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Algebra in Elementary Astronomy and Space Science

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Introduction

When I was growing up in my parents home in Atlanta, I would meditate in their living room before going to my room to fall asleep because it was so relaxing to sit on the sofa, look out through all the windows, peek through the trees to see the dark sky with all the stars gleaming through. This ritual was very spiritual, and it helped me to love and appreciate life. It is the main reason why I love living in Atlanta. It is a room that I will design in my dream home. These experiences led me to have an interest in astronomy.

A crucial component of American student's mathematics education is algebra. Algebra is the language through which the world communicates mathematics. It is a process that fosters generalizations and insights and provides a means of operating with concepts at an abstract level. Algebra has long been viewed as the fundamental course that can determine the success of any student future in upper level math courses. In fact, it is a basic tool and is called the "*gatekeeper*" by some. This is because algebraic representation is a prerequisite for further studies in all upper level math courses and other subjects such as economics, physics, chemistry, and astronomy, as well as many jobs.

Although algebra is a requirement, many minorities and students living in low-income areas have not had adequate opportunities to learn algebra fundamentals at an earlier grade before high school. Based on reading several journals and articles over the years, the ratio of students enrolled in algebra is higher in suburban schools and those in affluent communities than in urban schools and low-income communities. The success rate in any math course is low in most inner city suburban schools. However, the achievement gap is decreasing but at a slow rate.

As a mathematics teacher, I often find it a struggle to get my students involved in learning algebra. Mainly, I feel that this has been a problem over the years due to the fear that some students have because the word "algebra" sounds foreign, and because of the negative experiences they have often heard from others. My goal as an algebra teacher has always been to bring in more real-world applications, so that my students can understand the subject better, and make them understand that it is a universal language that is used in other subjects. However, I often find myself in a dilemma because I have not been able to find a variety of real-world applications that have already been written and that will interest my students'. The overall issue for my students is often boredom. The lack of interest often causes them to get off task, which leads them to miss the fundamentals. The integration of other subjects incorporated with algebra must be versatile in order to keep the interest of my eighth grade students, which is a struggle to achieve in the first place.

Why do I consider algebra to be an important class to learn? Some of my students asked me that same question almost daily over the years. In the past, my answers were something like, "you will need it for college," or "algebra is a fundamental skill that you will use on your job." Of course, my students will mumble and say "she does not know; she just wants us to think we will need her class in the real world." Well, my responses are true but I had to realize that I must teach algebra relating it to the "real-world" and integrate other subjects that uses algebra when appropriate constantly, which will make the learning process real for them. If not my students will never understand the importance of algebra.

Algebra is the language of generalization. In other words, if you are solving or working on a process again and again, algebra provides a simple language for describing your process. Algebra is the language through which we describe patterns. Most of the general patterns are simply formulas. The formulas state one quantity in terms of another. Some of the patterns are just rules written in an easier way if you understand algebra. It is a long simple verbal rule written in a shorter algebraic rule.

For the reasons I stated above, I believe that a curriculum unit on Algebra in Elementary Astronomy and Space Science will broaden students' interest in mathematics and science. Learning the correlation between the two content areas will definitely capture the true-science lovers to take an interest in mathematics, and mathematics lovers will develop a secondary interest in science. The context of astronomy and space science will improve learning in my algebra classes because students will develop a fundamental link between the two disciplinary content areas.

The institute will help me to learn and understand Astronomy and Space Science so that I can incorporate it into my Algebra class this year. This unit will be the first Astronomy and Space Science unit I have ever introduced to my students to teach algebra. It will increase my students' knowledge beyond their textbook and will take away the boredom of learning algebra without any integration of another subject not related to pure mathematics or engineering.

I chose the Astronomy and Space Science seminar because the school district that I teach in is currently promoting Concept Based Units. For the past two years, we were given a topic and told to write a unit on that chosen topic. Now we have been given the liberty of creating our own topics, and submitting them for approval. The topics are encouraged to be based on the core subjects' science and social studies. I felt that Astronomy and Space Science was the best seminar for me because I already had an idea of how I can teach my students algebra around the theme, and I know that it is a topic that is briefly focused on in eighth grade science.

The goal of this unit is to create an interdisciplinary approach of some elementary astronomy and algebra to make learning algebra more interesting, as well as to get my students to understand and learn that algebra is truly used in a variety of subjects. Hopefully, this curriculum unit will broaden my eighth grade algebra students' interests in the field of mathematics and science, which are subjects they often try to avoid.

This curriculum unit will also allow me to reach another goal that mathematics teachers are encouraged to accomplish by the National Council of Teachers of Mathematics (NCTM). One of the visions that NCTM has encouraged over the years is for mathematics teachers to teach a curriculum that promotes deep understanding of mathematics that will challenge, engage, and motivate students. My linking of the topics of Astronomy, Space Science and Algebra will encourage my students to become personally involved in understanding open-ended astronomy and algebra investigations. The integration of the two topics will induce my students to learn algebra at a level that is attainable and interesting. My students will also be encouraged to be engaged in reasoning and problem-solving, from which they will develop a conceptual foundation for understanding the correlation of science and mathematics.

