
   - How is it changing right now?
   - What about a "Big Crunch"?
   - Can we go to another universe? Will this save us?

Important Points

1. **Be creative!**
   This is a story. Make it interesting. Make this complex history easy to understand. Use illustrations if needed.
2. **Be scientific!**
   Do not change historical facts based on scientific evidence! If there is an unanswered question, try to make an educated guess based on what evidence is out there. Then, and only then, should you make something up.

(continued)

3. **A word about religion…**
   This is a science class. We use the scientific method to answer our questions. If there are questions that have not been answered scientifically, we might choose to find answers in faith. You may choose to ignore scientific knowledge in your personal life, but your job here is to demonstrate an understanding of science, not religion. Hopefully, one of the realizations that you will have is that the conflict between science and religion is largely hype. There are so many unanswered questions about our existence (see part one of the outline) that even the Pope (that's right!) acknowledges the Big Bang. Who says that having faith in the laws of nature isn't spiritual? These laws determine what happens in our lives, are far beyond the ability of humans to create and are clearly much larger than our existence.
4. **Keep in mind the Poetry of the Universe project.**
   Science and religion are ways of looking at the world. So is art. Maybe writing this story will give you some ideas about how the universe is beautiful, poetic and elegant!

Lesson 12

Aim:
Present the possibilities for Time Travel

Standard:
Explains the structure of our universe

Vocabulary:
Black holes, wormholes, hyperspace

Motivation:
How can we travel through time?

Materials:
Illustrations of black holes and wormholes from Internet or *An Illustrated History of Time* (see *Resources*)

Procedure:
1. Do Now: How did Einstein show we could travel through time?
2. Discuss answers to this question in terms of the Twin Trip example.
3. What are some other options?
   Explain how since mass distorts space-time that some people think black holes offer a way to get back in time. Students may recall that black holes are one possible ending for massive stars. The problem is that the force of gravity from the Black Hole would cause you to accelerate as such a rate that you would die. However, since mass and energy are equivalent, you could create a hole using energy. People call that a wormhole.
4. What are the problems with wormholes?
   Emphasize that in the equation $E = mc^2$, since "c" is so large, it would require tremendous energy to create the same gravity that the mass of a black hole creates. You might mention how everyone pays for energy. Where is this energy going to come from? Could we better use it some other way? Again, since this is theoretical idea, students will have many questions. Read up and try to answer as many as you can.
5. If we travel in time, can we get back?
   Mention that just because we can travel in time, it doesn't mean that we can get back. Use the Granny Paradox as an example. Many people use the example of going back in time and killing your grandmother as an example that we cannot travel backward in time. How would you exist? There are some good refutations of this that include the idea that something would stop you from killing her and that there are infinite alternate universes. Still, it may be harder to travel backward.
6. Even if we can do it, should we?
   Again, this raises the social impact of using so many resources to send a few people on a very tenuous mission traveling through time. Students will have their own opinions.

Homework:
Find and read on article on time travel. Students can use previous resources at the PBS website as well as others.

Follow up:
Watch the film *Contact*. Is it realistic? If not, what was problematic?

Lesson 13

Aim:
Predict how time travel will impact society; describe changes; apply understanding of how Industrial Revolution changed society

Standards:
Demonstrates an understanding of the impact of science and technology; argues from evidence.

Vocabulary:

Motivation:
What will a future with time travel look like?

Materials:
Chart comparing Industrial Revolution, summary of Industrial Revolution from *Globe Fearson's World History*, format sheet for interview.

Procedure:
1. How did IR change the world? Read summary aloud.
2. Fill out IR side of chart as a class.
3. Have groups work to fill out TT side of chart.
4. Groups share ideas from each category. One per group -- like a jigsaw.
5. What is a good interview? What are good questions?
6. Brainstorm "good questions."
7. Write questions on one side of interview sheet.
8. Write answers on the other side.

Follow-Up:
Write out the interview in complete sentences. Be sure to add details that reflect the impact of time travel.

Impact of Science

	Industrial Revolution	Time Travel
Economics Who has money? Who makes it?		
Labor What jobs do people have? Who has them?		
Politics Who has power? How do they use it? Is there more equality?		
Arts and Leisure What do people do in their free time? How do people express themselves?		
Science What questions are left to answer? What do we need to do with science now?		

