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Math Facts of Natural Gas & Pollution

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1. Introduction

The consumption of gas has enormously increased, despite that the prices have gone historically high, leaving us wandering if we should drive at all or if we should step in and participate in the democratic process of trying to change things. Gasoline and diesel consumption are just some of the causers of air pollution, respiratory illnesses and increment of the air quality index. The social manipulation of media contributes enormously to the feeling of "I need a car," and therefore the anxiousness of buying a new one increases at a similar rate than the variety of advertisement in the media.

The reasoning that drives me to write this curriculum unit is to provide a contribution to the educational system, showing how research can help us to understand the problems related to our environment, and, therefore, through a set of lessons, teach our students about these problems. The solution to the problems may arise with combined efforts from all sectors. Topics about pollution, combining science, math, politics and history are wonderfully teachable and need to be exposed to the general population. The amount of current data recorded about problems caused by pollution and overuse of energy, plus, their link to health conditions make us wonder if more regulations are needed. All the scientific studies have accumulated enough data to create readable charts and graphs compatible with the teaching standards that are taught at a high school level, more precisely, Algebra-1 and Algebra-2, which are ultimately my focus of concentration.

The 1,185 student population in the school where I teach is richly racially and ethnically diverse. Forty-four percent are Hispanic, thirty-three percent Filipino, four percent African American, three percent Chinese, three percent Samoan, three percent White, and ten percent from other ethnicities. Our student body is comprised of immigrants from over thirty-two different countries. Approximately seventy percent of Jefferson students come from families where English is not their primary language and sixty-five percent of Jefferson students participate in the subsidized lunch program.

After having several conversations during the school year with students and families, I found out that the American dream for many of these young students is to own a brand new car, own a house, and, to have a secure job. In my calculations I suddenly have 1,185 students who will own a brand new car after they graduate, meaning that the number of cars will increase yearly in around 1/4 of 1,185 (equals to 296.25 cars) on a regular basis.

This fact made me think that I should share with my students the pros and cons of having a gasoline operated car, versus a diesel, a hybrid, electric one or a compressed natural gas vehicle (CNGV). The number 237 is just a little portion of what reality is. There are thousands of schools, plus, there are other consumers that are not even included, for which, my thoughts really scared me. How much pollution can mother earth take?

In terms of efficiency, the use of CNG represents big savings. For instance, a regular medium size vehicle uses 100 soles (around $40 US) to fill up a tank with gasoline, while a full tank of CNG is only 16 soles (around $7 US). In both cases, the amount of miles covered per tank is the same. The efficiency of mileage per gallon, per dollar has turned Peru in one of the pioneers in the industry of CNG motors. Currently Toyota has just launched a plant in Peru that specializes in converting motors from gasoline to CNG. It seems that the business is growing up very quickly.

2. What is Natural Gas?

Chemically, natural gas is primarily methane, with low concentrations of other hydrocarbons, water, carbon dioxide, nitrogen, oxygen and some sulfur compounds. After the natural gas is processed under high pressure, it turns from gas to liquid, being odorless and with a certain tendency to be white color. Due to the compression processed, it is called "Compressed Natural Gas" (CNG).

2.1 Some Data

The compressed natural gas in the US (CNG) is called in Peru "*gas natural vehicular,* GNV." Saving money using CNG instead of regular gasoline, is just one of the benefits I have encountered while learning about the use of natural gas. Other immediate benefits are the decrease of the pollution index, cleaner air and therefore, health benefits. The pollution index is in reality called the Air Quality Index (AQI). I will explain a bit more about AQI in section 2.3.

According to the American Lung Association State of the Air 2004 report, more than 160 million of Americans live in areas where the air is polluted and it is dangerous to breathe. Although for more than thirty years the efforts to reduce smog has been one of the main priorities, half of US population still has unhealthy levels of ozone air pollution. In addition, up to 28% of US population breathes air with short-term particle pollution, while 23% of US population lives with year-round levels of particle pollution. [1]

The most affected cities in each region, according to the report are:

Northeast**:** New York City, Philadelphia, Harrisburg, Pa.; Pittsburgh, Washington, D.C.: Newark, N.J., Bridgeport, Conn.; and Baltimore.

Southeast**:** Atlanta, Birmingham, Ala.; Knoxville, Tenn.; Louisville, Ky.; Charleston, W.V.; Raleigh-Durham, N.C.; and Winston-Salem, N.C.

Midwest region**:** Chicago, Cleveland, Cincinnati, St. Louis and Detroit.

Southwest**:** Dallas-Ft. Worth; Houston; and Phoenix

West**,** Los Angeles: San Diego; San Francisco; Sacramento, Calif.; Fresno, Calif.; Eugene, Ore.; Seattle; Provo, Utah; and Salt Lake City

2.2 Definition of Air Pollution

Since I am continuously referring to air pollution in this document, I will define what air pollution is.

When particles and chemicals mix with the air, we say that the air is polluted. The particles could be carbon monoxide, ozone, nitrates, lead, sulfur dioxide, tobacco smoke vehicle emissions, diesel exhaust, tire fragmentation, road dust, industrial and residential combustion, agricultural and wood burning, power generation, smelting, construction and demolition, windblown soil, pollens, molds, forest fires, volcanic emissions and sea spray. These fine particles are easily inhaled deep in the lungs where they can penetrate the body's defense systems.

According to Norman H. Edelman, MD, consultant for scientific affairs for the American Lung Association, particle pollution is linked to high risk of asthma and heart attacks, strokes, lung cancer and premature death. The same conclusion has been obtained by the National Institute of Environmental Health Sciences (NIEHS) in a combined effort with University of Southern California and the University of Washington.

It is interesting to see all the data related to air pollution vs. lung diseases, and how with prevention, the amount of illnesses can be decreased. According to the estimates on air pollution of the Environmental Protection Agency, by the year 2010, the commitment of new air quality standards and cleaner air will prevent 23,000 premature deaths in the US; 1.7 million cases of asthma will be as well prevented, along with the prevention of 67,000 new cases of acute asthma. The list keeps growing with the prevention of 22,000 hospital admissions of respiratory-related illnesses and 42,000 for cardiovascular diseases.

