COSMOS EDUCATION

Under African Skies Curriculum, 2004

Major Themes: Water-Health-Environment

Duration: Two, three hour sessions of educational material to be used in secondary school (high school) classrooms.

Format: Designed for hands-on activities in small groups of 10-25 students. Maximum total size should be 100 students so that the Cosmos team can provide 2 team members per group of ~20 students.

Curriculum Sequence

The following sections are for the entire group (100 students)

Introduction: Earth as Home

Introduce Cosmos Education, describe what we do and who we are – introduce team members.

Holding up globe, ask ‘What is this?’. Students will say, Globe, Earth, Planet, etc. ‘What is THIS!?’. Eventually say that it is HOME! Home to all of us and home to everyone we know, everyone we ever have known and probably everyone you ever will know. Earth is Home to all of humanity and we need to make sure that it is a safe, clean, and beautiful home for our generation and all the generations to come. We need to cooperate to take care of our Home. The future of our Home depends on the youth of today – you the students are the future! Ask them if they can and will work hard to make sure Earth is a safe, clean, and beautiful Home for their children and their children’s children. Ask them three times and make sure they yell loudly ‘Yes!’

Now explain that before we break into groups we have three easy rules to follow

Our Three Rules

Rule #1: *Slow Down*. We want to be sure that you understand what we are saying. Thus, if we are speaking to fast or you don’t understand what we are saying, tell us to ‘Slow Down’ (make the motion in the air with your hands and have the students repeat it). If you can, speak quickly after this to test them – they will probably laugh and make the sign for you to slow down.

Rule #2: *Ask Questions*, Rule number 2 is that you must ask questions! Science is about asking questions and it is through asking questions that you learn new things and make new discoveries. Asking questions is very important in life and it is the most important part of your education.

Rule #3: Have fun. The last and final rule is the most important. (Pause). It is very, very important and you must listen carefully. Rule number three is that you must Have FUN!. Can you do that?!? The students will say YES!

Now break into groups and go outside for the activities. Based on how many total students are in the entire group, break into groups so that there will be 2 instructors for every 10-20 students

After breaking the students and Cosmos team members into groups be sure to introduce yourself to the group. If the group is small, have the group go around and everyone say their name.

Inform the students that we are now going to be discussing three big topics: Water, Health, and the Environment. We will be doing activities to explore concepts related to these topics and it is important that everyone pay attention and cooperate.

To begin with, we are going to study WATER! Ask the students why water is important. Next ask them how much water is available for life on Earth.

Water is Where? How much potable water exist?

Objectives:

- To gives students an understanding of where water comes from and how it travels from place to place.
- To demonstrate to students that water is a precious resource.

Introduction:

All of the water on the earth today has been here for a very long time but cycles through the world. The basic water cycle can be described as follows. Water on the ground goes into the air through *evaporation* and *transpiration*. When the sun heats up, for example, rivers and lakes, some of the liquid water is transformed into water vapor and travels up into the air. Transpiration is the process by which plants lose water out of their leaves, which also helps to get water vapor back up into the air. Once in the air, water vapor will eventually turn back into liquid water and form into clouds when it gets cold enough. This is called *condensation*. When clouds become too heavy with water the water must fall back to earth in the form of rain, hail, sleet, or snow, all of which are called *precipitation*. Back on land water is ready to start the whole process over again.

It is important to know that water also percolates into the ground traveling down through the soil and onto the water table. It is able to move back up to the surface through capillary action or it can move vertically/horizontally under the earth's surface until it reaches a surface water system like a lake or a river. Rather than percolating under ground, water can also merely run overland into streams and lakes.

Discuss with students some of the important regional bodies and water. For example:

- Lake Victoria (Kenya and Tanzania): Second largest freshwater lake in the world and largest tropical lake; covers 67,850 square kilometers (size of Ireland!); shared by Kenya, Tanzania, and Uganda; forms headwaters of the River Nile. Recent problems: chemicals from nearby cash crops like tea, coffee, and sugar plantations; industrial waste and untreated sewage entering from nearby rivers; proliferation of water hyacinth (blocks sunlight for organisms below and depletes oxygen levels)
- Indian Ocean (Kenya and Tanzania)
- Lake Tanganyika (Tanzania and Zambia)
- Zambia: Zambezi River, Lake Kariba, Lake Bangweulu, Lake Mweru
- Tanzania: Lake Nyasa, Rufiji River
- Kenya: Lake Rudolf

Usable Water

Objective:

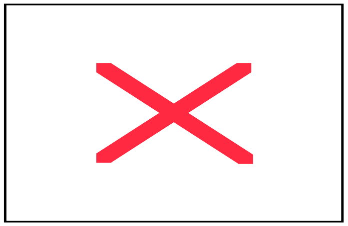
- To show students how little of the earth's water we actually have access to.

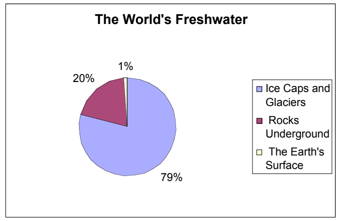
Materials:

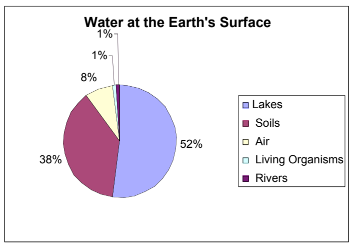
- A large bucket (approximately 5 gallons or 19-20 litres)
- A smaller bottle (For example, cut off the top of a larger plastic bottle to get something with capacity for approximately 600ml)
- A very small container (with capacity for approximately 6ml)

Procedure:

- Begin with the large bucket/container full of water. Explain to the class that this represents all of the water in the world. Ask the students about the different kinds of water in the world. Highlight the distinction between freshwater and salt water. Then explain that 97% of the water in the world exist in oceans. This is salt water that we cannot consume and which is very expensive to desalinize. Show the students how much of the large bucket of the world's water represents freshwater. To do this, pour from the bucket into the 600ml container. Now the 600ml container represents all of the freshwater in the world. Students should be impressed by how little this is in comparison to the bucket.
- Proceed from the 600ml container of water to discuss where freshwater can be found on the earth. Explain to students that a lot of the freshwater is actually found in ice caps and glaciers or in rocks underground. These sources of freshwater can also be difficult to access. Tell students that the amount of freshwater that actually exists on the earth's surface is only 1% of the 600ml container. In other words, the freshwater available for us to use is only 1% of 3% of the total amount of water on Earth – this is the same as saying that the total available water is only 0.03% of the total water. That would be like having 3333 Kwacha, Shillings, or Dollars and only being able to use 1 of them. Or like having 1 million Kwacha, Shilling, or Dollars and only being able to use 300 of them. Have them visualize this by pouring water from the 600ml container into a 6ml container. Again, students should be impressed by how little water there is available on the earth's surface.
- Now proceed from the 6ml container and discuss with students places on the earth's surface where we can find water. This should include things like lakes, soils, air, living organisms, and rivers. Show the students that of the 6ml container about half of it is in lakes, 2/5 in soils, and only a few drops of the water are in rivers and living organisms.