Interviewing your great-grandchild …100 years in the future!

Question	Answer

Lesson 14

Aim:
Prepare time travel debate

Standards:
Argue from evidence; scientific communication

Motivation:
Win the debate

Materials:
Copies of time travel articles listed in *Resource* section and as many others as you can find; Internet access

Procedure:
1. Do now: Will humans travel through time?
2. Discuss answers recording them on the board.
3. Split class into two teams, assigning each team the affirmative or negative side of the question "Will humans travel through time?"
4. Give each team the first planning sheet. Walk them through the steps.
5. If the team needs more articles, have a folder for each team with as many articles as there are team members. Students can choose to do research on their own, but that will waste time.
6. If teams get through the first planning sheet, give them the next that has more specific questions that they need to think about.
7. Do not let the class leave unless each person knows what their responsibility is to the group!

Time Travel Debate: Will Humans Travel Through Time?

What are some possible hypotheses to this question?

Yes	No

Which hypothesis will your group argue?

Each member of your team must have a job!

Job Title	Job Description	Team Member Names
Facilitator (1)	Make sure that everyone is involved and sharing the work	
Speakers (4-5)	Orally present evidence during the debate. Respond to other team's arguments.	
Visual Scientists (1-2)	Create visual displays of your evidence that speakers can use.	
Fact Checker (1)	Organize all facts on note cards. Check other team's information and give their own team facts for rebuttal during the debate.	
Other Jobs (?)	Must be approved by the teacher!	

Every team member is responsible for researching one article on time travel and recording the information on note cards!

Team Member	Article

Your team should have a plan for what you will present during the debate. You need to make your argument but also to tear down the other team's argument.

Main reasons supporting your argument	
Evidence supporting your hypothesis	
What you think the other team will argue	
What you think their evidence will be	
How you will respond to their argument	

Time Travel Questions

Here are some questions that you might need to answer during the debate. You might also want to ask these questions of the other team!

Remember…

An Answer = Evidence + Analysis

- What evidence is there that black holes exist?
- What evidence is there that they might be used for time travel?
- What evidence is there that wormholes exist?
- Do the laws of physics allow for wormholes to exist?
- What evidence is there that wormholes might be used for time travel?
- What evidence is there that gravity alters time?
- What evidence is there that traveling at high speeds might alter time?
- Is the evidence for these things based on theory or experiments? Which is better?
- How much energy will time travel require in the future?
- Is there research on creating ways to make more energy in the future?
- Are there dangers in using a time machine?
- Is time travel is possible, is there any way from stopping people from doing it?
- How long will time travel take?
- Can we travel into the future? What about the past?
- Will people want to time travel if they cannot travel back to when they came from?

Things you need to prove	Things the other team needs to prove

Lesson 15

Aim:
Prepare for time travel debate in groups

Standards:
Communication of scientific ideas; arguing from evidence, structure and evolution of the universe

Motivation:
Make a convincing argument for your hypothesis.

Materials:
Handouts for debate format, debate game plan and debate rubric; supplemental articles for research; note cards

Procedure:
1. Review debate format stressing the time limit for each section.
2. Review debate rubric going through the criteria. Ask students for good and bad examples of each area of assessment, especially the presentation style. The students should have ideas about how to make a good presentation.
3. Give teams the debate game plan handout. The goal should be to have this filled out by the end of the period, organizing their evidence on note cards.

Time Travel Debate Format

Team 1 = Yes = Affirmative = Humans will travel through time.
Team 2 = No = Negative = Humans will not travel through time.

Time	Team 1	Team 2
5 min	**Affirmative Opening Argument** Why will humans travel through time? What evidence do you have? What is your reasoning?	
4 min		**Negative Cross-Examination** Why are the opponent's arguments weak? Why is their evidence faulty? Why is their reasoning wrong?
5 min		**Negative Opening Argument** Why will humans not travel through time? What evidence do you have? What is your reasoning?
4 min	**Affirmative Cross-Examination** Why are the opponent's arguments weak? Why is their evidence faulty? Why is their reasoning wrong?	
4 min	**Affirmative Rebuttal** Continue arguing your position. Respond to other team's attacks.	
4 min		**Negative Rebuttal** Continue arguing your position. Respond to other team's attacks.
4 min	**Affirmative Closing** Summarize your argument.	
4 min		**Negative Closing** Summarize your argument.