2.3 The London Smog Disaster and the Clean Air Act

Between December of 1952 and March of 1953, about 12,000 people died mainly from pneumonia, bronchitis, tuberculosis and heart failure. Since the winter was extremely cold, people burned more coal and traveled more by car instead of biking or walking. The car emissions and the fumes from burning the coal, combined with light winds and high moisture, created dense smog consisting of soot, tar and gaseous sulfur dioxide. With light winds, the smog would not move and the high moisture would increase the spreading of the toxic particles, creating a mortal effect. Three years later, in 1956, this disaster would be the reason to create the first "Clean Air Act."

In order to be able to reduce air pollution, the U.S. Congress passed the Clean Air Act in 1990, which was a revision of the 1970 act. Through various regulated reductions in emissions, the act is designed to protect the environment and reduce air pollution. According to the Act, the Environmental Protection Agency (EPA) has the responsibility to protect the quality of the air and the stratospheric ozone layer. Georgia created in 1996 the Georgia Clean Air Force Agency, which is empowered to implement environmental protection measures in the state and follow the standards defined by Georgia's Environmental Protection Division and the EPA.

2.4 Air Quality Index (AQI)

The air quality index is a piecewise linear function of the pollutant concentration. The AQI measures the quality of the air on a scale from 0 to 500. A low number means a good air quality while higher numbers mean worse air.

To convert from concentration to AQI, the following equation is used:

$$I = \frac{I_{high} - I_{low}}{C_{high} - C_{low}}(C - C_{low}) + I_{low}$$

- I = Air Quality Index
- C = Pollutant concentration
- C_{low} = Concentration breakpoint that is ≤ C
- C_{high}= Concentration breakpoint that is ≥ C
- I_{low} = Index breakpoint corresponding to C_{low}
- I_{high} = Index breakpoint corresponding to C_{high}

The Air Quality Index is calculated for a single pollutant. In other words, there are as many AQI numbers as there are pollutants. To compare AQI for different cities, one has to be careful to compare the AQI for the same pollutants.

For example, to illustrate the application of the above formula, I am going to use the average concentration of fine particles known as $PM_{2.5}$, recorded in a monitor for a 24-hour period. The reading of the concentration "C" on the monitor is 12.0 micrograms per cubic meter. The table of breakpoints for $PM_{2.5}$ is provided by EPA [2] and is given below:

C_{low}	C_{high}	I_{low}	I_{high}	Category
0	15.4	0	50	Good
15.5	40.4	51	100	Moderate
40.5	65.4	101	150	Unhealthy for Sensitive Groups
65.5	150.4	151	200	Unhealthy
150.5	250.4	201	300	Very Unhealthy
250.5	350.4	301	400	Hazardous
350.5	500.4	401	500	Hazardous

Fine particles $PM_{2.5}$ are called like that because their size is less than 2.5 micrometers in diameter. Due to their small size, they can be detected only with a very special microscope called "electron microscope." The sources of fine particles within the $PM_{2.5}$ category are combustion of motor vehicles, power plants, residential wood burning, forest fires and other industrial processes. [2a]

The formula given above provides an AQI of:

$$I = \frac{I_{high} - I_{low}}{C_{high} - C_{low}}(C - C_{low}) + I_{low}$$

I = (50 - 0)x12.0/(15.4 – 0) + 0

I = 39

Depending on the number obtained for the AQI, a color is assigned. A green color represents a good standing value for an AQI range of 0 to 50. A yellow color is considered moderate for an AQI range of 51 to 100. Orange is in the range of 101 to 150 as "Unhealthy for sensitive groups." Between the values of 151 to 200, in red color, is considered unhealthy. From 201 to 300, with purple color is considered "very unhealthy." From 301 to 500 in brown color is considered hazardous. See table below. [2b]

For our example, the result of the AQI is 39 and, therefore, it is placed under the green color category of safe.

Air Quality Index (AQI) Values	Levels of Health Concern	Colors
When the AQI is in this range:	*..air quality conditions are:*	*...as symbolized by this color:*
0-50	Good	Green
51-100	Moderate	Yellow
101-150	Unhealthy for Sensitive Groups	Orange
151 to 200	Unhealthy	Red
201 to 300	Very Unhealthy	Purple
301 to 500	Hazardous	Maroon

I hope to persuade students that conserving our environment is very important. How much can mother earth take from careless people who keep using the resources without looking at the consequences? It is true that the use of certain resources is a great commodity for most of us; and a large part of our society is not willing to let it go that easily. Echo-friendly organizations are trying their best to educate the population to use less resources thinking about the future. Electric and hybrid cars, solar energy, as well as air pollution and car emissions data are just the result of many years of scientific research. We, **"*The clients,*"** should be aware that we are using resources that in the past were thought to be impossible to of run out of. Now these days, the expression "*impossible to of run out of*," is not true any longer.

At the beginning of my writing, I was very excited (following media advertisement), that finally, the consumption of oil was going to stop or at least to decrease. In the bright moment of my thinking, I believed that it was just a matter of disseminating the information among the news, schools, and government agencies. I would include as well close friends and family members, who are the hardest to convince.

After doing my research, I found out other information that was not mentioned to me at the beginning of the writing.

Polluted land, contaminated water, improper exploitation of resources, along with improper treatment of toxic waste are the new components of my unit.

New words and expressions for the vocabulary of my science background is piling up. For instance, fracking or hydraulic fracturing, strip mining, sludge, and shale are just part of my new knowledge. I am sure that the lexicon of this unit will continue increasing.

Strip mining and sludge need to be described/ defined before continuing with the narrative. Strip mining is a type of mining done on the surface of a land where several layers of rocks and soil may be found and removed. Sludge is a set of residual of semisolid materials from industrial wastewater or sewage treatment.

2.5 The Conga Project

During a visit to Peru, while doing my research on natural gas, I looked at some of the consequences of extracting natural gas. The land, including rocks, has to be drilled vertically for about 1.5 miles. Some chemicals are added to the water in the area and the mixture is place in the land. The chemicals will soften the soil and the rocks. After the vertical drill, a deep horizontal drilling is done as well, in order to break some of the structures and release the pressured gas. Of course, the chemicals added don't go away. The residuals composed of acid chemicals will stay in the land. See Figure-1.