Water in Your Life

Objectives:

- To get students to brainstorm why water is important to them in their lives.
- To allow students to begin to see the importance of caring for water.
- To empower students to take care of themselves.

Introduction:

Begin by having students brainstorm what humans use water for. This list might include: hydration of humans and animals, growth of plants, agriculture, irrigation, hygienic purposes e.g. bathing and washing hands, cooling down, hydroelectricity (accounts for 20% of electricity in the world), and steam power.

Water & Agriculture:

70% of the fresh water drawn is used for agricultural purposes. However, lots of water used for irrigation lost through evaporation. This is why it can be important to water crops at night and use drip irrigation. The stomata can open and close to control how much water the plant loses. Even so a large plant with a lot of leaves may transpire a large amount of water every day, especially if the weather is hot, dry and windy. Water absorbed by the roots must replace all the water lost. The amount of water used by a plant depends on its type, how much light it gets, and how old it is. A mature house plant can transpire its body weight every day. If people needed that much water, an adult would drink 20 gallons of water a day

Table 3: CROP WATER NEEDS IN PEAK PERIOD OF VARIOUS FIELD CROPS AS COMPARED TO STANDARD GRASS

-30%	**-10%**	**same as standard grass**	**+ 10%**	**+20%**
citrus	cucumber	carrots	beans	paddy rice
olives	radishes	onions	maize	sugarcane
grapes	squash	peanuts	tomato	banana
		spinach	potatoes	nuts & fruit trees with cover crop
		tea	sunflower	
		grass	wheat	
		coffee		

Water Pollution:

Causes of pollution include untreated sewage, agricultural chemicals, and livestock waste. Groundwater can be contaminated by salt water and other bad things seeping into the soil.

Water & Health:

Water is essential for human survival. It is also essential, however, that water used for consumption is clean water. 80% of diseases in developing nations are estimated to be water related. There are many diseases that are *water-borne* such as cholera, typhoid, and infectious hepatitis. There are also many diseases associated with *poor hygiene*, such as bacillary dysentery, enteroviral diarrhea, paratyphoid fever, and typhus. Finally, there are diseases related to *inadequate sanitation* such as hookworm. Remember, it is not water itself which is bad, but the contaminants (such as bacteria and viruses) within the water that can be extremely dangerous. This is why it is important to both filter water (get out gross stuff you can see) and purify water (kill bad stuff you cannot see) before consumption. It is also why it is important to have good habits like washing your hands before eating, washing your hands after using the toilet, and before preparing food.

What is Water? Water and Its Properties

Objectives:

- To introduce students to the atomic and molecular level of matter.
- To help students understand the various properties of water so they can later understand the various consequences of these properties.

Introduction:

What is *WATER*?!?

Get the students to provide answers to this question. They can raise their hands or if it is a small enough group they can call out their ideas. Some of the answers might be: a liquid, wet, an ocean,…and perhaps a few students might say H_2O. Be sure to support all the answers given and tell the students 'good idea'. Eventually you want to focus on the answer of: *Water is H_2O!*

The most scientific definition for water is: Water is H_2O! What does this mean?

Ask students if they have ever heard of H_2O and then ask them why water is called H_2O. Each water molecule is made up of two atoms of hydrogen and one oxygen atom, yielding the name H_2O. Ask the students if they have heard of molecules. What about atoms? Introduce students to the concept of atoms and molecules. Atoms are the fundamental building blocks for everything around us. Tell them that thousands of years ago, people in Greece thought that if you took something (say a piece of chalk) and kept cutting it in half, eventually you would come to a piece that could not be cut. They called it an "atom". The reason is that in Greek (the language of the Greeks) "A" means not, and "TOM" means cut. A-TOM means a thing which cannot be cut.

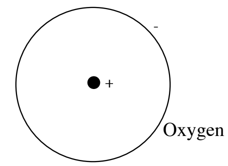
Amazingly, they were almost right and the smallest piece of an element is called an atom. Some Atoms like to join with other Atoms. When this happens, they make a molecule.

<u>Demo:</u>

- Have some paper hats ready. 2 marked with the letter 'O'. Call for two helpers. Give them each a hat to wear.
- Stand them apart from one another. Tell the students that each of these helpers is an atom of Oxygen. Make them repeat it. Now remind them that some atoms like to join together.
- Tell them that Oxygen likes to make 2 joins.
- Ask the helpers to raise both hands and open and close their fists. Tell them that each Oxygen Atom is now ready to make two joins (or bonds). Now get the helpers to join hands with each other (ask the students to shout "bang" as each hand is joined.) They have now formed an Oxygen Molecule. Tell the students that the two Oxygen Atoms have made one Oxygen Molecule. (Get them to repeat it!)
- Thank the helpers and ask them to resume their seats.

Introduce students to the concept of the size of atoms and molecules. We cannot see atoms with our own eyes, in fact atoms are so tiny that if an orange were the size of the Earth, then the atoms of the orange would be the size of something very small, like a cherry or a grape (or the seed of a mbera? Assuming a 6cm diameter orange, anything about 1cm across will be fine)…i.e. a magnified picture of the atoms in an orange would reveal billions of "somethings" tightly packed into a globe the size of the Earth. In the center of each atom is a nucleus containing positively charged protons (+). Electrons (-), which are negatively charged, fly around the outside and it is often through the sharing of electrons that atoms are able to form bonds with other atoms and make molecules.

Drawing a picture at this point will help if you have a blackboard or some dirt to sketch in, or a piece of rope:



The atoms combine in millions of different ways, making millions of different kinds of molecules and forming everything around us – people, plants, rocks, petrol, the air, and everything else, including you!

Remind the students why water is called H_2O.