Overview

The unit is designed for eighth grade students who will be enrolled in Introduction to Algebra, and Algebra I. Most of the students who are enrolled in one of the two courses are not proficient in the prerequisite courses. This unit is designed to increase the students' awareness of algebra beyond the scope of the current integrated units. The majority of the students are from low socioeconomic backgrounds with little to no outside educational resources. The school is a Title I middle school with fewer than 600 students enrolled. Additionally, the school has been on the failing school list for the state of Georgia for the past seven years. On average, the school only meets about 60% - 69% of the school system targets and the state's Adequate Yearly Progress report. Over 90% of the student body is on free or reduced lunch, and 98% of the students are African-American.

The neighborhoods are riddled with prostitution, drug-abuse, and crime. Several students turn to the school for help and resources that they are deprived of at home. Morning and after-school programs are offered, but the programs focus on test skills for each core subject, rather than introducing our students to information that they are not likely to encounter in class. Some students are not able to walk into a room and choose a book on any topic to read. Watching television is something that most can do, but tuning into the History Channel, Discovery Channel, or PBS (Public Broadcasting System) is unlikely, because most have to watch what the majority of their residence at home are interested in watching, and for some the channels above are not available in their household.

Education presents endless opportunities of resources and knowledge. As educators we must understand that our classes need to have a real world experience in the classrooms, especially with what technology offers today, such as the "*world wide web*". Due to the background of the students, it is my responsibility to introduce them to the world of possibilities that mathematics has to offer. As a mathematics teacher, I constantly search for professional development to improve my skills and content knowledge, so that I can present to my students the endless promise of mathematics.

The curriculum unit is designed to last between two and four weeks, depending on the student's prior knowledge and mathematical aptitudes. The unit will integrate subjects other than mathematics and science. Technology will be used in some of the activities to fulfill the goals of the National Council of Teachers of Mathematics, Georgia Council of Teachers of Mathematics, Georgia Quality Core Curriculum designed and approved by Georgia Board of Education, and the Superintendent of Atlanta Public School's goal of incorporating technology with mathematics and science. Various forms of technology will be used in teaching the curriculum unit, such as multi-media projector used with a laptop and Smart Board. In addition, an interactive Texas Instrument 83 Silver-Plus Graphing Calculator can be viewed and operated on the Smart Board to instruct students. Students will have an opportunity to use laptops to construct spreadsheets and graphs, and use a Texas Instrument 83 Silver-Plus Graphing Calculator to assist in solving problems that link meaningful concepts to one another, and to practical algebraic applications that are used in Elementary Astronomy.

The final product of the curriculum unit will consist of a writing component. Students will respond to the final product by completing a performance task, and constructively respond to some higher-order thinking, open-ended questions that will measure their knowledge on Algebra that is used in Elementary Astronomy.

Objectives

Mathematics is a fundamental subject that all must master in order to survive at a basic level in our society. The more levels of mathematics that one master, the better their chances are in pursuing any of several careers with a mathematics background. Algebra is one of the fundamental levels of mathematics, and is considered the "gate-keeper". Algebra is abstract, but it is feared because variables and equations are introduced on this level of mathematics. Some students consider mathematics to be more difficult than any other core subject. Some complain that mathematics, on all levels, is tedious, boring, and difficult. Sadly, some adults help fuel the mathematics fear in our students by believing that it is irrelevant to some extent. Unfortunately, you can also find some adults whose careers involve mathematics that are not able to communicate how they use mathematics on a daily basis. The challenging task that a mathematics teacher must tackle is creating an interesting world of mathematics in the class. This curriculum unit is a difficult unit to devise, because it must interest students into devoting time and effort to the study and practice of algebra through astronomy and space science.

As stated earlier, this curriculum unit is developed for an eighth grade Introduction to Algebra and Algebra I class. The approach of an interdisciplinary unit is to make learning algebra interesting through Astronomy. Students will have the opportunity to gain a broader knowledge base in Astronomy and Space Science by learning Algebra and why algebra is important to know in Astronomy. Hopefully, after learning a little Astronomy and Space Science, students will have opened their eyes to the world of mathematics and science.

This unit is related to Georgia's Quality Core Curriculum standards for eighth grade mathematics, which is Introduction to Algebra and high school Algebra I. Since Georgia has approved new standards for mathematics that will be implemented for eighth grade mathematics in two years, this unit will also address some of the new Georgia Performance Standards for eighth grade mathematics. However, the unit will not be limited to the objectives and standards that will be identified in the lesson plans. The standards that are stated in the lesson plans are standards that students must master, to pass the Georgia Criterion Reference Test (GCRCT), which they will be tested on in the middle of April. In addition, the GCRCT must be mastered by eighth graders in order to be promoted to the next grade level in Reading, Language Arts, and Mathematics.

The mathematics objectives that will be taught in this unit are powers of ten, perfect squares, perfect cubes, writing numbers in exponential form, writing exponential numbers in expansion form, converting a number to scientific notation, converting scientific notation to a number, multiplying and dividing numbers in scientific notation, adding and subtracting with scientific notation, solving equations, substitution, speed, distance, density, units of measurements, converting units, and determining ratios. The science, technology, reading, and writing objectives related to this curriculum unit will also be included in the lesson plans. The science objectives are broad, because they are based on the algebra that is involved. The astronomy topics that will be taught are temperature scales, distances (light years, astronomical unit, and parsecs), velocity, Newton's Laws of Motion, Kepler's Laws of Planetary Motion, and the Doppler Effect.

