Formation of the Universe

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Overview

This curriculum unit is intended for Biology students, grades 9-12. Students will begin their study of the universe with an introduction to the various terms that they will encounter. The class will then construct a concept map linking the various terms together. Each coupling, in the concept map, will be accompanied by an explanation as to how the terms relate to each other. This activity should give students a working vocabulary that will aid them in their understanding of the subject. The concept map should also allow students to develop relationships between the various terms.

The unit will then proceed with an introduction into distances within space. Students will become acquainted with the light year as a measurement used by scientists to determine distances as well as time. Students will be introduced to the fact that light from distant galaxies has traveled great distances, over large expanses of time in order to reach us.

Students will be introduced to molecular theory through constructing a nested model that represents a string. This will give students an idea of the vastness of superstrings. This will also help students develop an understanding of how matter interacts.

The curriculum unit will cover the fact that the universe is expanding. Students will perform a number of exercises that demonstrate this concept. Students will be able to see that although distances changed, the ratios between the points did not vary.

The curriculum unit will cover stars and address some of the questions that

students most frequently ask. Why are some stars brighter? How does temperature relate to the stars' physical parameters? What are stars made of? How are stars driven by nuclear fusion?

The unit will end with a discussion on the formation of the solar system. Students will make comparisons to other planets and determine what makes earth habitable. Students will also discuss the six numbers that Martin Rees discusses in his book Just Six Numbers. We will talk about how fine tuning the numbers relates to the existence of life as we know it. Completion of this curriculum unit will give students sufficient background in order to study the formation of earth's atmosphere and the introduction of life onto our planet.

Rationale

Within the past few years there has been growing movement towards the adoption of inquiry based teaching techniques. This movement was sparked by the completion of the TIMSS study. The TIMSS study includes data from countries all around the world. It was found that students tend to grasp subject matter with greater ease when taught using inquiry based techniques. As an attempt to stay current with contemporary educational practices, the Pittsburgh Board of Education has adopted an inquiry based text for the districts biology program.

Students include a wide range of learners from 9^{th} to 12^{th} grade. This curriculum unit can be taught to mainstream students as well as Scholars students. The district's biology text, Biology a Human Approach, attempts to draw the student's imagination into the subject through discovery and open ended questions. The current text includes a section that deals with the formation of the earth and the beginnings of life. The text fails to discuss the formation of the universe. Hopefully this curriculum unit will start students to think about this important area of science. I also hope this unit will give students an understanding of how different disciplines of science can intermingle.

A Brief History of Cosmology

Over time human nature and the nature of science have driven our quest for information concerning the universe. Turiel states, "Even before the Greeks, the Egyptians, Chinese, Indians, and Babylonians made detailed astronomical observations" (7). As civilization progressed technology prevailed, "Galileo's use of the telescope put an end to the era of naked-eye astronomy" (Turiel 38). Through the development of new technology scientists continued to compile new information. Rees states, "All parts of the universe seem to be evolving in a similar way, without this uniformity cosmology would have gotten nowhere"

(12).
This basic understanding seems to form the basis of present day cosmological advances.

The Universe

The universe can be defined as, "The sum of all matter and energy that exists, that ever has existed, and that ever will exist" (Dobson 526). How did the universe come into existence? How did the various parts of the Universe form? What does the universe contain, and how are these parts inter-related? These as well as other questions have been asked over and over again throughout the ages.

The Light Year

Before one examines the universe an understanding of its size must be achieved. Due to large distances in space, scientists use the light year as a measure of distance over time. Couper defines the light year as, "9.5 trillion kilometers, the distance that light would travel in one year" (166). "This distance is so large that driving it in a car moving at highway speed would take over 10 million years" (Dobson 527).

As stated by Mitton, **"**Light travels at just over 186,000 miles in one second" (6). Given this value it stands to reason, "We see the universe as it was in the past" (Dobson 527). Mitton writes, "Large telescopes show us galaxies billions of light years away" (6). These galaxies would have been in existence billions of years ago. The light from these galaxies is just now becoming visible to us. "The farther away an object is, the older the light is that we get from that object" (Dobson 527).

Galaxies

The universe contains galaxies which contain stars and interstellar matter. "Interstellar matter is dust between stars that provides new material for stars to be formed" (Dobson 528). Although galaxies are substructures found within the Universe, they are vast. According to D'Amico, "It is estimated that the universe contains 100 billion galaxies and that each one contains an average of 100 billion stars" (6). "All galaxies are held together by their own gravity" (Couper 210). "The gravitational force is a field force that always exists between two masses, regardless of the medium that separates them" (Serway 263). "Gravity also holds galaxies into formations called clusters" (Mitton 10).