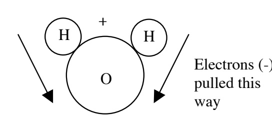
<u>Demo:</u>

- Call up three volunteers – preferably one tall and two short. Have 3 hats or necklaces prepared – one marked 'O' and two marked 'H'.
- Give the hats/necklaces to the helpers with the O going to the taller student. Stand the students apart from one another and get the students to appreciate that they represent two Hydrogen Atoms and one Oxygen Atom.
- Remind them that Oxygen likes to make two joins (get the Oxygen Atom to open and close both hands). Now get the two Hydrogen Atoms to put one hand behind their backs and open and close the other. Tell the students that Hydrogen makes one bond.
- Now form H_2O getting the students to shout "bang" at each join being formed.
- Tell the students that this is a Molecule of Water. Stand the helpers so that they form a "V" shape and tell the students that this is the shape of a Water Molecule. Draw it on the board or ground for them.
- Thank the helpers and reseat them.

How are the atoms in water arranged? How do the two hydrogen atoms combine with the atom of oxygen?

Something special about the bonds inside a water molecule is the fact that the shared electrons are pulled closer to the oxygen atom than the hydrogen atoms. The oxygen nucleus is blanketed by the electrons, thus there is more negative charge around the oxygen part of the molecule. Meanwhile, the nuclei of the hydrogen atoms are exposed, and thus the positive charge of the protons makes these end of the molecule more positively charged.

Draw this for the students. Explain that when the Atoms join together they share their electrons. However the electrons are pulled towards the Oxygen.



So the oxygen end is more negative, and the hydrogen end is more positive. We call this property *polarity*. Water molecules are polar – they have positive charged regions and negatively charged regions.

Remind/Tell the students that positive things are pulled towards negative things. Draw some more water molecules around the one you've already got and in similar orientations. Explain that the positive end of one molecule of water is pulled towards the negative end of another. In other words, water molecules like to stick together.

This is a bit like the poles of a magnet. Magnets have a North and South pole and opposite poles like to stick to each other. The molecules of water have positive regions that like to stick to negative regions and negative regions that like to stick to positive regions. Thus, the molecules behave a bit like tiny magnets. They are constantly moving around sticking to each other, becoming unstuck, and then sticking to other molecules.

Remind the students that water molecules are made from (get them to tell you Hydrogen and Oxygen Atoms). Remind them that Atoms contain positive protons and negative electrons (as well as some things called neutrons but they don't need to know about that right now.) Remind them that H_2O is shaped like a 'V' and that the electrons are pulled towards the Oxygen so it is positive at one end and negative at the other.
Remind them that this makes the water molecules pull on each other.

This property of polarity is what causes *surface tension* – the apparent 'skin' on the surface of water. It is also important for *capillary action* – the way water moves through tiny tubes. In addition, polarity helps water to dissolve other substances. Water molecules use polarity to pull apart other molecules into positively and negatively charged particles, or ions. This also allows water to transfer nutrients into plants and animals.

Properties of Water: Surface Tension

Objectives:

- To demonstrate to students surface tension at work.
- To get students to start thinking about how surface tension applies in their life – i.e. how surface tension can be used as a tool for humans to get things done.

Water's Skin

Materials:

- Pan or dish
- Piece of wire, needle, or paperclip

Procedure:

- Bend the wire into a flat spiral and bend one end of the wire up to use as a place to hold the spiral. Carefully place the spiral on the top of the water in a glass. What happens? Why? The surface of the water bends around the weight of the paperclip like stretched rubber.

Explanation:

- This is because water has *surface tension*. The surface tension is strong enough to support the wire. If you are having trouble getting this to work, make sure your spiral shape is flat and that it wound so that there are only a few millimeters (about 5 or so) between each spiral.

Source: Newton's Apple <http://www.ktca.org/newtons/tryits/9/9scitry.html>

A Cloth Cap for Water

Materials:

- Clear glass or jar
- Water
- Handkerchief
- Rubber band

Procedure:

- Fill a glass three-quarters full with water. Place a handkerchief over the top of the glass and hold it on with a rubber band place around the rim of the glass. Push down on the center of the handkerchief until it touches the water (the experiment works best if the handkerchief is slightly wet). Keep your fingers pressed on the handkerchief and turn the glass upside down. The water will remain in the glass. Now, pull the handkerchief tight, so that the concave shape disappears. Observe the bubbles.

Explanation:

- Surface tension prevents the water from seeping through the handkerchief. Air is able to go into the glass because of the holes in the cloth, but the water is unable to escape because the strength of the surface tension is stronger than the force of the water trying to push through the tiny holes.
- When you straighten out the handkerchief, the water drops down to a new level, reducing the pressure in the air space at the "bottom" of the glass. The higher air pressure outside the glass forces air to penetrate the handkerchief and bubble through the water.
- Note that if the water is very hot, then the surface tension is reduced. This is because the molecules in hot water are moving around very quickly – they have a lot of energy. As a result, the bonds from polarity (the magnet-like bonds) break easier and thus the surface tension is reduced.
- Adding soap to the water also reduces the surface tension because now some of the water molecules are attached to soap molecules and thus there are not as many water molecules available to make a strong bonded surface layer. In other words, the surface tension is reduced.

Source: Newton's Apple <http://www.ktca.org/newtons/tryits/9/9scitry.html>

Charged Stream and Surface Tension Trick

Materials:
- Nail or thumbtack
- Tin can/Plastic jar
- Water

Procedure:
- Use a nail to make three to five holes 5 mm apart very near the bottom of a tin can or a hot nail to melt hole in the bottom of a plastic jar.. Fill the can with water and watch the water coming out of the can in five streams. Pinch the jets of water together with your thumb and forefinger to make the five streams into one. If you brush your hand across the holes in the can the water will start to flow in five separate streams again.

Explanation:
- You are able to pinch the jets of water together because of surface tension! Once the streams are joined they stay together because the surface layer around the stream holds them together.
- As an additional experiment you can take a comb, piece of plastic, or balloon and rub it in your hair or on a piece of dry cloth. You are trying to build up the static charge on the object. Next hold the object close to one of the streams and observe that the stream is attracted to the object. This is another demonstration of charge attraction. The object has extra electrons (you got them by rubbing with the cloth or in your hair), as a result the object is negatively charged and when you hold it next to the stream the positive regions in the water molecules (hydrogen atoms) are attracted to the object and the stream bends.