Debate Game Plan: Affirmative Team

Position	*Speaker*	*Arguments, Evidence, Visuals and Questions*
Opening Argument 5 min		
Cross-Examination 4 min		
Rebuttal 4 min		
Closing 4 min		

Debate Game Plan: Negative Team

Position	*Speaker*	*Arguments, Evidence, Visuals and Questions*
Cross-Examination 4 min		
Opening Argument 5 min		
Rebuttal 4 min		
Closing 4 min		

Time Travel Debate Scoring

Affirmative: *Humans will travel through time.*

	1	2	3	4
Organization and Clarity Viewpoints and responses are clear and orderly.	Unclear in most parts.	Clear in some but not overall.	Clear and orderly in all parts.	Completely clear and orderly presentation.
Use of Arguments Reasons are given to support viewpoint.	Few or no relevant reasons given.	Some relevant reasons given.	Reasons given are relevant but not overwhelming.	Reasons are relevant and convincing.
Use of Evidence Quotes and facts support reasoning.	Little or no relevant evidence.	Some relevant evidence.	Relevant evidence supports argument.	Diverse types of relevant evidence support argument.
Use of Rebuttal Arguments are refuted and dealt with effectively.	No effective counter-arguments made.	Few effective counter-arguments made.	Some effective counter-arguments made.	Counter-arguments made refute major criticisms of other team.
Presentation Style Tone of voice, gestures, and level of enthusiasm are convincing.	Few style features were used. Not convincing.	Few styles were used convincingly.	All style features were used, most convincingly.	All style features were used convincingly.

Negative: *Humans will not travel through time.*

	1	2	3	4
Organization and Clarity Viewpoints and responses are clear and orderly.	Unclear in most parts.	Clear in some but not overall.	Clear and orderly in all parts.	Completely clear and orderly presentation.
Use of Arguments Reasons are given to support viewpoint.	Few or no relevant reasons given.	Some relevant reasons given.	Reasons are relevant but not overwhelming.	Reasons are relevant and convincing.
Use of Evidence Quotes and facts support reasoning.	Little or no relevant evidence.	Some relevant evidence.	Relevant evidence supports argument.	Diverse types of relevant evidence support argument.
Use of Rebuttal Arguments are refuted and dealt with effectively.	No effective counter-arguments made.	Few effective counter-arguments made.	Some effective counter-arguments made.	Counter-arguments made refute major criticisms of other team.
Presentation Style Tone of voice, gestures, and level of enthusiasm are convincing.	Few style features were used. Not convincing.	Few styles were used convincingly.	All style features were used, most convincingly.	All style features were used convincingly.

Comments:

Affirmative Total: _____ Negative Total: _____ Winner: _____

Lesson 16

Aim:
Students will execute the debate.

Standards:
Scientific communication; structure and evolution of the universe

Motivation:
How can you present your argument publicly?

Materials:
Other teachers for judges, video camera, a public space to hold an audience.

Procedure:
1. Invite teachers and other members of the community to act as judges. Provide the rubrics ahead of time and field questions from judges before the debate starts.
2. Have a volunteer set up the video camera.
3. Introduce the debate and review the format.
4. The teacher should keep time and tell teams when they have one minute left in their section.
5. When the debate is finished, teams can evaluate the debate using the rubric as well.
6. The judges vote and the teacher tallies the votes.
7. Judges and teachers use feedback to teams.

Follow up:
Have students review the videotape of the debate while looking at the rubric.

Lesson 17

Aim:
Explain the similarities between poetry and the universe.

Standards:
Demonstrates an understanding of big ideas and unifying concepts

Motivation:
What is the poetry of the universe?

Materials:
Handouts for comparing science/the universe and art/poetry, photocopies of short poems (whatever you think is relevant), handout for poster project

Procedure:
1. Do now: What is poetry?
2. Record answers on the board. Direct students toward some sort of idea that it is an expression of life and how humans see the world. Also think about the rules that involved in different types of poems. What are poems made of? Why do people write them? Why do we read them? Again, the big ideas here are organized elements but also a way of looking at things in order to better understand the universe.
3. Give students the handout that defines poetry, art, the universe, and science. After reading the definitions, have students add to the list for the poetry and art side and then fill in ideas about science and the universe. "What is science?" is a good question to ask. How is it different from art? To keep them focused, remind them that we are looking at the connections between the two.
4. Introduce Poster Project
   Give students handout on the project. Emphasize that while they need to have a thesis, the objective is to be creative and to show their ideas visually. If they need help coming up with a thesis, you can use some of the question on that handout as prompts. Students should leave the class with some thesis that the teacher has approved.