Galaxies are not always typical, but they do fall within a certain size range.

"The diameter of galaxies ranges from 3000 to more than 500,000 light years" (D'Amico 6). "There are three types of galaxies; barred, elliptical, and spiral" (Dobson 529). Bergamini states, "The Milky Way is a spiral type galaxy" (156). Our solar system is included within the Milky Way galaxy.

Expanding Universe

How do scientists know so much about the universe? Rees states, "Recent advances bring into focus new mysteries about the origin of the universe, the laws governing it, and even its eventual fate" (12). Recent discoveries have provided us with a great deal of knowledge that ultimately leads to answering further questions. "Albert Einstein mathematically predicted the expansion of the universe, as a side effect of his Theory of Relativity" (Dickson 114).

Meanwhile in 1917, "Astronomer Vesto Melvin Slipher announced that galaxies were moving rapidly away" (Couper 221). A red shift is seen when objects move away as compared to a blue shift when they are moving toward the point of reference. "Edwin Hubble found that the speed of a galaxy is directly linked to its distance" (Mitton 11). "In 1929, Edwin Hubble calculated the universe's rate of expansion as 500 km/s per mega parsec" (Couper 221). The discovery of an expanding universe changed the way scientists look at the universe.

The Sun and Stars

According to Dobson, "Stars are huge balls of hot gas that can be seen from earth with the unaided eye" (527). The sun is the nearest star to the Earth. Couper states, **"**The sun has been blazing for 4.6 billion years and will burn for about the same length of time" (154). Bergamini writes, "If we could take a census of the Milky Way galaxy's hundreds of billions of stars, the sun would come out quite respectably in the top 5 percent, larger and brighter than average" (69). "The mass of the sun is about 2×10^{30} kg, or more than 300,000 times the mass of the earth" (Dobson 536). Due to the light that the sun produces the earth's atmosphere contains oxygen as a by-product of photosynthesis. Without the sun life would not exist, all organisms would perish as a result.

Some stars are brighter than other stars. "Brightness of a star depends upon the star's temperature, size, and distance from the earth" (Dobson 536). The sun is brighter than other stars due to its close proximity to earth. Temperature is related to the color of a star. The stars with hotter temperatures tend to give off a bluish color, which is a shorter wavelength. Stars with a cooler temperature give off a reddish color due to the longer wavelength. "By studying spectral lines

found in stars scientists are able to distinguish their composition" (Couper 163).

It is general knowledge that molecules contain atoms. In turn, individual atoms contain protons, neutrons, and electrons. The proton carries a positive charge, while the neutron is neutral, and the electron is a negative particle. Nuclear fusion is a reaction that occurs within the center of stars. Rees states, "Atoms of a particular element can exist in several variants, called isotopes, with different numbers of neutrons" (48). During fusion reactions, the hydrogen of a star is converted into helium causing it to heat up and continue to react. According to Couper, "Hydrogen and helium are changed into heavier elements" (170). The reaction continues to produce heavier nuclei until the core becomes iron. "The core then implodes releasing enough energy to blow off the overlying material, creating a supernova" (Rees 48). The elements are then released during the explosion. The heavier elements are created during the explosion.

Structure of the Solar System

According to Mitton, "The sun with everything in orbit around it, including even tiny particles of dust between the planets, is called the solar system" (30). The nine planets that orbit the sun are Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune, and Pluto. The solar system has many other objects within it which include meteors, comets, and asteroids. The asteroid belt is also included in our solar system. The asteroid belt is located between Mars and Jupiter.

"The asteroid belt contains many small rocky objects ranging between 3 km to 700 km in diameter" (Dobson 545). Within recent years the subject of asteroids has been the focus of many science fiction movies. In fact, it is thought that the extinction of the dinosaurs was caused by a large meteorite striking the earth. A strike of this magnitude would cause the blocking out of the sun by dust. Entire ecosystems would be upset by this type of catastrophe.

The Inner Planets

Mercury is the inner most planet to the sun. According to Chartrand, "The quick motion of Mercury prompted the ancients to name it after the messenger of the gods" (641). Mercury does not have an atmosphere. "Temperatures on Mercury range from 400 ° C to -170 ° C thus making it inhospitable" (Chartrand 642).