Source: UNESCO Sourcebook for Science Teaching (10).

Properties of Water: The universal solvent?

We have learned that water is a polar molecule, meaning that it has positively charged and negatively charged regions. Now we will explore how water mixes with some substances and not with others.

Optional activity: Bubbles, Bubbles, and More Bubbles

Objectives:
- To observe how films of soap form shapes on different surfaces

Materials:
- 1-3 small buckets of water and soap, good for blowing bubbles
- Wire for making bubble blowing shapes (Approximately 30 cm per student)

Procedure:
- Give each of the students a piece of wire and tell them to bend it into a loop of any shape.
- Dip the shape into the soap and see how a soap film fills the surface

Explanation:
- The soap film creates a surface of minimum energy and thus of minimum area. This is also why bubbles are round.

Activity: Soap and Surface Tension

Objectives:
- To show how soap affects the surface of water.

Materials:
- Two dish plates
- Thread
- Talc powder or pepper
- Liquid soap or strong soap solution made by dissolving soap chips in water.
- Water

Procedure:
- Pour water into the dish and once it has settled gently sprinkle talc or pepper on the surface in order to make the surface film easily visible,
- Touch a piece of soap to the edge of the water and observe how the layer of talc or pepper responds

Explanation:
- Soap molecules reduce the surface tension in the area touched by the soap and as a result the surface layer ‘skin’ over the rest of the dish contracts away from the area touched by the soap.
- Now try the same trick except this time instead of using talc on the surface, make a loop of thread and touch the soap to the inside of the loop.

Activity: Soap and Fat

Objectives:
- To show students the importance of soap and why it works.
- To show that not all liquids can be mixed (e.g. polar and non-polar liquids)
- To demonstrate how soap can help make water and oil mix.

Materials:
- Two glass jars
- Oil

- Liquid soap or strong soap solution made by dissolving soap chips in water.
- Water

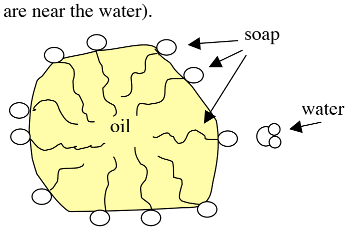
Procedure:

- Fill two glass jars with warm water and add some type of oil to a depth of around 1 cm. In one of the jars, also add half a cup of soap. Shake both of the mixtures and allow them to stand. Observe how the fat is broken up into droplets/globules and then collects on the surface of the mixture without soap. In the mixture with soap, the globules of fat are broken up and distributed so that the mixture looks like milk.

Explanation:

- This happens because oil and fat is made of long molecules which prefer to stick to each other rather than to water. Water is made of small polar molecules which prefer to stick to each other than to oil. Soap, however, is made of a long fatty molecule with a polar end.
- If students observe that after a long period of time layers do form, explain to them that because of gravity the lighter material still floats to the top. Thus the layer that they see is a mixture of oil, soap, and water – which is lighter (less dense) than the water and soap mixture below. If the bottle was floating in space, the layers would not form.

When mixed with oil and water, the long fatty bit sticks to the oil and the polar bit sticks to water. The oil is thus stuck to the water. You can draw miscelles if you wish. These are small droplets of oil with the long bit of soap molecules stuck in them with their polar bits on the outside (so they are near the water).



This is how soap helps the oil to form small droplets which are suspended in the water. The hydrophobic end (the end that doesn't like to mix with water) attaches to the oil molecules and the hydrophilic end (the end that likes to mix with water) attaches to the water molecules. The oil particle gets covered with soap molecules, all with their hydrophilic ends outward toward the water. As a result, the water can easily carry the oil particle away – thus, for instance, cleaning and oil mark from a dirty cloth or shirt.

Now you are going to have the students pretend to be water, oil, and soap molecules. Make a circle on the ground with the rope. Have some of the students make a 'W' shape with their arms – these are the water molecules. Have them move around the circle and tell them to shake hands with other water molecules whenever possible. Now tell some students that they will be oil molecules – they are instructed to hold their arms down low in an 'L' shape. Have the oil and water mix in the circle. Notice that the water people can only shake hands with water people and oil people can only shake hands with oil people. Now ask them what they think soap would look like. How could soap get the two types of molecules to mix. A few students are likely to guess correctly – one hand up and one hand down, like an 'S' shape for soap! Have the oil, water, and soap people enter the circle and tell them when you say 'Molecules in Motion' you want them to dance around like molecules shaking in a fluid. Say the words and after a little while tell them to 'Freeze!'. Make sure everyone is shaking hands with someone. Ask the soap people to hold up their hands – they should be connected to both a water molecule and an oil molecule. Ask them if they now understand how soap works. Once any questions are answered or written down, have them give each other a round of applause.

Source: UNESCO Sourcebook for Science Teaching (103).

Soap and Cells

We have discussed the molecular and atomic properties of nature by exploring water and molecules and the physics and chemistry of how these particles interact.

Now we are going to discuss biology.

What is the smallest unit of living material?

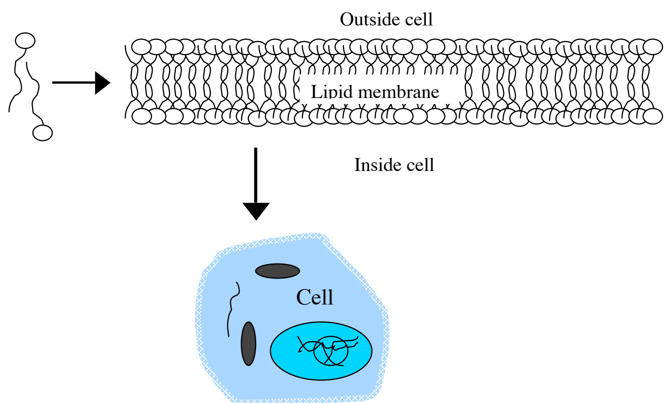
Cells – what are cells? Basically a compartment to hold things together. Using a loop of rope make a circular or oval shape of a cell on the ground.

What is inside the cell? Ask students this question and as they answer with ideas like 'nucleus, mitochondria, DNA, cytoplasm' and other organelles and cell component, draw some of these items in the dirt with a stick or add additional pieces of rope or objects to represent organelles and other things.

Now ask the students what most of the cell is filled with? What takes up the rest of the space inside the cell? The answer is water.

Next ask the students what fills up most of the space outside of the cell? For instance, our blood cells – what do they exist in? Again, the answer is water.