Suddenly, the land has suffered a severe condition of pollution. The problem does not stay there. Because of the slope of the land, all the pollutants contained in just that particular place, will be flashed down the hill, being mixed with land that was not polluted. Furthermore, the rain will wash the pollutants down to rivers and the pollution just got expanded. A similar exact problem occurs in the mines. One can imagine the consequences of the pollutants in the water. The people who have been living a healthy life may become ill. In this particular place in Cajamarca, Peru; for the last 25 years, the town has been suffering without drinkable water and without electricity. Currently, there are protests from the population who is asking to have part of the earnings dedicated to offer better services, construct hospitals, schools and provide the houses with water and electricity. It is important to mention that the extracting company pays 30% of their earnings to the central government, but the towns do not really see any progress for them.

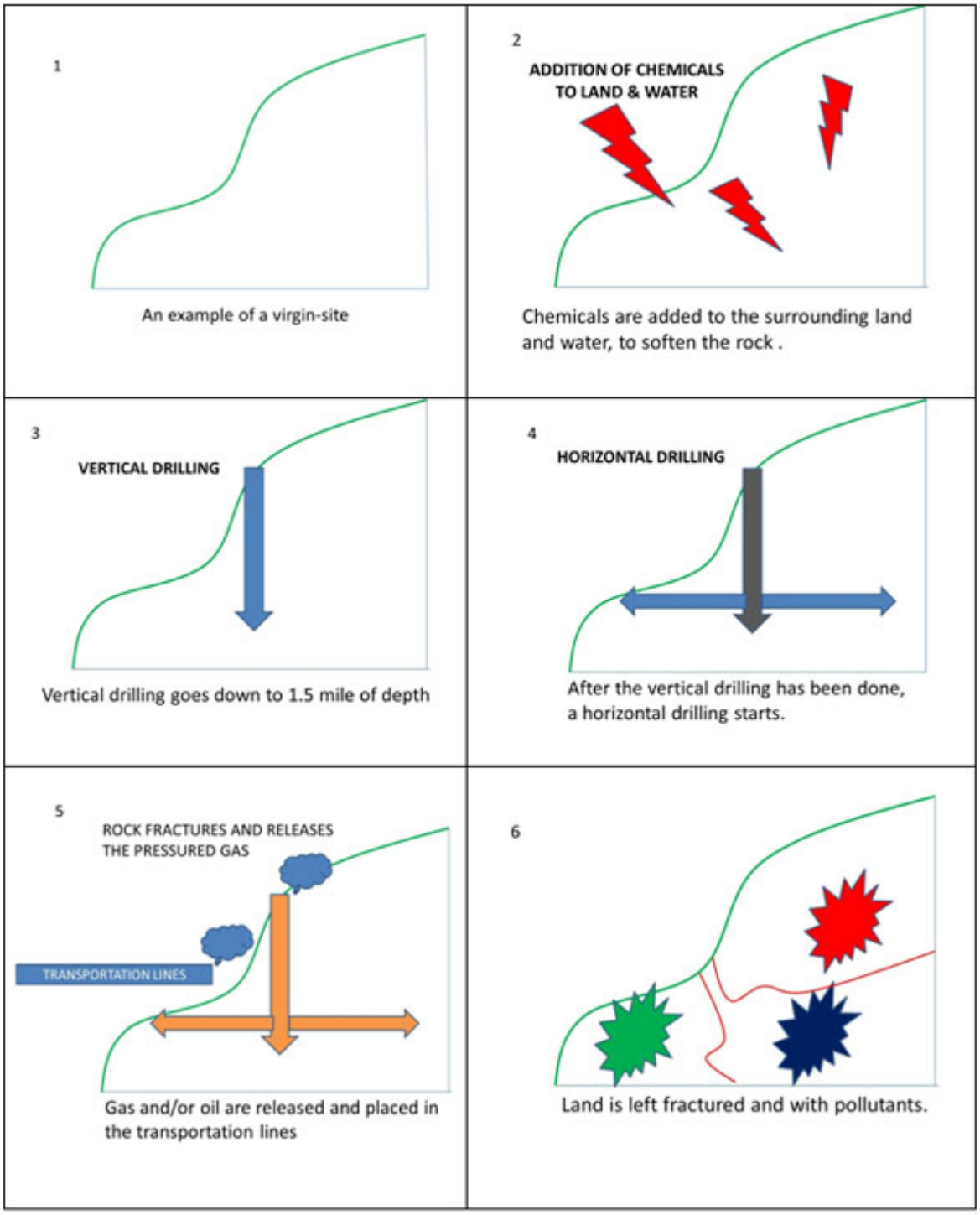


FIGURE-1

Transportation lines are the tubes set close to the fracking station to transport the gas or the oil extracted. They are part of a pipeline network.

The reason, for which I am including this information about Conga Project in this unit, is because I believe that the general public has to know that on one hand natural gas vehicles are cleaner, but on the other hand, the extraction of natural gas creates pollution. It is important to mention as well that although battery operated vehicles seemed to be the solution to the consumption of oil, the use of Lithium for the batteries are also

raising concerns on the extraction of Lithium from the mines. At the end, I believe that we will need to make a choice and pick the least dangerous option, but keeping in mind that there must be a land-remediation process for the land that has been used for mining or gas extraction purposes. For instance, one way to remediate the polluted land is to use sludge combined with wood chips to fill-in the emptiness of a polluted natural gas land or a stripped mine mountain. The application of this remediation actually fits perfectly. However, legislation and politics, along with ignorance on the topic makes it difficult to apply.

3. Background about Natural Gas & the Conversion Process

The political impact and decision-making of agencies, banks and corporations are rapidly changing the approach of conversions of cars in order to let the new era of natural gas start. Attractive loans that are re-paid with the own use of the natural gas are being offered. In other words, the converted cars are loaded with a "smart" microchip that is able to discern if the car is authorized or not to be refilled. Every time that the tank is filled, a portion of the cost paid goes to the loan.

Some of the natural gas companies are owned by the same gasoline companies. Others are new in the business that seems to be very promising.

Central and local governments regulate the conversion process of gasoline motors to natural gas. The laws are now very clear on what to expect. To provide more information, the conversion companies use all the advertising available, but the government has its own informational website too.