"Venus located between Mercury and the earth, has an atmosphere with a mass 100 times greater than that of the Earth" (Couper 124). Temperatures on Venus on average are extremely high. Venus has a high degree of volcanic activity which adds to the hostile environment found on the planet's surface.

Fortunately earth's atmosphere and temperature are much more hospitable as compared to the other planets. Although at the beginning of the Earth's history conditions were far from accommodating. Volcanic activity and high temperatures helped to create gases which eventually created our atmospheres. Earth eventually cooled and water vapor condensed. "Earth for the first time was experiencing violent rain storms" (Biggs 398). These rain storms formed the oceans, which were critical in the formation of life.

The Outer Planets

"Mars, the red planet, was named after the god of war because its color reminded the ancients of blood" (Chartrand 650). Mars has an extremely thin atmosphere. "The atmosphere is thick enough to support huge dust storms, some of which cover almost an entire hemisphere" (Chartrand 652). Couper states, "The average temperature on Mars is -63 ° C" (114). Obviously the low temperatures of Mars make it too cold to support life.

Jupiter is the largest of all the planets. Jupiter experiences strong winds due to its short rotation. "Winds have been measured at speeds up to 400 miles per hour" (Mitton 46). Temperatures on Jupiter are extremely cold. "Jupiter's atmosphere is made up of primarily hydrogen and helium" (Chartrand 655).

Couper states, "Saturn is the second largest planet, it is easiest to recognize because of the bright rings around its equator" (128). Saturn is colder than Jupiter due to the fact it is farther away from the sun. Saturn also experiences massive storms on its surface.

Uranus and Neptune lie beyond Saturn. "Neptune and Uranus have atmospheres containing methane, giving them a bluish color" (Dobson 547). Uranus and Neptune mostly contain hydrogen and helium in their atmospheres.

"Pluto is the smallest of all the planets and farthest from the sun" (Chartrand 668). "Pluto has a thin gaseous atmosphere and a solid icy surface" (Dobson 548). Pluto orbits at an angle as compared to the orbits of the other planets.

Formation of the Solar System

The nebular model is the most widely accepted model for the formation of the solar system. "The model suggests the sun and the solar system condensed out of a nebula, a huge cloud of interstellar gas and dust" (Dobson 548). The solar system started out as a rotating disk of dust and interstellar gas. Through gravity

and the collapse of the center of the cloud the sun formed. The planets formed through accretion. Dobson states, "Accretion occurs when small particles collide and stick together to form larger masses" (548).

Future of Cosmology

We are certainly in the golden age of cosmology. Recent discoveries have fueled the quest for further information regarding the formation and future of the universe. New discoveries will continue to occur as long as we remain dedicated to the search for knowledge.

Unfortunately the discovery of new knowledge pushes the boundaries of cultural beliefs and practices. Although new discoveries can benefit and improve our quality of life they can also test our beliefs. The fact that new discoveries do not always prove to contain the answers that we would hope does not mean they should be abandoned.

Science is not meant for everyone, but the need to exercise an individual's thought processes is something everyone shares. The study of cosmology does not have to relate strictly to science. The study of cosmology can relate to language arts as well as other creative areas of thought. Science fiction writings have been entertaining us for decades. A lot of ideas found within science fiction material have gone on to become reality.

Hopefully young minds can be stimulated through the study of cosmology. It is truly an area that has something for everyone. Cosmology is becoming more and more accessible to the general public which is helping to advance the cause of the subject.

Objectives

After completing this unit my students will:

1.) have a basic understanding of the structure of the universe
2.) have an understanding on the history of cosmology
3.) be able to demonstrate how the universe is expanding by use of models
4.) be able to explain the concept of the light year
5.) be able to explain the concept of galaxies and how earth fits into that concept
6.) be able to explain the process of star formation and evolution
7.) be able to describe how elements are created during a supernova explosion

8.) be able to illustrate the nebular model and how our solar system was formed

Students will satisfy standards by modeling scientific concepts while integrating mathematics. Students will also be required to make detailed written descriptions of some of the concepts covered within this unit.