Draw water on both the inside and outside of the cell. Ask the student how the cell stays together? Why doesn't the cell come apart?



Explain that the cell membrane is made of soap-like molecules. The membrane is made of molecules with a hydrophobic end (the tail) and a hydrophilic end (the head). If possible show them the picture to explain. In the cell membrane there are two layers of these molecules and the layers are arranged so the tails (the hydrophobic ends) are pointed to the middle of the membrane layer and the heads (the hydrophilic ends) are on the outsides of the layer. As a result the membrane like to mix with water both on the inside and outside of the cell. Note that the membrane also has many other components that help regulate what flows in and out of the cell, but the two-layer (bi-layer) membrane is the major part.

The Microbial World

Our bodies are made up of millions of cells working together. We have cells of many different types – blood cells, skin cells, nerve cells...all sorts of cells each with a specific function in the human body. All of the cells work together in order to make our lives possible.

What about more simple life forms. What about organism made of only one cell – what do we call these? *Microbes!*

Microbes are very tiny, single celled creatures. Can you see them with the naked eye? No. Then how do we know they exist?

Activity: Making a simple lens

Objective:

To use the surface tension of water to make a small natural lens that can be used to see some magnification in the letters of the newspaper or other objects.

Materials:

Paperclips/Wire
Water
Newspaper

Procedure:

Using a paperclip or small piece of wire make a small loop about 3-5 mm in diameter. Make sure that the loop is complete – i.e. the wire at the neck of the loop is wound closely so a complete closed loop of wire is made.

Dip the loop into water and try to get a small round drop suspended in the loop. Use the water drop as a small lens and observe the magnification of the letters on the newspaper.

Explanation:

The surface tension of the water pulls the water drop into a oval or sphere shape and create a lens. This lens then acts like a small magnifying glass as light from the newspaper is collected by the lens and focused into your eye.

Seeing Microbes

What causes disease? Ask the class what different causes of disease there are, if a chalkboard is available write their answers up on the board. If they name a disease, place it under/next to its cause, and if the cause is not up yet, ask them if they (or anyone) knows what causes the disease.

You should end up with a list like:

1) Germs/microbes (possibly split up into viruses and bacteria)
2) Genetic diseases
3) Poor nutrition
4) Exposure to toxic substances
5) Cancer

Before the invention of microscopes, scientist did not understand diseases very well. Their causes we mysterious. With the invention of the microscope scientist were able to observe extremely small organism – microbes (bacteria, etc.). They discovered that diseases are not caused by supernatural forces, gods, spirits, or invisible beings – just really, really SMALL beings, which are biological in nature just like you and me. But because they're so small, it's hard to have everyday experience about them, and easy to make up stories about what causes disease.

We will be talking about viruses and bacteria. Who knows what they are? Who knows how they're different?

For practical disease-treatment purposes, the main difference is that bacteria can be killed by medicine (antibiotics), while viruses cannot. It is up to our Immune System to kill viruses, although the Immune System is also extremely important in killing bacteria.

Bacteria can survive for long outside a body with nutrients, while viruses can only survive for a short amount of time. So a virus is usually "caught" by contact with someone who is infected, or with fluids from their body. Bacteria can be caught this way as well, but they can also be caught through contact with dirty, rotten, or otherwise unclean and possibly infected materials.

Bacteria reproduce by growing larger as they absorb nutrients, and then dividing into two when they're large enough. If surrounded by nutrients, they can double every 20 minutes or so. If one enters your body, and doubles every 15-20 minutes, how many will be in your body after 8 hours? Who can guess? Over 10 million. (This is called exponential growth, when the number of things is multiplied by a certain number – 2 in our case – for every period of time – in our case, 20 minutes. This can lead to extremely fast growth once numbers/amounts build up, unless it is slowed down or stopped by reducing the multiplying number or lengthening the period of time). By taking antibiotics, you "poison" many of these bacteria, so not all of them can double, and many die. Your immune system also helps in this.

Viruses

What are they? How do the work? Back to ground model of cell. Use scissors to represent virus breaking into cell and injecting genetic material. Entering the cell, replicating, bursting the cell, infecting other cells.

Viruses are much smaller than bacteria. Viruses reproduce in a different way. They enter your cells and make your cells turn into virus factories. Cells have a material called DNA, which is arranged in very long molecules that store information like a long line/strip of text. This information is about what materials the cell must produce in order to develop and survive, and about when these materials must be produced (materials like proteins, hormones, etc). The virus inserts its own DNA into the cell, and the virus's DNA makes the cell manufacture as many viruses as it can, all the time, until the cell is so full of viruses, it bursts. Now, thousands of copies of the virus all go and try to find their own cell, and all those newly infected cells will each produce thousands more viruses. One reason why viruses are so hard to kill is that they try to hide inside cells for as much of the time as they can (as soon as the cell that they were created bursts, they're off to try to get into another one), so to harm the viruses, any medication would have to harm the cells in your body that the viruses inhabit.

Sexually Transmitted Diseases (STDs)

It is important to take some time to talk about sexually transmitted diseases. During unprotected sex – and sometimes during protected sex – there occurs an exchange of bodily fluids, and extensive physical contact between two people. Many diseases can only be transmitted during sexual activity, and many of those cannot be cured. This is why it is important to only have sex with someone you trust, and to use a condom when you do. Many times, it is impossible to tell that someone has an STD just by looking at them, and often it is not obvious to the infected person that they are infected. Many STDs lead to painful infections in the genitals or in the areas around them, making urination painful and sexual activity unsafe.

STDs can only be transmitted through the exchange of bodily fluids that are rich in nutrients, such as blood and semen. So you cannot catch them by simply coming into physical contact, or sitting in the same room, or drinking from the same glass or using the same toilet, as someone with the disease. However, by coming in contact with their blood, you CAN catch these diseases. This can happen if you use a needle used by someone with an STD. While needles used in hospitals and doctors' offices are new, sometimes needles used in less legitimate places or situations (like the injection of illegal drugs) may have been used before, possibly by someone with an STD. So make sure you only use new, sterilized needles. And don't do heroin, if you needed another reason.

One of the most dangerous and widespread STDs is AIDS. AIDS is caused by HIV, the Human Immunodeficiency Virus. It's called an Immunodeficiency virus, because it attacks the cells in your immune system. Here be sure to explain each of the terms: immune system, deficiency. This means you can get all kinds of diseases much easily and can never get better from them, because your immune system is weakened.