A few years ago, the numbers of stations with natural gas were very limited, but in the last 3 years their number has increased rapidly. At the same time the number of conversion shops and the amount of cars converted has increased too. On one side, using natural gas helps the environment with reduced emissions, but on the other hand, the extraction process leaves a bad impression of destruction and pollution of the natural resources. It is this part that has to be evaluated, taking under consideration all pros and cons.

With the rising prices of oil and with several nations at war, a new source of energy is needed. The so called renewable sources are not in a secure list as "renewable" any longer. Similarly, the melting ice due to the global warming, was supposed to stay forever; well, the definition of "forever" I guess has changed.

3.1 Air Pollutants

Several things and our own actions that we are not aware of are causing serious changes in the environment. Using perfumes, drinking bottled water, driving instead of walking / biking, ladies make-up, packaging and transporting foods, cutting trees to construct houses, burning the garbage in a metal cylinder in the backyard, leaving the faucet open when is not needed, longer than needed time in the shower, the abusive use of electricity in a "taken for granted" status, the unnecessary purchase of new clothes when the old ones are still usable, the use of detergent, aromatherapy, the use of pesticides, hormonally active chemicals in our daily diet, genetically engineered products, may explain many illnesses in society. What type of legacy are we going to leave for our future generations? You might focus this paragraph on air pollutants for cohesion.

3.2 Looking for a Solution: Natural Gas Vehicles

After comparing the average emissions rates in the United States between natural gas, oil and coal, a big impression is left that the source that causes the least damage to earth is the use of natural gas. The comparative table presented below shows this analysis. [3]

	EMISSIONS (in lb/MWh)		
	Carbon dioxide	Sulfur dioxide	Nitrogen oxides
Natural gas	1135	0.1	1.7
Coal	2249	13	6
Oil	1672	12	4

Looking at the above table and asking the question, which of the three combustibles produces fewer emissions, the answer will be obvious. Given the numbers, students can produce a graph-bar or a similar visual tool to explain the amount of emissions per each one. Furthermore, the data is so strong, that the first obvious questions from the audience would be: "Why don't we have more natural gas operated vehicles in the US? However, on the other hand, there is not a presentation of the emissions caused to produce each of the above mentioned combustibles; but at the end, assuming an equitable and well managed extraction processes, the industry of natural gas will continue its growth.

Let's take a look to the consumption of natural gas in California and where it is coming from.

Out of the natural gas used in California, 13.5% is obtained in state, 23.5% from Canada, 23% from the Rocky Mountains and 40% from Southwest. See figure-2

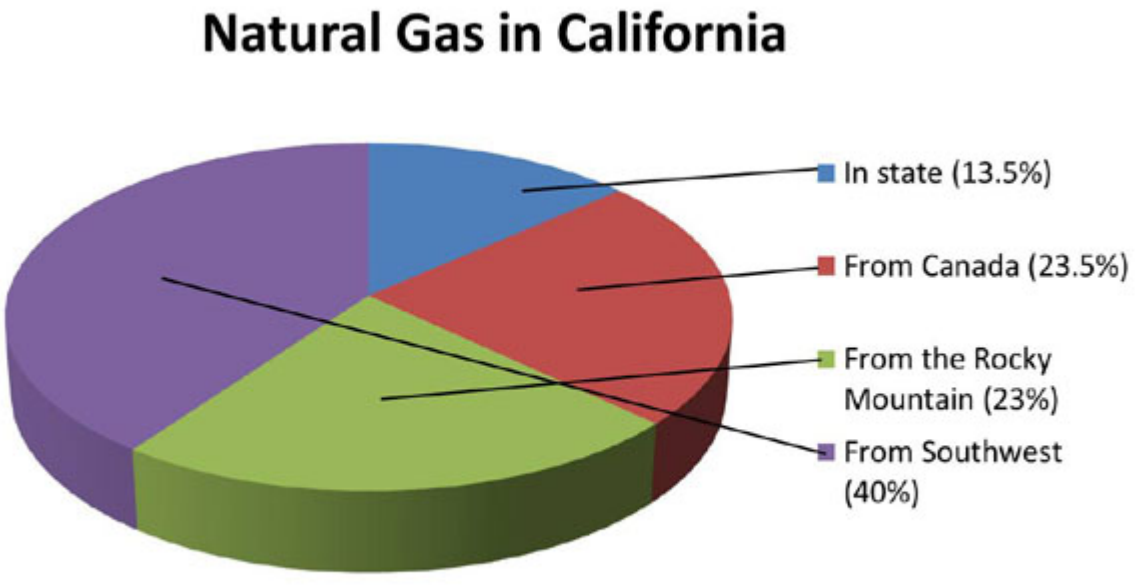


Figure -2

Natural gas Vehicles in Peru

In Peru, the cost of gasoline is approximately $3.00 US in average, while the price of equivalent amount of natural gas is around $0.50 to $1.00 US. These numbers were found during my research in Peru and the comparison of prices is related to the same efficiency per gallon and per mile of usage.

Economically, using natural gas seems as the best alternative with fewer emissions than its counterparts Diesel and gasoline.

GNV is a popular acronym used in Peru for "*Gas Natural Vehicular*" that means Natural Gas for Vehicles. In US is called "Compressed Natural Gas," (CNG). Several places offer the so called "conversion" of a motor using gasoline to the same motor using GNV. The process of adaptation takes a few hours, adding a tank to hold natural gas and keeping the original tank that uses gas. Therefore, the car could use just gasoline at any time. The experts suggest that the car should start the ignition with gasoline, and after warming up, changing it to GNV with a switch. The newest version has an automatic internal switch that transfers the source of energy from gasoline to natural gas.

Cars with motors have been originally created to use gasoline, and the use of GNV, makes it easy for the motor to deteriorate with the accumulation of residuals from the combustion of the gas. Due to this fact, another suggestion from the experts is that the motor should be checked every 6 months to change the "automatic transferring valve" to continue with the smoothness of the ride. Not doing so implies that the motor will be shutting down continuously, causing a possible deterioration of the starter.

As a positive consequence for our environment, there are fewer contaminants emitted, benefitting air quality. I want to add that after a long time, Lima that had the worst air pollution in South America, given the number of cars using gasoline and diesel, or straight petroleum, has improved its air quality significantly. This is due to the enormous amount of vehicles using GNV.