Follow up:
If students have a thesis, they can start brainstorming on how to represent that main idea.
Students can also research art that uses science or scientific images that are artistic. What makes them so? What is the difference between an artist and a scientist?

Homework:
Students should have a list of things that they want to show on their poster. They can also start looking for or creating images that they might use.

Poetry: verbal compositions designed to convey experiences, ideas, or emotions, characterized by the use of condensed language chosen for its sound and suggestive power and the use of literary technique such as meter, metaphor, and rhyme.	**Universe:** all matter and energy, including Earth, the galaxies, and all the contents of intergalactic space, regarded as a whole.
Art: human effort to imitate, supplement, alter, or counteract the work of nature	**Science:** the observation, identification, description, experimental investigation, and theoretical explanation of nature.

Poetry of the Universe: Poster Project

The purpose of this project is to illustrate the poetry of the universe on a poster.

What does "poetry of the universe" mean anyway?

Think about what makes up a poem. What is it? Poetry uses words to express something much larger than those words themselves. Of course, that's just one way of looking at poetry.

There are also many ways for you to create a poster about the universe. You should try to focus on explaining the poetry or elegance of the universe more than just throwing pictures and words on a big piece of paper.

Here are some questions you should think about **before** starting work on your poster!

What do we know about the universe? (Background information)

- What is it made of?
- Where did it come from?
- How is it changing?
- What are the rules in our universe?
- How did we find out this information?

What is the connection between poetry and the universe?

- Is the way we try to understand poetry the same way we understand the universe?
- How does understanding the universe help us find meaning in life?
- Is the way we understand the universe similar to the way we understand other things?
- Why does understanding the universe require so much imagination? Is this similar to poetry?
- How is the universe beautiful or elegant? Is this similar to other things we know about?
- What do we still need to know?

This project will be graded on three criteria:

1. Does the poster represent what we know about the universe?
2. Does the poster represent what makes the universe "poetic"?
3. Does the poster use visuals creatively?

This is going to be a subjective grade for a reason – you need to be able to express what you want in a way that is creative. If you are not sure what the criteria are beyond these questions, please ask. I will be able to give you some examples of what I mean by these questions.

Lesson 18

Aim:
How can we show the connection between poetry and the universe visually?

Standards:
Demonstrates an understanding of big ideas and unifying concepts

Motivation:
How can we show ideas?

Materials:
As many art supplies as possible: poster paper, markers, paint, clay, found objects, scissors, glue, magazines and newspapers, etc.; visual art books to use as examples

Procedure:
1. Choose a work of art that you think that you understand well, or find one you can easily learn something about. Modern work is often a little more abstract and full of more diverse images. Something by Dali, DeChirico, Picasso, etc. would be nice and possibly different. Ask students what the artist is trying to show. How does the artist show more than the objects in the work? Another way to do this is to have them create a title for the work before they know anything about it. Some will be concrete; others may be abstract. Work with both.
2. Give students the poster planning worksheet. Have them list what they want to represent on the left-hand column.
3. Have students share some of the things that they want to represent. It may give others ideas of their own. It will also allow you to briefly talk about what the relationships are between these items and how you might represent connections as well.
4. Students will then create a visual plan for their poster. Have them think of how to put all these things together, but to do it in a way that is thoughtful and creative. It should be more than just a collection of items, which is something worth mentioning to the students and perhaps showing them in other artwork.
5. Students are not allowed to begin work on their posters once they have a plan approved by a teacher.

   Note: If there is any way to get some support from an art teacher or an artist in the community, do so! Although you can be successful in helping them represent their ideas without this support, it will be difficult for you to support students in developing their artistic skills alone.

Poetry of the Universe: Poster Planning

Things to represent	Visual/poster plan

Lesson 19

Aim:
Finish poster project.

Standards:
Demonstrates an understanding of big ideas and unifying concepts

Motivation:
How can I develop my ideas visually?