Activity: Hand-shaking game

<u>Objective:</u>

Physically illustrate the spread of a disease through a population

<u>Procedure:</u>

1: Each student is asked to write a vertical column of numbers on the left of a piece of paper, from one to 4 or 5 (enough for that power of 2 to be most of the students in the classroom).
2: Each student is asked to shake hands with one random student, then write this random student's name by the number 1 on their sheet of paper. The teacher also does this.
3: Step 2 is repeated until all 4 or 5 numbers have a name by them.
4: The teacher reveals that the handshakes were analogous to having unprotected sex, and that one person started out with an STD. Each "round" corresponded to an unprotected sexual relationship, where if one person has an STD, the other will catch it. Who wants to guess how many of you are now infected, after only 4 or 5 partners?

5: The teacher reveals he/she started out with the STD. *Who shook hands with me in the first round? This student here did, so he caught the STD.* That student is asked to stand up. *Who shook hands with either of us in the second round? So now you two caught it as well. Stand up. Who shook hands with any of the four of us in the third round? You stand up too…* and so on. That's the thing about exponential growth – it gets faster and faster, because at each step the problem is bigger to begin with. This is true in the way bacteria and viruses invade our body, and in the way an epidemic spreads through a population. At some point, something must stop that growth, or hold it back (so not everyone can pass on the disease, or not every virus or bacteria can reproduce), otherwise it will destroy any system. For example, if nothing stopped an epidemic – like people taking the proper preventive measures – soon everyone would catch the disease. When bacteria multiply in the body, they soon eat up a lot of the nutrients in the area they occupy, and in addition, your body temperature rises, and eventually your immune system starts killing bacteria. If it were not for these measures, the bacteria would grow indefinitely, and your entire body would be just bacteria…

6: That's part of the beauty of science: models are really useful, and phenomena of very different scales are often rules by parameters that have relationships analogous to the parameters of another system. In other words, some very different stuff sometimes behaves according to the same math, and if you understand why certain bits of math (like exponential growth) apply to one situation, you'll often be able to guess when that math applies to a new situation, as this insight will enable you to model it better, and to apply that knowledge more easily. For example… How does a virus spread?

Explanation/Discussion:

When you have unprotected sex with someone, you're having sex with all the people he/she's ever had sex with, and all the people THEY've ever had sex with, etc. This means unprotected sex can be much more dangerous that it might seem. You saw how quickly the disease spread in this classroom. *If someone from the outside came and "shook hands" with one of you in this classroom, they'd probably get infected too, because almost all of you had the disease, even though only I originally did.* Unprotected sex can lead to a LOT of disease transmission, because the odds of catching the disease, as well as the rate at which the disease spreads, grows with each time.

Important Concept: Exponential growth

Notice that in the model we have just described and performed, the more people who are sick the more likely it is that more people will get sick.

It's interesting to know how the math for bacteria reproduction works the same as for the spread of an epidemic in a population – it's exponential, until something (like nutrients or healthy individuals) starts to run out. [Note that saying 'exponential' is the same as saying 'raised to the power.']

This is something very neat about science: Sometimes you come up with a model to describe a system – say, how leaves grow on a plant, or how a pendulum oscillates – and then that model turns out to describe some other system on a different scale – how animal populations grow, or how the planets move. When you really understand the details and implications and parameters of a model that describes a system, you start seeing analogous behavior all over the place. So lots of things that you learn in science apply to many different kinds of situations – situations that even scientists may not recognize. It is very important in science to try to observe the connections that exist between different phenomenon in nature. Just a little knowledge and skill in observing such patterns can help you understand things from the very, very small (atoms, molecules, microbes) to the very, very large (planets, stars, galaxies, the Universe).

Activity: Paper folding challenge

Objective:

Provide a very hands-on example of exponential growth: with each fold you are try to bend exponentially more paper (2^n where n is the number of folds). In other words, the exponent is growing (the number 'n' in 2^n is increasing by one with each fold).

Materials:

Newspaper

Procedure:

Give each student a sheet of paper. Ask them how many times they think they can fold it in half. Some will say 20 times, others will say 100 times. Few, if any will guess correctly (about 7-8 times). Tell the students to fold the paper in half precisely each time and to count each time they fold the sheet in half.

Explanation:

The sheet of newspaper can only be folded 7-8 times because of the exponential growth of the number of sheets requiring folding. Even if you had a sheet the size of a football field you would still only be able to fold it about 10 or so times. For the first fold there is only one sheet folded in half, so you have two sheets. The second time there are four sheets. On the third time there are eight. On the fourth, 16. On the fifth, 32. Then on the 6^{th}, 7^{th}, and 8^{th} fold there are 64, 128, and 256 layers of paper. Thus in order to fold a 9^{th} time you would have to be able to fold 256 sheets of paper! To fold ten times you would have to fold 512 sheets! And for 11 folds – 1024 sheets!

Note that in this case if we think of the equation: $x = 2^n$, here 'x' represents the number of sheets and 'n' represents the number of folds. Thus, after 4 folds we have $x = 2^4 = 2 \times 2 \times 2 \times 2 = 16$ sheets of paper.

If we think back to viruses reproducing we see that the equation changes depending on how many copies of the virus are produced each time the virus infects a cell. For now, let us say that the virus makes 1000 copies before the cell bursts (in reality it can be much higher.) So now our exponential growth equation looks like this: $x = 1000^n$, where now 'x' equals the total number of copies of the virus and 'n' equals the number of infecting cycles that we consider. This can be thought of as the reproduction cycle – in other words, the cycle from when the virus infects the cell to the time when the cells bursts. Thus, after one cycle (n =1), we have 1000 copies of the virus. Now those copies go out and infect new cells. After the second cycle we now have $1000^2 = 1000 \times 1000 =$ 1,000,000 copies. After the third cycle the number of copies is 1,000,000,000 ($x = 1000^3 = 1000 \times 1000 \times 1000$). As you can see there numbers get very large very quickly!

Now we are going to play a game that also demonstrates exponential growth.

Activity: Towers of Hanoi Challenge

In the legend of the Towers of Hanoi, there exist a tower of 64 gold disks. These disks rest on a pillar and a group of monks have been given the task of moving the entire tower from one pillar to another. There are a total of three pillars. There are two rules the monks must follow when moving the disks: 1) they can only move one disk at a time, and 2) they cannot place a larger disk on top of a smaller disk. The legend says that when the monks have finally completed moving the tower, the world will end!