In the 70's, Peru had vehicles using just gasoline. Many transportation agencies started changing to a new diesel burning engines. In those years, the comparison of prices was 10 soles ($1US) for a gallon of gasoline and only 50 centavos ($0.05US) for a gallon of petroleum. The savings were great but the downside was a negative effect in the environment, not well known in Peru in those days. However, the prevalence of lung diseases increased, and the facades of buildings turned dirty quickly due to the emissions. The houses that had their windows open to receive fresh air, were often seen by their tenants with a lot of black powder on their floors, table clothes, laundry and inclusive their plate of food. Many believed that petroleum was the best fuel choice, misunderstanding the particles and gases emitted. Campaigns from echo friendly agencies induced the government to mandate schools to teach about pollution. Now, after 40 years, the city of Lima has begun a new clean era using GNV. I am personally a witness of these facts.

3.3 The Conversion Process

It was very interesting to see the pipes added to the car I happened to observe for my research in Peru. They were very similar, if not the same, as the ones used in the houses in the USA for the use of gas in the stoves and heaters. The pipes were accompanied by a pressure meter (barometer) that looked like a clock. I have seen this type of barometer in some propane stoves. See figure-3.

The gas companies have rapidly increased the number of stations that offer GNV. They have a sophisticated equipment to measure the pressure of the GNV in the tank, to calculate if it is full or not and to predict how

much money would take to fill up the tank.

The government has given all possible facilities to the common individuals to make the changes in their personal vehicles. There are banks currently lending money with very low interest specifically to change to GNV. In addition, to absorb the cost of the conversion, COFIDE (Financial Development Corporation) has created a system where the expensive conversion process is paid with the consumption. In other words, every time the tank is refilled, a portion of the amount paid goes to pay the debt. This is controlled by an electronic device installed in the car and, only authorized stations can refill the tank of an authorized vehicle.

Figure-3

The cost of the change is 4,000 soles (around $1,700US). There are certain makes that offer cars that come from the factory with a motor ready to use GNV, such as Hyundai, Toyota and Nissan. Most universities and technical institutions in Peru are offering GNV instruction in their curriculum, having a new generation of engineers ready to create new versions of GNV cars, with the intention of increasing the efficiency of the use of natural gas. On the other hand, the benefit of the conversions provides a positive outcome to public health. This outcome however is continuously under study.

The number of conversions in Peru since 2006 to 2009 is illustrated in figure-4.

To give an idea of the difference in the amount of emissions between natural gas and gasoline operated vehicles, the US Department of Energy shows on its website the following:

"Natural gas emits approximately 6% to 11% lower levels of GHGs than gasoline

throughout the fuel life cycle." [3a]

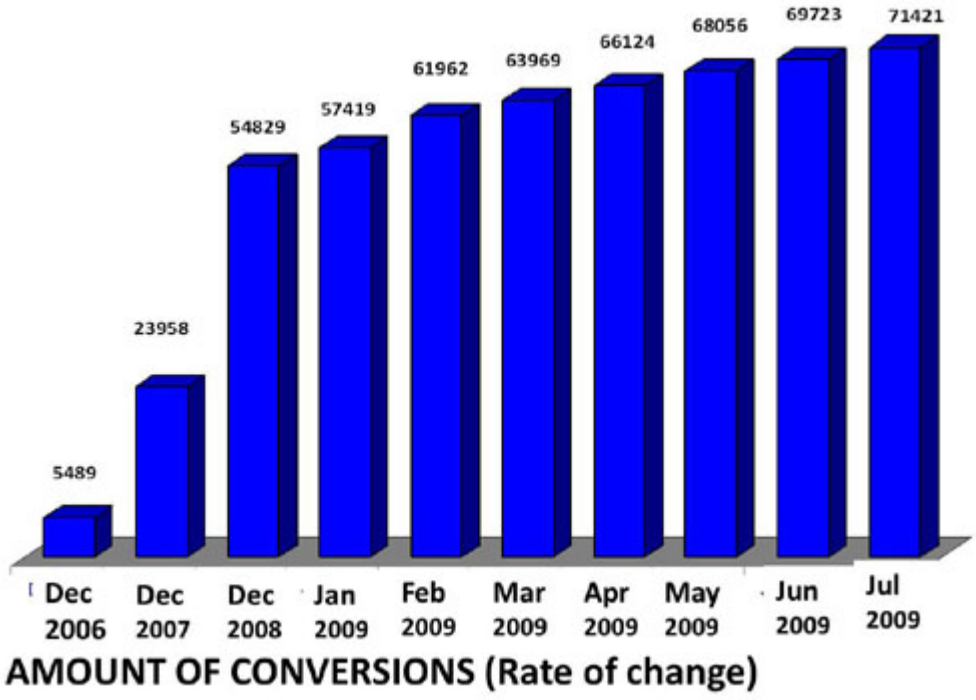


Figure-4

On the other hand, the EPA has a calculator to find the amount of emissions per mile, per combustible type, which is recommended to access for further information. [3b]

GLP is the acronym for "*Gas Licuado de Petróleo*," that means Petroleum Blended Gas, which is very close to the term "Liquefied." For a while, GLP became very popular, because it was cheaper than gasoline and with fewer emissions than petroleum. It became the substitute of petroleum in Peru. However, although is also gas, there is a process to use regular oil to convert it into GLP. It is this process that creates pollution at a different level, plus the cost of the labor and chemical processors to make the change. Therefore, given that GNV appears in a natural stage, and, because it produces fewer emissions than GLP, it becomes the cleanest combustible to use for cars.

The cost of processing petroleum to convert it to GLP is just half of the cost of processing petroleum to convert it into gasoline. The amount of emissions from GLP is fewer than from gasoline. However, the cost of production of GNV is less than the cost of producing GLP. At the same time, GNV produces fewer emissions than GLP. Comparing these facts, it is obvious that there is a big tendency to change from gasoline, petroleum or GLP to GNV. As a matter of fact, the car that I observed for my research, initially had been converted from gasoline to GLP, but it was at the shop, in the process to be converted to GNV. The conversion process took a few hours and at the end, it was suggested to leave the car for two to three days in the shop for further tests. After this period of time, it was recommended to ride the car smoothly for a few more days. Another suggestion was to let it warm up a few minutes to allow the automatic change from gasoline to GNV. Rewrite this paragraph for greater clarity; I'm not sure what you mean.