Astronomy Key Concepts

Before beginning to teach the curriculum unit, students should be surveyed for what they already know about Astronomy and Space Science. Since the goal is to teach algebra by introducing an elementary level of astronomy and space science, some key concepts in Astronomy and Space Science should be discussed.

Temperature Scales

There are three types of temperature scales. The Fahrenheit scale is commonly used in the United States. The Fahrenheit scale is defined by the fact that water freezes at 32°and boils at the temperature of 212°. The Celsius scale is used internationally. The freezing point of water is 0°C and the boiling point is 100°C. The third temperature scale, Kelvin, is used more by scientists. Kelvin is used by scientists because it truly reflects available energy. The Kelvin temperature scale is the same as the Celsius scale, except for its zero point. The coldest possible temperature on the Kelvin scale is 0 K, which is known as absolute zero. The absolute zero, 0 K, is equivalent to -273.15° C. Basically, the Kelvin temperature value is 273.15 degrees greater than its Celsius value.

Students will use the three temperature scales to understand a basic form of conversion and solving for unknown values.

$Tf = 9/5 \times Tc + 32$

$Tk = Tc + 273.15$

(Tf is temperature in the Fahrenheit scale, Tc is in the Celsius scale, and Tk in the Kelvin scale).

Distance

The measurement of distance is essential in astronomy and algebra. In astronomy, the measurement of distances is vital, and a lot of attention is focused on distances in space. Since the distances in space include an extremely large range of values, astronomers use several different units to describe distances namely, parsecs, light years astronomical units, etc. Students will learn about the measurement of light years and astronomical units as it relates to their world by determining the distances of cars and other objects.

Parsecs

A parsec is approximately equal to 3.26 light years. It is the distance to an object with a parallax angle of 1 arc second. An arc second is 1/60 of an arc minute, or 1/3,600 of 1°. Astronomers use parsecs because it is more appropriate, but light years are used mostly in popular press.

Light Years

The meaning of a light-year is hard for some to grasp because of the common misconception of the meaning of a light-year. Some people use the word light-year out of context. Light-year is not a unit of time, but rather a unit of distance. A light-year is the distance that light travels in one year. The distance of a light-year is 9.46 trillion kilometers (approximately ten trillion kilometers). If you prefer to refer to light-years in miles, then one light-year is about six trillion miles.

Astronomical Units

In astronomy, not only is a light-year used as a unit of distance but astronomers also use another unit of distance, the astronomical units (AU), especially to refer to distances in the Solar System. The AU is defined as the average distance of the Earth from the Sun. The average distance between the Earth and the Sun is about 149,600,000 kilometers or 93,000,000 miles.

Velocity

The term velocity is often used in astronomy and upper level mathematics. Introducing the term in algebra will help students understand and learn a new word that is often used to recognize speed and direction of motion.

The velocity, v, of an object is defined as the distance it travels per unit time, i.e.

$$V = d/t$$

Density

Density will be discussed in this unit because it is a formula that is used greatly in science and is relevant to algebra. The density formula allows students to work with substitution and units of volume. Density is usually referred to as mass density. When the term density is used it describes the mass packed into each unit of volume. The tighter the object is packed, the higher the density. The unit of density commonly used is grams per cubic centimeter. The formula for density is $d=m/v$. Students will use this formula to calculate the density of packed items that is relevant to them such as cereal in a box.

Ellipse

An ellipse is often represented as an oval shape. This curriculum unit allows students to learn about ellipses at an earlier stage in algebra when discussing astronomy. Students will learn that the shapes of bound orbits of the planets in the Solar System are ellipses rather than circles. Discussing ellipses will permit students to learn that it entails a major axis, a minor axis, a center, and two foci. Examples of real-life tangible ellipses should be brought to the students' attention, such as a slice through the long axis of a football and an egg. (Remember that an ellipse is two-dimensional, whereas an egg or a football is three-dimensional).

Newton's Laws of Motion

Newton's laws of motion are a great teaching "hook". The laws of motion should get the students interested in understanding and engaged in the mathematical insight of his second law $F = m \cdot a$. Discussing Newton's three laws of motion will spark discussion and interest in learning why and how forces affect motion and how it pertains to algebra.

Newton's First Law of Motion

Newton stated in his book *Principia*, that "***In the absence of a net (overall) force acting upon it, an object moves with constant velocity***" (Bennett, 134). Newton wrote this based on what he learned from Galileo's discovery that objects will remain in constant motion until some type of force causes the motion to change. He stated that objects will remain in motion at a constant speed and direction if not acted upon by a force. If an object is not moving, it is considered to be at rest with a velocity of zero.

As a teaching hook for Newton's first law students should discuss his first law as it applies to a parked car on no slope, a car traveling along a straight road with no slope, and the sensation of motion that a person does not feel when traveling in an airplane on a flight with no turbulence or any other net force at a constant speed.

Newton's Second Law of Motion

Newton's second law of motion introduces basic algebra, a formula that contains variables and requires substitution. The second law of motion explains motion of an object when force is present. This law allows us to quantify the relationship of the motions of an object when it is acted upon by a force which causes it to accelerate in the direction of the net force. In order to quantify the relationship of an object's momentum and force, we multiply the mass and the acceleration to determine the force ($F = m \bullet a$). Remember that acceleration means the rate at which an objects velocity changes, which can be a change in speed, and/or direction.