Materials:
As many art supplies as possible: poster paper, markers, paint, clay, found objects, scissors, glue, magazines and newspapers, etc.; visual art books to use as examples

Procedure:
1. Have the students pair up and share their poster plans with each other. Students should write down feedback and think about how they might incorporate these new ideas in their artwork.
2. Most of the period should be spent executing the individual plan. Support students by asking them questions about what they are trying to show and force them to think about alternative ways of representing that idea.
3. Again, you should collaborate with an art teacher or an artist from the community if at all possible.

Homework:
Finish poster.

Lesson 20

Aim:
Present visual work on the poetry of the universe

Standards:
Demonstrates an understanding of big ideas and unifying concepts

Motivation:
How can I express my ideas about poetry and the universe to others?

Materials:
Tape or other material for mounting posters to walls

Procedure:
1. Each student has a few minutes to present his/her poster (depending on number of students).
2. Each student must state the thesis of the poster and briefly explain why he/she represented the ideas in this manner.
3. If time permits, students can ask questions about the posters.

Follow up:
Posters can also be used to create a gallery of work that can be viewed by other classes and teachers. If there are a large number of students, students can choose one piece in the gallery to analyze in depth rather than having each student give incredibly short presentations.

Resources

Books

Poetry of the Universe: a mathematical exploration of the cosmos by Robert Osserman
Anchor Books; ISBN: 0385474296 (1995)
This is the book that provided the inspiration for this unit. It has some solid science that focuses on how we understand the shape and the dynamic nature of the universe, making many useful visual connections to mapmaking in general. The illustrations are essential in helping students understand the four-dimensional nature of the universe and space-time in general. All this is placed in a context that underscores the art and imagination required in such a scientific journey.

The Illustrated Brief History of Time by Stephen W. Hawking
Bantam Books; ISBN: 0553103741; (1998)
This is the more accessible version of Hawking's classic and it provides important visuals in understanding space-time, relativity and time travel. Again, these illustrations are essential.

Conceptual Physics by Paul Hewittt
Prentice Hall; ISBN: 0321052021; 9th edition (July 2, 2001)
This is an excellent book for the concepts of physics that offers good explanations and diagrams of ideas about Newton's laws and Einstein's relativity. Selecting examples of both areas to give to students will make it easier for students to grasp these ideas without much real mathematical discussion.

Fearer's United States History by Joanne Suter
Globe Fearon; ISBN: 0822468948; 2nd edition (December 1998)
Although most U.S. History books will provide information about the industrial revolution, this particular book offers simple language, plenty of visual depictions of working conditions, and a timeline of that period. It is also a book that the students had already used in their History classes. Keep in mind that book selection should provide as few obstacles as possible to obtaining enough historical information to demonstrate the idea that technology can profoundly affect other aspects of society.

Time Travel in Einstein's Universe: The Physical Possibilities of Travel Through Time by J. Richard Gott
Mariner Books; ISBN: 0618257357; (September 19, 2002)
While this book may be beyond the students reading level, it does a great job of exploring the issues of time travel and, if nothing else, will help teachers guide students through the process of developing their own hypotheses about time travel.

The Theory of Everything: The Origin and Fate of the Universe by Stephen W. Hawking
New Millennium Pr; ISBN: 1893224546; (June 2002)
This is a great overview of current cosmology from Hawking. While some parts will be redundant and beyond students reading level, it does outline some of the key issues about the future of our universe.

The Future of Spacetime by Stephen W. Hawking (Editor)
W.W. Norton & Company; ISBN: 0393020223; 1st edition (June 2002)
This book addresses more-advanced issues of where cosmology is going and the implications for how we understand our universe.

Art & Physics: Parallel Visions in Space, Time, and Light by Leonard Shlain
Quill; ISBN: 0688123058; Reprint edition (January 1993)
Offers many examples of connections between art and science from how the science of light is demonstrated in painting to how Einstein's contemporaries in the art world had to adjust their own philosophies as a result of his work. Very provocative.

CALLA Handbook: Implementing the Cognitive Academic Language Learning by Anna Uhl Chamot and J. Michael O'Malley
Addison-Wesley ISBN: 0201539632 (January 1994)
While this handbook is primarily used as a method for teaching ESL in content areas, it does a great job of providing examples of how to use visual learning with graphic organizers to probe complex concepts without getting hung up on language obstacles.