Strategies

I will determine the student's misconceptions concerning the subject matter by giving them a short verbal test in the form of a discussion. The class will construct a concept map of the discussion that takes place. The concept map will then be placed into a folder for viewing at the end of the unit. At the end of the unit we will construct another concept map of the material that was covered. The class will then compare the two concept maps and describe what misconceptions were corrected and which misconceptions still need to be addressed. The unit will begin with a brief description of the history of cosmology. Students will be required to come up with the name of a person involved in the study of the universe along with a brief written description of the person's contribution. Students will then be required to make a model of the universe after reading a description of its makeup. Students may use what ever materials they want. The intentions of the unit are to follow inquiry based methods. Students will then learn what the light year is using a small worksheet on interstellar distances. Students will then describe what a galaxy is by writing a creative essay in a science fiction format using a list of terms that were covered in class. A model of an expanding universe will then be constructed by the students. The beginning of the lesson will begin with a short discussion concerning methods to be used in the exercise. The teacher should guide students into a method that will prove to be successful. Students will then write a brief description of the nebular model that will be accompanied by an illustration. The students will then construct a chart comparing and contrasting the earth and the other planets found within our solar system. This is a good point to incorporate this unit into the existing biology curriculum. The existing curriculum then proceeds with the beginnings of life on earth. Students will be required to keep a journal. All finished work will be kept in order to incorporate it into the students existing portfolios. A final formal assessment will be given at the end of the unit.

Class Activities

Day One

Procedure

Students will begin the lesson with a discussion of the information covered within the unit. Sometimes students need to be pulled into the discussion, the following list of questions can help start the activity.

1.) What does the universe contain?
2.) What is a star?
3.) What is space?
4.) Why does the earth contain life as compared to the other planets in our solar system?
5.) What is in the solar system?
6.) Is the universe changing or is it static?
7.) Are all the planets made up of the same materials?

Have a student come up to the chalkboard and begin to draw a concept map that reflects the discussion that is taking place. Draw the map on a large sheet of butcher block paper so that all classes can compare their maps with each other.

Students might need to make a short list of guidelines concerning the construction of the concept map. Make sure to have descriptions between shapes in order to facilitate understanding of the map.

Students will need to make a copy of the concept map for their journals.

Analysis

Have students complete an analysis of the activity that was just done. Ask them to write answers to the following questions in their journals:
1.) What have you learned about the universe that you did not know prior to today's lesson?
2.) Do you believe life exists within the universe? Include some reasons for your answer that were covered within the lesson.
3.) How can we describe distances in space?
4.) How will discoveries concerning the universe test cultural bounds?

You can bring closure to the lesson by having students write two or three questions in their journal that they hope to answer by the end of the unit.

Day Two

Procedure

Provide students with a collection of books concerning cosmology, the universe, physics, earth space science, and astronomy. Students will be required to find a person in these books that has made a contribution to our understanding of the universe. A brief description of the contribution should be written under a small picture of the individual. The date should also be included with the text along with a citing from the source. The individual assignments should then be collected and assembled into a timeline. Have students answer the following questions in a classroom discussion.

1.) Are there any trends as to when discoveries were made?
2.) Are there gender differences in the people making the discoveries? Explain.
3.) Are the various discoveries interrelated or do they stand alone?
4.) Is your scientist considered a major contributor by the scientific community or the general public?

Have students then write an essay on what would have happened if their scientist had never existed. Have each student describe the impact this would have had on history. Have students read their essays out loud to the class. Pick the top three essays and post them in the classroom.

To end the lesson have students describe two or three discoveries that they would like to see discovered within their lifetime.

Day Three

Procedure

Students will be asked to make a model of the universe. Students will take notes from the overhead. The notes will contain information on the structures found within the universe which will include the sun, planets, stars, moons, and the asteroid belt. The model is not restricted to these structures but, these structures must be included.

Students must work in groups of four students. Each group must design its model on paper prior to construction. The model must be presented to the teacher for a confirmation to continue with the activity. A materials list is to be submitted at this time.

Students can be given additional time in order to complete the assignment. Students will have to write a descriptive essay on the steps they took in order to complete their model.

Students will then appoint someone from their group who must present the project to the rest of the class. Students can be graded based on originality and accuracy. A point system can be created by the teacher.

Have the students answer the following questions.

1.) What could have been included in the model that wasn't included?
2.) Is the model an accurate depiction of the universe?
3.) How could the model be improved?
4.) Could the model be used to teach about the universe without an explanation of its various aspects?

Have students post their answers on sheets of paper for the rest of the class to read. Discuss the answers with the rest of the class. This activity is a good way to teach students how to critique themselves honestly.