Newton's Third Law of Motion

Newton's third law of motion states that "***For any force applied (action), there always is an equal and opposite force (reaction)***" (Bennett, 135). The third law of motion helps us to understand how gravity allows us to stand still on the ground. Our bodies exert a gravitational force on the Earth permitting us to stand at rest on the ground; at the same time, the Earth exerts the same force on us, but in an opposite direction.

Kepler's Laws of Motion

Thanks to Sir Isaac Newton, scientists now understand Kepler's laws of planetary motion. Newton explained Kepler's laws as they are relevant laws of motion and are a consequence of the universal law of gravitation (Bennett, 139). Kepler's laws are great examples of the application of a mathematical solution to a scientific theory. Kepler was not only an astronomer but he was also a mathematician.

Kepler's First Law of Planetary Motion

Kepler's first law states that the planetary orbits are ellipses, and the Sun is located at one focus, which disproves the misconception that they are perfect circles. This law allows students to observe that at some points on the orbit the planet is closer to the Sun, and at other times it is farther away.

Kepler's Second Law of Planetary Motion

The second law of planetary motion that Kepler stated was that a planet moves faster when it is nearer the Sun, and slower when it is further away from it. Newton helped explained this law by understanding conservation of angular momentum. This law is illustrated by the fact that a planet on a circular orbit will continue to orbit with no need for fuel, because the radius from the Sun will remain constant. The orbital velocity must stay constant in order to conserve angular momentum. This law is also explained by understanding a dancer when spinning. If the dancer arms are extended out, she will have a large radius but her velocity of rotation will be small. If her arms are brought inward crossing over her chest, then her radius will decrease and her rotational velocity will increase. The formula $m \bullet v \bullet r$ is used to calculate the conservation of angular momentum. The ***m*** represents the mass of the planets or object. The orbital speed of rotational velocity is denoted by the variable ***v***. The radius is signified by the variable ***r***. Conservation of angular momentum works with circles and ellipses because the product of *m•v•r* will remain constant, as long as the radius decreases when the velocity increases or when the velocity decreases the radius increases.

Kepler's Third Law of Planetary Motion

The third law of planetary motion relates the distance of a planet to the period of revolution around the Sun (that is, the length of the year on that planet) by the formula $\boldsymbol{p^2 = d^3}$. The planet's orbital period in years is denoted by the variable ***p***. The variable ***d*** represents the planet's average distance from the Sun in astronomical units (AU).

Kepler's third law of planetary motion is another great way for students to practice substitution in conjunction with learning exponential functions, perfect squares and perfect cubes.

The Doppler Effect

The Doppler Effect is another concept of astronomy that links algebra to science. This effect explains the shifts of wavelength of light emitted by objects that are moving towards or away from an observing object or person. The Doppler Effect affects wavelengths in sound and the spectrum of light. When dealing with sound, the wavelengths are referred to as high and low pitch sounds. Wavelengths are described with the color blue and red when the shift is based on the spectrum of light, often referred to as blue-shift and red-shift. When a light source is moving towards us, the wavelengths will be shorter creating a high-pitched sound or a blue-shift. If the object or light source is moving away from us, then the light is shifted to longer wavelengths producing a lower pitched sound or a red-shift. A popular example used to understand the Doppler Effect is a moving train. When the train is moving towards us, the whistle that the train blows is a high pitched sound, versus the low pitched whistle sound when the train is moving away.

Once again, a formula is used in astronomy where students can apply substitution and solving for an unknown variable. The Doppler Shift formula demonstrates how symbols are also used to represent the unknown like variables. The formula is expressed as, $\frac{v}{c} = \frac{\lambda - \lambda_0}{\lambda_0}$, where v is the object radial velocity, c is the speed of light, $\boldsymbol{\Lambda_0}$ is the rest wavelength of a particular spectral line, and $\boldsymbol{\Delta \Lambda}$**,** ($\boldsymbol{\Lambda}$ ***ñ*** $\boldsymbol{\Lambda_0}$), is the wavelength shift (positive for a red-shift and negative for a blue-shift). The Doppler Shift formula can also be written as $v = c\,\frac{\lambda - \lambda_0}{\lambda_0}$.

Strategies

Students will be arranged in cooperative groups, which will contain four students. Each student will have roles depending upon the lesson activity. If students are working on individual assignments, they are still allowed to collaborate by assisting each other in understanding how to complete the activity or solve the given problems. The class structure is divided into six parts. The class agenda schedule is Homework/Pre-Requisites Skill Review, Problem-Solving, Focus Lesson, Exploration Problem(s), and Reflections.

The lessons will begin with homework or prerequisites skills review for approximately the first ten minutes of class. Afterwards, a fifteen minute problem-solving period will follow. The problem-solving time frame allows the students to focus on one problem-solving strategy, which will assist students in solving the investigation and exploration problems that will be focused on during the Focus Lesson. The problem-solving strategy is another important component of the daily lesson routine, because most of the students are able to solve a problem but when it comes to "*word problems*" they seem to misunderstand the overall question and do not choose the ***best*** answer. During the problem-solving strategy period, only one problem relevant to the lesson will be examined.