Here will try a much simpler version of the puzzle.

Objective:

Provide an experience of exponential growth in the amount of time it takes to accomplish a task. With this example students will discover that the number of moves required to solve the puzzle increases as we add more pieces to the puzzle. In other words, the amount of time needed to solve the puzzle grows exponentially as you add more disks to the initial tower.

Materials:

- Four cardboard disks of increasing size. Each disk should have a hole in the center.
- Three straight sticks about 10-20 cm high, mounted vertically in a block of wood, a sheet of cardboard, or just stuck into the ground.

Procedure:

Begin with the disks stacked on the center stick. The disks should be stacked so that the smallest disk is on top and the largest disk is on the bottom. The disks in between must also be stacked in decreasing size as you go up. The task is to relocate the entire stack, the Tower, to one of the other sticks. The final stack must be the same as the initial stack – in other words it should make a pyramid of disk of decreasing size as you go from the bottom to the top. You can only move one disk at a time and you cannot put a big disk onto a smaller disk. Have a student solve the problem with three disks. Have another students solve the problem again but this time have the class count the number of moves.

They will most likely do it in 7 moves, this is the minimum number required for solving the puzzle with three disks.

Next add another disk and ask for a volunteer to solve the puzzle. They will find it much more challenging this time as there are more opportunities to make a mistake. Have 1 or 2 students try it and then have the class count the number of moves required. If the student solves it in the most efficient way, it will take 15 moves.

Explanation:

Start with one, two and then three disks to get an understanding for how a simple algorithm can result in increasingly complex and time consuming solutions. For any given number of disks (n) the number of moves required to solve the system is precisely equal to $2^n - 1$.

Now if we consider the monks of Hanoi (Note that Hanoi is in Vietnam, but the puzzle was actually invented by a French mathematician in 1883. Thus Hanoi, Vietnam has little to do with the story other than that Edouard Lucas (the mathematician) may have been inspired by the architecture.

Now let's think about another form of exponential growth…

Exponential growth of population and pollution

From exponential growth of population we have exponential growth in use of natural resources, need for energy, and as a result of our current energy system, based on burning fossil fuels – exponential production of waste and **pollution**.

Ask the students what kinds of pollution have humans created? Water! Air! How have humans damaged the environment? Deforestation! Deforestation – the World has lost 80% of the original forests that covered the Earth! What are some of the causes of pollution? Industries! Factories!

Okay, we are going to consider air pollution for the moment. To begin with, what is in the atmosphere? What are the major gases?

Major gases in the air:

- Nitrogen, N_2 (g) – 78.04%
- Oxygen, O_2 (g) – 20.95%
- There is also quite a bit of Argon Ar (g) – 0.93 %

The atmosphere also has several gases in smaller quantities, these are called trace gases in the atmosphere. Some of these gases are natural and some are human-made pollutants:

- H_2O (water vapor): the most abundant greenhouse gas (GHG) & biggest contributor to global warming

- CO_2 (carbon dioxide): another GHG produced from respiration, combustion, ocean evaporation
- NO (nitrogen oxide): mainly from vehicles
- NO_2 (nitrogen dioxide): mainly from vehicles
- O_3 (ozone): naturally present in the stratosphere but increase due to NO, NO_2, CH_4, CO, etc.

Did air pollution always exist? No, it is the result of human civilization transforming the environment.

We can define air pollution as the presence of contaminants in the atmosphere, which degrade the air so much that they impede human and biological processes (or anything in the environment.)

Two types of air pollution:

Indoor: kerosene or gas appliances (carbon monoxide)
Outdoor: forest fires to clear land for wood/farming (pollutants), cars (nitric oxide, nitrogen dioxide, carbon dioxide), factories (same as cars, others depending on the type of manufacturing that occurs); burning fossil fuels to produce energy and fuel cars

Effects of Air Pollution on Human Health
Health impacts: Lung/breathing difficulty; chronic bronchitis, Nausea, Dizziness, Organ damage, and Cancer

When discussing trace gases, it is also important to emphasize that some of these have been increasing beyond the natural levels due to man-made emissions over the past one-hundred or so years. The danger exists because some are harmful to life and some lead to effects like global warming, among other consequences.

Activity: Focus on Global Warming

Now we are going to consider one particular type of air pollution: Carbon Dioxide! Carbon dioxide is released when we burn fossil fuels (oil, petrol, gas, coal, etc.) and it is released when trees are burned (deforestation). Over the past 200 or so years the amount of carbon dioxide (CO_2) in the atmosphere has been increasing as a result of human activity. Here we explore the effect of this increased carbon dioxide. Over the past two hundred years, CO_2 in the atmosphere has increased from about 280 parts per million (ppm) to its current level of 360 ppm.

The climate on planet Earth is changing – some places are getting colder and some are getting hotter. Some places are experiencing larger floods than in the past and some are experiencing larger droughts. The global climate is changing in many different ways and life on Earth is feeling this change. It is difficult to know exactly why these changes are occurring but one scientifically measured change that may be contributing significantly to

global climate change is the amount of carbon dioxide (also known as CO_2) in the atmosphere. The carbon dioxide molecule (CO_2) is particularly good at retaining heat energy. As a result, CO_2 in the atmosphere makes the atmosphere a better insulator of planet Earth. If you think of the atmosphere as a blanket around planet Earth, adding more CO_2 to the atmosphere makes it a warmer blanket.

As energy from the Sun enters the atmosphere, much of it passes straight through the atmosphere and reaches the ground (this is energy in the 'visible' part of the light spectrum). The ground of the Earth absorbs this energy and then re-emits it (sends it back out into the atmosphere) as heat energy (energy from the 'infrared' part of the spectrum). The CO_2 is very good at absorbing this heat energy and as a result the atmosphere of planet Earth becomes warmer. This effect is given the name '**The Greenhouse Effect**'.

So adding CO_2 to the atmosphere increases the Greenhouse Effect on Earth. Carbon dioxide (CO_2) is thus called a Greenhouse Gas. Other Greenhouse Gases include water, methane, and ammonia.

How are we adding CO_2 to the atmosphere? Burning of fossil fuels and burning of our precious forests!

Activity: The Greenhouse effect – how does it work?