Day Four

Procedure

Have the students conduct a brainstorming session concerning distances in space. The teacher can lead the discussion by asking questions such as,

1.) How do distances in space compare to the distances we travel on earth?
2.) Would the mile be a practical unit to use when talking about distances in space?
3.) What unit is used in discussions concerning the universe?

The teacher can then give the students a list of distances found between objects in the universe. The students can then create a diagram of the objects by setting the distances into a scale. The scale can be decided on by the student. The diagram must be able to fit onto a regular sheet of ditto paper.

Analysis

Have students answer the following questions in their journal.

1.) What scale did you decide on for your diagram?
2.) How difficult was the assignment?
3.) What part of the assignment was the most difficult to complete?

Day Five

Procedure

Give the students notes on the concept of galaxies. Have the students come up with a short story which must contain accurate information concerning galaxies. The short story must be in a science fiction format. Remind students to cite any research they might include in their story.

Have the students present their short stories by reading them to the class. Create a coffee house atmosphere with donuts and hot drinks. Have students kick back and enjoy a day of storytelling.

At the end of the lesson have students write a reflective essay which must include any new information they might have picked up during the activity.

Day Six

Procedure

Discuss with the students how the discovery of an expanding universe has changed the face of cosmology. Describe the details of the concept to the students. Brainstorm with the students on how they could illustrate the concept of an expanding universe. Try to lead them into the direction of using something expandable like a balloon.

Have students draw dots onto the balloon and measure the distance between them. Then have the students stretch the balloon and measure the new distances between the points. Have students create ratios between two distances one ratio will be calculated before the stretch. The next ratio will be calculated after the stretch.

Analysis

1.) What has happened to the ratios after the stretch?
2.) How can your results relate to the expanding universe?
3.) Do you think the expansion of the universe is infinite?

Have the students write their answers on separate sheets of paper and fold them up. Students must then pick from a hat and read the answers that were submitted. Each student must either agree or disagree with the answer they have picked and give a reason for it. Hopefully this will get students thinking from a

different perspective.

Day Seven

Procedure

Describe the aspects of the nebular model to the students. Have students create a drawing of the model. Make sure the students label all parts of the drawing. Have students hang the drawings and vote on the most artistic and accurate illustration. This is a good exercise to get students drawing. Drawing is an important aspect of being a scientist.

Day Eight

Procedure

Have students research the planets and the conditions found on each one. Have students create a chart that compares and contrasts the various planets. Have students answer the following questions. Post the answers to the questions on a sheet of butcher block paper.

1.) What makes earth more inhabitable than the other planets?
2.) What conditions does earth have that make it conducive to support life?
3.) What planets if any have the potential or had the potential to support life?
4.) Would life exist on earth if the distance between the earth and the sun were different?
5.) How long do you think life will exist on earth given the present estimate of the sun's remaining life?

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Appendix A

Standards

This unit addresses the following Pennsylvania State Standards that are also used by the Pittsburgh Public Schools

Science and Technology

1.) All students explain how scientific principles of chemical, physical, and biological phenomena have developed and relate them to real-world situations

2.) All students demonstrate knowledge of basic concepts and principles of physical, chemical, biological, and earth sciences.

4.) All students explain the relationships among science, technology, and society.

5.) All students construct and evaluate scientific and technological systems using models to explain or predict results.

6.) All students develop and apply skills of observation, data collection, analysis, pattern recognition, prediction and scientific reasoning in designing and conducting experiments and solving technological problems.

7.) All students evaluate advantages, disadvantages and ethical implications associated with the impact of science and technology on current and future life.

Reading, Writing, Speaking and Listening

1.) All students use effective research and information management skills, including locating primary and secondary sources of information with traditional and emerging library technologies.

2.) All students read and use a variety of methods to make sense of various kinds of complex texts.

3.) All students respond orally and in writing to information and ideas gained by reading narrative and informational texts and use the information and ideas to make decisions and solve problems.

4.) All students write for a variety of purposes, including to narrate, inform and persuade, in all subject areas.

6.) All students exchange information orally, including understanding and giving spoken instructions, asking and answering questions appropriately, and promoting effective group communication.

8.) All students compose and make oral presentations for each academic area of study that are designed to persuade, inform or describe.

Mathematics

1.) All students use numbers, number systems, and equivalent forms to represent theoretical and practical situations.

2.) All students compute, measure, and estimate to solve theoretical and practical

problems using appropriate tools, including modern technology such as calculators and computers.

3.) All students apply the concepts of patterns, functions and relations to solve theoretical and practical problems.