The heart of the class period is based on the focus lesson. The focus lesson is divided into five parts that should flow. During this time, the teacher is mainly a facilitator. The focus lesson should start with scaffolding, an engagement period. The engagement frame is when students are surveying the activity and discussing how they should tackle the lesson. In most cases, a question is posed to the class, and students are brainstorming for ideas. The scaffolding is then followed by an exploration. During the exploration phase, students are collaboratively working on completing an investigation activity. The investigation is usually a hands-on activity that requires students to work in groups or with a partner. Thirdly, I will introduce the lesson to my students. At this time, the class is no longer working collaboratively, but as a whole group. During this phase I am explaining new problems to the class. The discussion usually consists of me explaining what type of algebraic problems we are now working on, why they are important to know or relevant to the activity, and how to solve the problems, by explaining, in detail, each step. Once the explanation phase is over, the class moves into the elaboration phase. For the duration of the elaboration phase, I check the students for understanding. This phase is more of a guided practice period, where we work through several examples. The fifth phase of the focus lesson is the evaluation phase. At this moment I usually give students a pop quiz. The pop quiz can be turning in a given problem where they must work independently, or I can randomly pull names from the "***Go-Around Cup***" (the cup consists of each student name on a Popsicle stick) and ask questions pertaining to the lesson.

The fifth part of the agenda consists of exploration problems. Generally the exploration problems are no more than ten. Keep in mind this is more of a practice segment based on the lesson activity for the students, and not a "*drill and kill*" section.

Reflection will be given at the end of class. The reflection sector can be used in several ways. This section is based on time and the extent of the lesson given. It can be done orally or written. If it is done orally, I usually ask a student to explain what he or she learned today. Some students will be detailed and some are too general. I use this time to assess which students understand the lesson and enjoyed it, because they can be very vocal when they are speaking their opinions. In some instances, the reflection period is written. The questions or statements can range from "*Today, I learned...*"or they can be asked to explain how to solve a problem in narrative form, which is usually difficult for the average eighth grader.

Lesson Plans

Lesson 1: The 1000-Yard Solar System [1]

Objective: Students will be able to apply proportional reasoning to establish the distances in the Solar System, as well as the sizes of the planets, by converting miles and kilometers to astronomical units.

Purpose:

Materials: Access to a field or parking lot, graphing calculator or scientific calculator, computer with a spreadsheet software

Vocabulary: Miles, Kilometers, Astronomical Units, Yards, Proportional, Convert

Teacher Preparation: Determine where you will conduct the outdoor activity. The outdoor activity can take place on the school's field or the school's parking lot. Once you locate where the outdoor activity will take place, mark off the starting point for measurement for the class.

Have copies of the Mean Distances from the Sun of each planet ready to give to each group.

It is recommended that you complete the activity before giving it to the class, so that you can assist students if they make errors.

Procedure: Have students go outside and measure 100 yards. This is the hook for the lesson. It will get students to think about long distances. Then have students think about distances that are 200 yards long, 500 yards long and 1000 yards long. Next have students work in a group of four and ask them to create a list of the distance they thought of earlier. Once the lists are created, a group representative should share them with the class. Now the students are going to make a model of the Solar System that is based on 1000 yards. The scale will be based on the distance from the Sun to Pluto, which will be 1000 yards.

Using miles and kilometers to convert to an astronomical unit, the ratio will be expressed as $\frac{93{,}000{,}000 miles}{3{,}672{,}000{,}000 miles} = \frac{149{,}600{,}000 kilometers}{5{,}913{,}000{,}000 kilometers} = \frac{1AU}{39.44AU}$. The ratios are all approximately 0.0253.

Since the activity is based on 1000 yards, the students will have to express the same ratio for the scaled distances in the model. Earth distance in yards is not given, so students will represent the distance with the variable x. The distance should be set up as a ratio so it can be calculated. The ratio is represented as $\frac{x - yards}{1000 yards}$. Given that we are converting to astronomical units, have students to set Earth's ratio to equal 0.0253 and solve for x. The steps are listed below:

$$\frac{x - yards}{1000 yards} = 0.0253$$

- x = 1000 yards•0.0253
- x = 25.3 yards

Based on the solution above, students now know that Earth is 25.3 yards from the Sun. After finding Earth's distance as a class, have students calculate the distances of the other planets and record the information in a spreadsheet. Give students the mean distances from the Sun in miles and allow them to convert the mean distances in yards and astronomical units.

Mean Distances from the Sun

- Mercury 36 million miles
- Venus 67.2 million miles

- Earth 93 million miles
- Mars 141.5 million miles
- Jupiter 483.3 million miles
- Saturn 886.2 million miles
- Uranus 1782.9 million miles
- Neptune 2792.6 million miles
- Pluto 3672 million miles

Questions: Have students answer the following questions, and submit these answers with their spreadsheets and calculations.

1. If the object representing the Sun were placed at the front of the school, where would the object for Earth be placed?
2. Where would Mercury be placed?
3. Where would Venus be placed?
4. How did you determine where the above planets would be located in the school?

Student Reflection: Ask students to write in their math journals about the mathematics they learned and how it is related to astronomy, our Solar System.

Lesson 2: Finding Our Top Speed [1]

Objective:

1. Students will be able to determine the length of time needed to walk or run a given distance and to plot the data on a graph.
2. Students will be able to determine the distance walked in 8 seconds and to plot the data on a graph and then use the results to develop the concept of slope.