Understanding by Design by Grant P. Wiggins and Jay McTighe
Prentice Hall Professional Technical Reference; ISBN: 013093058X (December 2000)
This is the book to start with in thinking about designing standards based curriculum and assessment. If you have a big idea (such as the whole universe), it will help you narrow your focus and plan effective classroom activities to support student performance.

Internet Resources

Stephen Hawking's Universe
http://www.pbs.org/wnet/hawking/html/home.html
The companion site to the television series includes interviews with cosmologists, information about cosmology and time travel, and a teacher's guide.

NOVA: Time Travel
http://www.pbs.org/wgbh/nova/time/
Includes various points of view and a teacher's guide.

Time Travel for Beginners
http://www.biols.susx.ac.uk/home/John_Gribbin/timetrav.htm

Time Travel
http://freespace.virgin.net/steve.preston/Time.html
This offers a specific argument supporting time travel both forward and back in time.

NASA: Fate of the Universe
http://map.gsfc.nasa.gov/m_uni/uni_101fate.html
A specific site that is most useful for the graph showing the possibilities for the future of our universe. It also has some interesting links to how measurements and predictions are made by cosmologists.

History of the Universe Timeline
http://www.pbs.org/deepspace/timeline/
This site provides detailed information that would support students in basing their Creation Myths in scientific fact.

From the Big Bang to Me
http://www.ioc.net/~artboy/P/dottime.html
This list attempts to make connections between art and ideas about our universe. The art cited could be used as examples of how art incorporates ideas about science and cosmology.

Artchive
http://www.artchive.com/core.html
This extensive catalog of visual art work can be used to explore how art can express certain views of the natural world in supporting students in their own work to represent the modern view of the universe.

Creation Myths
http://www.dc.peachnet.edu/~shale/humanities/literature/religion/creation.html
http://www.magictails.com/creationlinks.html
http://library.thinkquest.org/29064/main.html
These sites provide examples of myths from different cultures.

Videos
Stephen Hawking's Universe, PBS Home Video 1997 (Available on DVD or VHS)
This six part series covers everything from the Big Bang to measuring the cosmos to the fate of the universe. There is a teacher's guide at the PBS site and you can see the guiding questions for students that I have developed in the student handout section.

Field trips
American Museum of Natural History
http://www.amnh.org
This museum has excellent permanent exhibits on the scale of the universe and general issues in astronomy and cosmology at the Rose Center. The museum if free, but you do need to contact the museum at 212-769-5200 to schedule a visit. They have teacher guides and students worksheets that they will send you if you indicate what you are interested in seeing. By subway, take the IND 8th Avenue C or B train to 81st Street, or take the IRT Broadway Local #1/#9 to 79th Street and walk two blocks east on 79th Street to the museum. By city bus, take the M10 uptown or downtown and get off at 81st Street and Central Park West, or take the M79 across town to the same intersection.

Metropolitan Museum of Art
http://www.metmuseum.org
Free and convenient – this is a great place to take students to look at artistic expression of views of our world. Although the museum claims that reservations are required of groups of ten or more, it is not necessary if you bring students in small groups into the museum. Take the 4, 5, or 6 train to 86th Street and walk three blocks west to Fifth Avenue; or take the M1, M2, M3, or M4 bus along Fifth Avenue (from uptown locations) to 82nd Street or along Madison Avenue (from downtown locations) to 83rd Street. Take the C, 1, or 9 train to 86th Street, then the M86 cross-town bus across Central Park to Fifth Avenue.

Materials

While this unit is largely conceptual and relies heavily on visual examples to make connections between what we know and the inaccessible instruments that are used to make important measurements, there are two technological areas that are useful. The first is a computer lab for students to explore the gravitational dynamics. The software listed below is simple and can be used on almost any computer. The second is a video camera to record the time travel debate for student review. Since there is a rubric for the debate, students can watch the tape and grade their own teams.

Software

There are two good gravity simulators that are available for free at www.download.com -- one for Windows and one for Macintosh. Both show the balance between mass and velocity that can help explain the structure of the solar system as well as the forces that determine the fate of the universe.

- Gravitator (Macintosh)
- Planets 0.1 (Windows)