4. Lesson Plans

Lesson plans are divided in two categories, according to the level of difficulty. One level is directed to Algebra-1 students, with applications of linear functions and systems of equations. The manipulation of variables in some formulas is also included. The lessons for Algebra-1 can be easily adjusted for a 7 th and 8 th grade math classes as well as a Geometry class, given that the word problems involve area and volume.

The second category is devoted to Algebra-2 and they could be used as well in Pre-Calculus and Trigonometry/Math Analysis. This second category includes lessons using linear, quadratic, rational and exponential functions. Graphing is a very important skill to master in order to continue to more advanced math classes; therefore, the interpretation of a graph in a real life situation is also very important to master. The word problems chosen to illustrate one of the aspects of pollution include Mathematical Reasoning, which is mentioned in the Common Core Standards for High School Math. [4]

Lesson Plan-1: Introduction of Curriculum Unit

Math Level: Algebra-1 & Algebra-2

Content Standards: California Content standards 5, 7, 9, and 16 are addressed in this lesson. These standards are related to solving word problems with equations, graphing lines and linear functions. [4a]

Learning Goals: Relating the danger of pollution, health complications, fracking and the consumption energy.

Prior Learning & Anticipatory Set

Students are familiar with the rising prices of gasoline, but are not aware of the extraction process and the pollution created as a collateral damage. Students will be in groups of 4.

Instructional Strategies

Warm-up for 5 to 10 minutes introducing new vocabulary used in the context of pollution.

A video called "Pollution for Morality" [5] will be shown in class for 4 minutes.

Group Work

Discussion about the consequences of pollution will be done within their groups for 5 to 10 minutes. Groups need to come up with 2 main ideas that they noticed were damaging the environment and 2 ideas on how can they quantify the damage. In other words, how can they use math to find the magnitude of the damage.

Sharing / Assessment

Groups will prepare a poster indicating their 2 main ideas about the information seen on the video and their 2 ideas on how can they use math to measure the problem.

Closure

In a video that is about 3:33 minutes in length, CNN explains what fracking is. The remaining of the time will

be devoted to discuss the video. [6]

Vocabulary (Language Objective for English Learners)

A list of unknown words will be created to help students understand the lesson. For instance, the words "Carcinogen," "Shale," and the phrase "Hydraulic Fracturing" are good examples of the new vocabulary.

Lesson Plan-2

Math Level: Algebra-1 & Algebra-2

Content Standards: California Content standards 5, 7, 9, and 16. These standards are related to solving word problems with equations, graphing lines and linear functions. [4]

Learning Goals: At the end of this lesson students will be able to analyze and solve word problems applying algebraic concepts of linear functions in a real life situation, as well as to calculate volume as a function of the variable radius, with a constant thickness.

Prior Learning & Anticipatory set

Students are familiar with working with variables and formulas as well as the concepts of functions and solving equations and, what they have heard in the news about oil spill. They will be in groups of 4.

Instructional Strategies:

Warm-up for 5 to 8 minutes with review of prior learning experiences, such as solving equations, calculation of volume of a cylinder and linear functions.

"Marine Pollution" video will be presented for 4:29 minutes [5a] showing the real life problem.

After the video, I will devote 5 minutes for comments and questions as whole class.

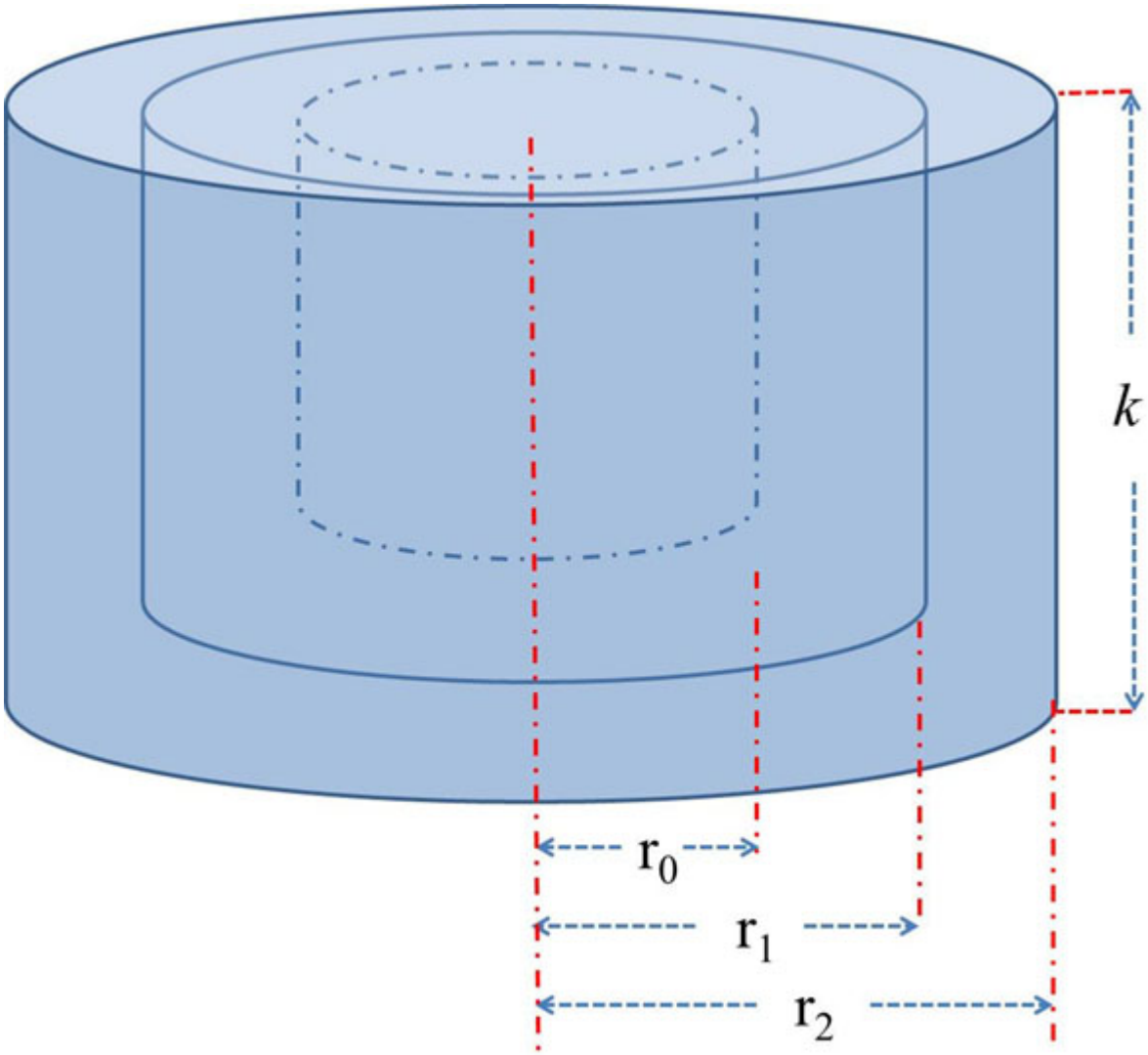
After the comments, a real life problem will be given to each group. The problem is the same, but the numbers may be different at the discretion of the teacher. This activity will take 10 to 12 minutes.