Purpose: This lesson is a hands-on activity that provides a real-world experience, and can be used to start a discussion of travel in the Solar System. By the end of this activity, students will develop an understanding of measuring time and distance.

Materials: Yardsticks or measuring tape, stopwatches, graph paper, index cards, and masking tape.

Vocabulary: Time, Distance

Teacher Preparation:

1. Mark off a hallway or outdoor area distances from 25 feet to 100 feet in increments of 5 feet.
2. Mark the intervals with masking tape.
3. Have an index card for each student with their name to record the number trials and feet they walked in 8 seconds.

Procedure:

1. Start lesson by asking students: "How far they can travel on foot in 8 seconds?"
2. Line up students and begin the trials.
3. The time allowed for walking is held constant at 8 seconds.

4. The distance will vary from student to student.
5. Make sure there is a timer for each student.
6. Each student should record their time on their index card.
7. For multiple trials, use an odd number of trials.
8. Have each student determine their mean distance to record on the class data.
9. As a class make a bar graph of the class data in the frequency table.
10. Be sure to discuss how to label each axis.
11. Discuss where the point will be located on the graph when time is zero and distance is zero.
12. Connect each point on the graph (representing each student distance walked in 8 seconds (0, 0).
13. The steepness of the line shows the rate of speed, or slope.
14. Discuss the concept of slope and give a definition of the slope of a line.

Student Reflection:

Lesson 3: An 8-second Trip [1]

Objective:

1. Students will be able to determine the speed of various toys by conducting experiments.
2. Students will be able to calculate the speed of various means of transportation by using algebra.

Materials: at least one toy car, at least 3 feet of track for a ramp, a board or strong yardstick, tape measure, masking tape, and stopwatches

Vocabulary: Speed, Acceleration

Purpose: The 8-second Trip activity allows students to explore the concept of speed as it relates to travel in space. This is an important activity because it gives students the opportunity to learn about quantify speed and compare rates of speed.

Teacher Preparation:

1. Assemble 3 feet of track.
2. Secure the track to a board in order to keep track straight.
3. Make sure one end of the track is elevated so the cars can roll down.
4. Mark each ramp with a starting point.
5. >Note: The toy cars might not stay in motion for 8 seconds. Have the students to time the cars and calculate the speed of the cars using the formula $d=r \cdot t$. The average speed can be calculated by using the formula $r=d/t$. Remember that the elevation of the ramp and other variables can change the speed in the toy car, which affects the time. The stopping time for the car will not be exactly 8 seconds, although the title is "An 8-Second Trip".

Procedure:

1. Start a discussion with students about ways to travel fast and record some possible ways.
2. Before students break into their groups, have them complete a few trials to determine a reasonable time for the car to travel down the ramp. This will determine the interval that all groups will use as a constant in the data, for example 6 seconds.
3. Group students into teams of four for the data collection.

4. Groups should determine one student to be the car starter, recorder, and two timers.
5. Each group should describe its ramp with the ratio of the height of the ramp to the horizontal length of the ramp.
6. Groups should collect three to five sets of data (each group must do the exact same number of trials). Students will be measuring the distance traveled over the agreed constant time.
7. Each group is required to collect data on three ratios of a ramp (1/3, 1/4, and 1/5). Before they begin have them predict which ramp will produce the highest speed and ask them to explain why.
8. Have the students organize the data in a spreadsheet describing the ramp ratio, trail number, distance in feet, time, and average rate of speed.
9. Have groups compare their data with other groups and compare predictions.
10. As a class discuss Newton's Laws of Motion. Make sure students understand that acceleration is the change in speed.
11. At this point if the class is ready, introduce the Pythagorean Theorem.

Student Reflection: Have students to write about how this activity is related to them in the real-world and why Newton's Laws of Motion is important.

Lesson 4: Investigation of a Scientific Quandary [2]

Objective:

1. Students will be able to use scientific notation to represent numbers.
2. Students will be able to convert numbers to scientific notation.

Materials: Graphing Calculator

Vocabulary: Scientific Notation

Teacher Preparation:

1. Create two lists of numbers. One list should contain numbers represented as scientific notation. The second list should be numbers not in scientific notation.

Procedure:

1. Give students two lists of numbers. Have students classify the numbers in scientific notation or not.
2. Students should explain how they determine the classification of each number.
3. Students should define what it means for a number to be in scientific notation.
4. Now have students use their graphing calculator's scientific notation mode to help them figure out how to convert standard notation to scientific notation and vice versa.
5. Give students a series of numbers to convert to scientific notation and from scientific notation.
6. Have students answer the following questions:
7. How is the exponent on the 10 related to the number in standard notation?
8. How are the digits before the 10 related to the number in standard notation?
9. If the number in standard notation is negative, how does that show up in scientific notation?
10. Have students write a set of instructions for converting 415,000,000 or a number of your, the teachers, choice from standard notation to scientific notation.
11. Write a set of instructions for converting 6.4×10^5 from scientific notation to standard notation.

Student Reflection: Have students write what is the difference between a number in scientific notation and standard notation. Ask students to think about what situations are best for using scientific notation.

Lesson 5: Temperature Scales [3]

Objective:

1. Students will be able to use two or more transformations to solve an equation.

Materials: three to five real-world word problems that involve temperature.