Objectives
- To explain the "Greenhouse Effect"
- To allow the students to get a physical sense of how the greenhouse effect works

Materials:
- Make a large rectangle with a piece of rope.
- Two sets of objects of different color. Say apples and oranges, red balloons and yellow balloons, red pieces of paper and yellow pieces of paper. Anything can be used – different colored stones, sticks and stones, …anything where you can have approximately 20 objects of each type.

Procedure:
- Have the students stand in the rectangle. The rectangle represents the atmosphere and the students are going to represent the air molecules in the atmosphere.
- Have one instructor carry one set of objects (say yellow rocks) to one side of the atmosphere rectangle – this will be the top of the atmosphere, the side if the atmosphere that reaches into outer space.
- Have the other instructor carry the other objects (say red rocks) to the other side of the atmosphere rectangle, the side represents the ground of the Earth.
- The students are instructed to jump around, pretending that they are molecules moving in the atmosphere.
- The instructor at the top of the atmosphere with the yellow rocks now passes the rock to students that come close to him or her. This represents light coming in

from the sun. The students are instructed to pass the yellow objects down to the ground side of the rectangle as quickly as possible. The best case would be for the instructor at the top to throw the stones directly across to the instructor at the other side, however, since we don't want anyone to get hurt, the students will pass the objects very quickly.

- Once the yellow objects reach the instructor on the 'ground' side of the atmosphere, that instructor exchanges the yellow object for a red object. The red object represents heat energy. These objects are then passed back into the atmosphere and the students are instructed to pass the red objects back out to the instructor at the top of the atmosphere.
- Explain to the students that this represents what would happen if there were no greenhouses gases in the atmosphere. The incoming energy gets re-radiated (re-emitted, sent back out) by the ground and the energy escapes back out into space.
- Now ask some of the students to pretend to be carbon dioxide and water molecules.
- These students are instructed to hold onto a red object if one is passed to them
- Repeat the above procedure, passing in yellow object from the top and sending red ones back out. This time however, some of the students hold onto the red objects.
- Explain to the students that this represents the Greenhouse Effect – some of the incoming energy is trapped by the greenhouse gases in the atmosphere. The atmosphere then acts like a blanket, helping to keep Earth warm enough for life.
- Now ask more of the students to pretend to be carbon dioxide molecules.
- Repeat the procedure and notice now that more of the red objects are trapped in the atmosphere. More heat energy is trapped. As more CO_2 is added, the atmosphere can keep the planet even warmer. If too much CO_2 is added, then perhaps the planet will become too warm for life as we now it!

Explanation:
The Greenhouse Effect is just one of many effects that play a role in determining our global climate. Other effects include the circulation of water in the ocean, the melting of ice caps, and deforestation. The combined effect of all the effects is difficult to predict. For this reason it is very important to study all of these effects and gain a better understanding for what is happening to our changing climate on planet Earth.

What's the solution to pollution?

We have to ***stop the source*** of pollution and we have to clean up the pollution that we have already created. How do we do that?

We must develop technologies that are clean, efficient, safe, and effective! Who can name some ways to generate energy – to make electricity for instance – without burning fossil fuels?

Solar! Wind! Hydro! Geothermal!

Yes these are excellent examples! If we build an energy infrastructure based on these technologies then hopefully we can stop polluting the atmosphere, oceans, and land! Hopefully we can make our Home a clean Home! But it depends on you and me! We must make the changes! We must work hard to develop the ideas, make the discoveries, and implement the changes that are needed for our home to be a clean, safe, and beautiful Home in the future! Can you do it? Can WE do it!? Yes!

Okay, so that's how we can stop pollution, but what about the pollution that already exists? ***How can we clean up the pollution that already exists?*** First – don't liter! Liter is a disgusting habit and only dirty people liter! Do you leave trash on the ground in your home? No! Then why leave trash on the ground of our Home! Okay, so don't liter!

Now how can we clean up air pollution? As an example, let's consider CO_2 in the atmosphere. How can we reduce the amount of CO_2 in the atmosphere? What takes CO_2 out of the atmosphere?

Plants! We can use plants, in particular trees and forests to take CO_2 out of the atmosphere! What can planting trees mean? For example, in New York City it was found that 322 city trees took 145 tonnes of pollutants out of the air. Quite a good thing don't you think?

But what are we currently doing to the forests of our home, the Earth? We're cutting them down. We need to stop this and plant more trees.

How can planting one tree possibly help reduce all the pollution and reduce the amount of CO_2 in the atmosphere?

The answer goes back to exponential growth!

If you plant one tree today, how many trees will have been born from the seeds of that tree 50 years from now? As an example, assume that only one seed successfully grows per year. So for year one we only have one tree, for year two, we have two trees, for year three we now have four trees. You see, here again we have an example of exponential growth and this time it is helping to do something very good – from just one tree we soon have hundreds, if not thousands of trees! So plant a tree today so that tomorrow our Home will be clean and beautiful!

Okay, let's every give a round of applause for our whole group. You are fantastic students. Did you have fun? Does anyone have any questions? If students have questions you cannot answer, have them write them down on a piece of paper and we will answer the questions during the entire group session.

Closing Group Session

Bring all groups together for final questions and assignments for next week. Ask them if they followed all three rules. Make sure they had FUN!

Careers: Vision for What Ahead

Have all the students sit down. Ask them to imagine themselves in 20 years – what are they doing? What is their career? How have they made the world a better place?

Now ask people to stand up when they hear their career called.

Who wants to be a doctor or a nurse? [Wait until these students have stood]
Who wants to be a teacher?
A scientist? An engineer? A politician? A lawyer? A pilot? A driver? Keep going with different careers until all of the students have stood up. If some are still seated, ask them what they want to be.

Tell the students that they must write half a page to a page describing how they see themselves achieving their career goals. They must write down what they want to be and then describe what subjects are important to study in secondary school, what they should study in college/university and any advanced schooling they may need. They must describe their profession. For instance, if they want to be a doctor they must say that they want to work in a hospital in Lusaka or work in a clinic in a rural area or work for the United Nations in some foreign country or become a specialized surgeon.

Week 2 Assignments

Towers of Hanoi – figure out the algorithm. Do it with more disks

List of 3 processes that demonstrate exponential growth

List of 3 processes that do not demonstrate exponential growth

Write down what you want to be when you grow up and how you see yourself achieving that goal. Write it twice so we have a copy on record.

Finally, have the students give a round of applause to the entire team and then have them give a round of applause to the teachers and administrators that allowed us to visit.