The problem: Oil Pollution

An oil slick spreads evenly in the ocean, in all directions from a ruptured tube (the central point) and it tends to be circular with a radius "y," which changes constantly as a linear function of time. The thickness of the slick is a constant $k = 0.023$ meters. The radius of the slick after 1 day is 140 meters and after 2 days is 260 meters.

Question-1: What would be the volume of the slick after one week?

Question-2: What is the radius of the ruptured tube?



Solution

A linear function can be written as the model $y = mx + b$, where ***y*** represents the radius of the slick and ***x*** represents the time in days.

The information given provides two points (1, 140) and (2, 260), which are going to be substituted in the linear function model to obtain a system of two equations as follows:

$y = mx + b$

$260 = m(2) + b$

$140 = m(1) + b$

After solving the system of equations, it is obtained that m = 120 and b = 20; therefore the linear function is $y = 120x + 20$

To answer question 1, the number of days would be $x = 7$. With this value we can find the radius y and, therefore, the volume of the slick after 7 days, using the formula for the volume of a cylinder V = 0.023?? r^2

The radius is y = 120 (7) + 20. After simplifying, y = 860 meters. This result will be substituted as follows:

$V = 0.023 (3.14)(860)^2$

$V = 53,413.912 \text{ m}^3$

To answer question 2, the constant b from the linear function represents the y-intercept of the line, which is the starting value of the radius of the slick. As a consequence, the radius of the tube would be 20 meters.

Closure

Each group will share on a poster, how they found their answer. If the problems have different numbers, it would allow finding a pattern in the solution of the problem. If the numbers are the same we can focus in looking at the different ways students approached the problem. Also, discussions about the consequences on the environment where the slick happened and similarities to the already well known cases of oil spill.

Vocabulary (Language Objective for English Learners)

Examples of words that might be new for English Learners are, slick, thickness, ruptured,

Lesson Plan-3

For this lesson, the approach would be exactly the same as lesson plan-2, but it will be directed to Algebra-2 and Pre-calculus students.

The problem: Oil Pollution

An oil slick spreads evenly in the ocean, in all directions from a ruptured tube (the central point) and it tends to be circular with a radius "y," which changes constantly as a quadratic function of time. The thickness of the slick is a constant k = 0.023 meters. The radius of the slick after 1 hour is 15 meters, after 2 hours is 24 meters and after 3 hours is 37 m.

Question-1: What would be the volume of the slick after 10 hours?

Question-2: What is the radius of the ruptured tube?

Answers: $V = 4,159.87 \text{ m}^3$ and radius r = 10m

The above problem can also be adjusted to use exponential equations instead of a quadratic model.

Lesson Plan-4

Math Level: Algebra-2 / Pre-Calculus

Content Standards: California Content standard 12 and 15. These standards are related to solving word problems with exponential functions. [7]

Learning Goals: At the end of this lesson students will be able to analyze data given with a graph, applying algebraic concepts of exponential and quadratic functions in a real life situation.

Prior Learning & Anticipatory set

Students are familiar with exponential and quadratic models, solving equations involving one of these concepts. They will be in groups of 4.

Instructional Strategies:

Warm-up for 5 to 8 minutes with review of prior learning experiences, such as solving equations with a model and points that belong to the given model.

"CNG Conversion" video will be presented for 5 to 15 minutes [8] showing how the process works.