Vocabulary: Fahrenheit, Celsius, Kelvin, Temperature

Teacher Preparation:

1. Find at least three real-world word problems that involve temperature.

Procedure:

1. Have students convert each problem to the two temperature scales that the temperature is not given in.
2. Ask students if any of the temperatures indicates freezing temperature.
3. Ask students if any of the temperatures indicates boiling point.
4. Give students the following problem and ask them to convert the Earth's surface and crust to Fahrenheit and the Kelvin scale.
5. The temperature within Earth's crust increases about 30° Celsius for each kilometer of depth beneath the surface. If the temperature at Earth's surface is 24°C, at what depth would you expect the temperature to be 114°C? (Formula: Temperature inside Earth = Temperature at Earth's surface + Rate of temperature increase x Depth below surface)

Student Reflection: Explain how to convert one temperature scale to another temperature scale.

Lesson 6: The Doppler Effect [4]

Objective:

1. Students will perform an experiment that will demonstrate the Doppler Effect.
2. Students will use substitute given values into the Doppler Effect formula to determine the object radial velocity or the speed of light.

Materials: splash out ball, 9 volt battery, 9 volt battery clip, rope, making tape, electronic noise making mechanism with pure tone (can be purchased from an electronic store)

Vocabulary: Doppler Effect, radial velocity, rest wavelength, spectral line, wavelength shift, red-shift, blue-shift

Teacher Preparation:

1. Prepare the ball before class.
2. Twist the splash out ball open.
3. Thread one end of the rope through the holes of the splash out ball.

4. Tie the end back to the rope.
5. Twist the wires of the electronic noise making mechanism together with the wires of the battery clip.
6. Plug the battery into the battery clip.
7. Tape the assembly to the inside of the splash out ball.

Procedure:

1. Allow one student to twirl the Doppler ball assembly in a circle above his or her head. Make sure the ball is able to gain enough speed.
2. Observers should record and describe what they hear as the Doppler ball move towards them.
3. Have students to record and describe what they hear as the Doppler ball moves away from them.
4. Allow other students to twirl the Doppler ball, and ask them to record and compare what they heard as they twirl the Doppler ball.
5. At the end of the experiment discuss with the class what they heard as the ball approach them and make a class list.
6. Ask students what they heard as the ball passed them and record the information in another class list.
7. Ask the students who twirled the ball did they hear the Doppler shift and ask them to explain why or why not to the class.
8. Relate the experiment to other real-world sounds by asking them if they can tell which way an emergency vehicle is traveling by the pitch of its siren. What about a train? What about a car with the music and base turned up loud?
9. Discuss with the students the phenomenon of The Doppler Effect. You should explain to them the meaning of The Doppler Effect.
10. Explain to the class what is meant by red-shift and blue-shift.
11. Explain the formula for The Doppler Effect and what each variable represents. Make sure that you explain that $\Lambda - \Lambda_0$ can also be written as $\Delta \Lambda$. By explaining the relationship, it will help prepare students for calculus and physics that Δ is the rate of change.
12. Give the students a series of known values for the formula and ask them to determine the radial velocity or the speed of light value.

Exploration:

1. The rest wavelength of one of the visible lines of the hydrogen is 656.285nm. This line is easily identifiable in the spectrum of the bright star Vega, but is appears at a wavelength of 656.255nm. What is the radial velocity of Vega?

Solution: Remember that a light-year is the distance covered by light, traveling at a speed of 300,000 kilometers per second, in a time of one year. Since the line's wavelength in Vega's spectrum is lightly shorter that its rest wavelength, the line is blue-shifted and Vega's radial motion is moving toward us.

$$\frac{656.255nm - 656.285nm}{656.285nm} \times 300{,}000\, {}^{km}\!/_{s}$$

$$= (-4.57 \times 10^{-5}) \times (3 \times 10^{5})\, {}^{km}\!/_{s}$$

$$= -13.7\, {}^{km}\!/_{s}$$

2. In hydrogen, the transition from level 2 to level 1 has a rest wavelength of 121.6nm. Suppose you see this line at a wavelength of 120.5nm in Star A, at 121.2nm in Star B, at 121.9nm in Star C, and as 122.9nm in Star

D. Which stars are coming toward us? Which are moving away? Which star is moving fastest relative to us (either toward or away from)? Explain your answers without doing any calculations. Determine the radial velocity for each star.

Student Reflection: Ask students to write in their journals about what they learned today during the experiment. Also, ask them to write about how math is related in astronomy and in a simple real-world activity.

Appendix - Content Standards

Georgia Performance Standards

Georgia has created new mathematics performance standards. Due to the new performance standards, by the end of grade 8, students will have completed the equivalent of traditional first-year algebra and much of the traditional geometry course. The standards listed below for Number and Operations, and Algebra is listed in its partial form as it relates to the curriculum unit.

Mathematics Grade 8

Number and Operations

Students will understand the numeric and geometric meaning of square root, apply

properties of integer exponents and use scientific notation.

M8N1. Students will understand different representations of numbers including

square roots, exponents, and scientific notation.

a. Find square roots of perfect squares.

h. Distinguish between rational and irrational numbers.

i. Simplify expressions containing integer exponents.

j. Express and use numbers in scientific notation.

k. Use appropriate technologies to solve problems involving square roots,

exponents, and scientific notation.