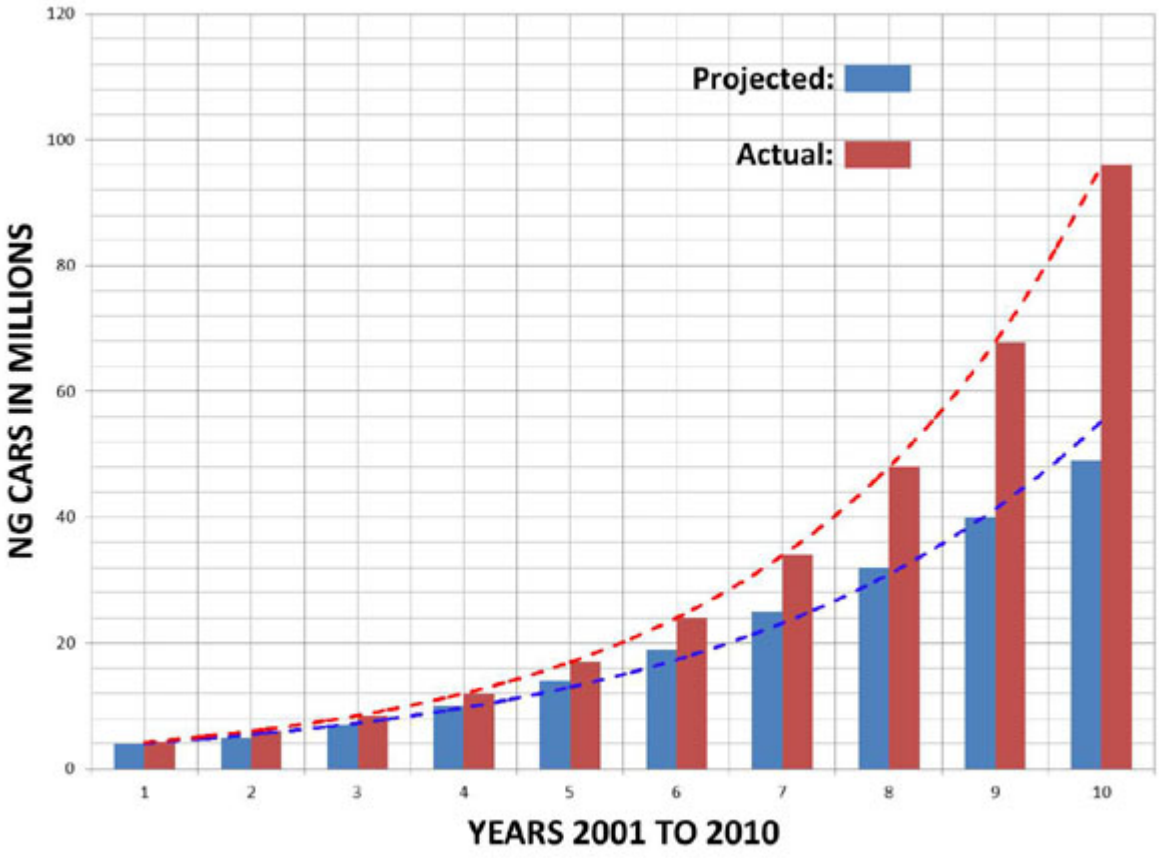
After the video, I will devote 5 minutes for comments and questions as whole class.

After the comments, a real life problem will be given to the groups. This activity will take 10 to 15 minutes.

The problem:

The number of natural gas converted vehicles between 2001 and 2010 is illustrated in the graph below. Blue color bars represent the projected outcome and the red bars represent the actual numbers. The graph uses curved blue and red trends to show the graph of the model.

Write the equation of best fit of the graph obtained with the actual numbers (red trend), knowing that it is of the form $y = a?b^{kx}$



Answer: One of the possible models is $y = 3 \times 2^{0.5x}$

Closure

Groups will compare their equations. Equations may differ, but should have similar numbers.

Language Objective for EL students

Projected vs. Actual, Acronyms CNG, NG,

Additional Problem

The average concentration of fine particles $PM_{2.5}$ is recorded in a monitor for a 24-hour period. The reading of the concentration on the monitor is 20.5 micrograms per cubic meter. What is the AQI? The table of breakpoints for $PM_{2.5}$ is given below.

C_{low}	C_{high}	I_{low}	I_{high}	Category
0	15.4	0	50	Good
15.5	40.4	51	100	Moderate
40.5	65.4	101	150	Unhealthy for Sensitive Groups
65.5	150.4	151	200	Unhealthy
150.5	250.4	201	300	Very Unhealthy
250.5	350.4	301	400	Hazardous
350.5	500.4	401	500	Hazardous

Solution

The value of the concentration "C" is 20.5, which is between 15.5 and 40.4. These two last numbers are the C_{low} and the C_{high} in the formula to calculate the AQI. The values of I_{low} and I_{high} are the corresponding numbers in the table.

$$I = \frac{I_{high} - I_{low}}{C_{high} - C_{low}}(C - C_{low}) + I_{low}$$

$I = (100 - 51)x(20.5 - 15.5)/(40.4 - 15.5) + 51$

$I = 60.84$

For this problem, the result of the AQI of 60.84 is under the yellow range, which is considered "moderate." The table appears above in section 2.4.

5. Bibliography for teachers

Overview of natural gas in California

http://energyalmanac.ca.gov/naturalgas/overview.html

Air pollution and lung diseases:

http://www.ehow.com/facts_6023469_air-pollution-lung-disease.html

Air Quality Index:

http://www.ask.com/wiki/Air_quality

Respiratory Illnesses

http://www.niehs.nih.gov/health/impacts/respiratory/

EPA resources for educators

http://www.epa.gov/climatechange/students/resources/index.html

6. Reading list for students

Answering questions about natural gas

http://www.energy.ca.gov/lng/faq.html

Air Quality in America:

http://www.webmd.com/asthma/news/20040429/air-pollution

Georgia and the Clean Air Act:

http://www.ehow.com/about_6390071_georgia-clean-air-act.html

Climate change

http://www.epa.gov/climatechange/students/index.html

7. List of materials for classroom use

Graphing calculator

Graph paper

Pencil

Color pens

Eraser

Internet access

Printer

Poster paper

Markers

Index cards

Endnotes

- [1] Air Pollution & Respiratory Disease
- http://www.niehs.nih.gov/health/impacts/respiratory/
- [2] Breakpoints for different pollutants
- http://www.epa.gov/airnow/aqi_tech_assistance.pdf
- [2a] Particle Pollution $PM_{2.5}$
- http://airnow.gov/index.cfm?action=aqibasics.particle
- [2b] Air Quality Index
- http://airnow.gov/index.cfm?action=aqibasics.aqi
- [3] Air emissions
- http://www.epa.gov/cleanenergy/energy-and-you/affect/air-emissions.html
- [3a] Comparison of emissions produced by natural gas and by gasoline
- http://www.afdc.energy.gov/vehicles/natural_gas_emissions.html
- [3b] Calculator of emissions
- http://www.epa.gov/cleanenergy/energy-resources/refs.html
- [4] Common Core Standards for Mathematics
- http://www.corestandards.org/the-standards/mathematics/high-school-algebra/reasoning-with-equations-and-inequalities/
- [4a] California Content Standards for Algebra-1
- http://aplusalgebra.com/california-algebra-standards.htm

- [5] Pollution Video for Morality
- http://www.youtube.com/watch?v=-rlp_0u1h8U
- [5a] Marine Pollution
- http://www.youtube.com/watch?v=YhcjbGdxBG8
- [6] CNN Explains what fracking is.
- http://www.youtube.com/watch?v=LAxsTJd7VCA&feature=fvwrel
- [7] California Content Standards for Algebra-II www.cde.ca.gov/ta/tg/sr/documents/algebraII1105.doc