Algebra

Students will use linear algebra to represent, analyze and solve problems. They will use

equations, tables, and graphs to investigate linear relations and functions, paying particular attention to slope as a rate of change.

M8A1. Students will use algebra to represent, analyze, and solve problems.

a. Represent a given situation using algebraic expressions or equations in one

variable.

b. Simplify and evaluate algebraic expressions.

c. Solve algebraic equations in one variable, including equations involving absolute

values.

d. Interpret solutions in problem contexts.

Process Standards

The following process standards are essential to mastering each of the mathematics

content standards. They emphasize critical dimensions of the mathematical proficiency

that all students need.

M8P1. Students will solve problems (using appropriate technology).

a. Build new mathematical knowledge through problem solving.

b. Solve problems that arise in mathematics and in other contexts.

c. Apply and adapt a variety of appropriate strategies to solve problems.

d. Monitor and reflect on the process of mathematical problem solving.

M8P3. Students will communicate mathematically.

a. Organize and consolidate their mathematical thinking through communication.

b. Communicate their mathematical thinking coherently and clearly to peers,

teacher's, and others.

c. Analyze and evaluate the mathematical thinking and strategies of others.

d. Use the language of mathematics to express mathematical ideas precisely.

M8P4. Students will make connections among mathematical ideas and to other disciplines.

a. Recognize and use connections among mathematical ideas.

b. Understand how mathematical ideas interconnect and build on one another to produce a coherent whole.

c. Recognize and apply mathematics in contexts outside of mathematics.

M8P5. Students will represent mathematics in multiple ways.

a. Create and use representations to organize, record, and communicate mathematical ideas.

b. Select, apply, and translate among mathematical representations to solve problems.

c. Use representations to model and interpret physical, social, and mathematical phenomena.

Annotated Resources

Baker, Robert H.; ***An Introduction to Astronomy.*** Van Nostrand Company, Inc. 1935.

* This book is an introduction to understanding some key concepts of astronomy.

Bennett, Jeffrey; Donahue, Megan; Schneider, Nicholas; Voit, Mark. ***The Solar System:***

The Cosmic Perspective. Pearson Education, Incorporated. 2004

*This book is easy to read and outlines misconceptions in astronomy in a user-friendly way.

Freedman, Roger A.; Kaufmann, William J. ***Universe***. W. H. Freeman and Company.

2004

*This book was highly recommended by the astronomy professor from the seminar. This book also covers a lot of astronomy topics.

Hathway, Nancy. ***The Friendly Guide to the Universe.*** Penguin Group. 1994

*This book explains the universe in a basic way.

Teacher Resources

Branley, Franklyn M.; ***The Planets in Our Solar System.*** Harper Collins Publishers.

1981.

Chaisson, Eric; McMillian, Steve. ***Astronomy: A Beginner's Guide to the Universe.***

Prentice Hall. 2001

Farndon, John. ***1000 Facts on Space.*** Barnes & Noble Books. 2001.

Hesse, Walter H. ***Astronomy: A Brief Introduction.*** Addison-Wesley. 1967.

Jones, Brian; ***The Practical Astronomer.*** Simon and Schuster. 1990.

Knox, Richard; ***Foundation of Astronomy.*** Halsted Press. 1979.

Kutner, Marc Leslie. ***Astronomy: A Phsyical Perspective.*** Cambridge University Press.

2003

Larson, Ron; Boswell, Laurie; Kanold, Timothy; Stiff, Lee. ***Algebra 1***. McDougal Littell

Inc. 2001

Murdock, Jerald; Kamischke, Ellen; Kamischke, Eric. ***Discovering Algebra: An***

Investigative Approach. Key Curriculum Press. 2002

O'Connor, Vincent F.; Hynes, Michael C. ***Mission Mathematics: Linking Aerospace***

and NCTM Standards Grades 5-8. The National Council of Teachers of

Mathematics, Inc. 1997.

Whipple, Fred; ***Orbiting the Sun.*** Harvard University Press. 1981.

Websites

Astronomy Place

http://www.astronomyplace.com

Explore Math

http://www.exploremath.com

Explore Science

http://www.exploresicence.com

NASA Education Program

http://www.education.nasa.gov

NASA On-line Resources for Educators

http://www.hq.nasa.gov/education

NASA Space-link and Regional Educator Resource Centers (RERCs)

http://spacelink.nasa.gov

The Solar System: The Cosmic Perspective Web page

www.astronomyplace.com

Quest

http://quest.arc.nasa.gov

Yahooligan

http://yahooligan.yahoo.com

1Unless otherwise noted, all lesson plans are condensed and taken from O'Conner (1997).

2Unless otherwise noted, this lesson activity was taken from Murdock (2002). Some of the information noted in this lesson activity was added to hopefully build a better foundation and exploration for students.

3Unless otherwise noted, some of the problems listed in this activity was taken from Larson (2001).

4This activity was found on the Internet and was adapted from one of the NASA resources for teacher's websites. The problems listed in this activity were taken from Bennett (2004).

*Unless otherwise noted, all astronomy facts and information in this curriculum unit were taken and combined from Bennett (2004), Freedman (2004), and O'Conner (1997). I synthesized this information to form appropriate astronomical and mathematics language to correspond the information to middle school mathematics learners.