Teaching Sustainability Through a Water Field Study

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Objectives

This curriculum unit is geared toward the middle school level. The students for which it has been designed are generally low performing on standardized tests and live in a high poverty, urban area without much access to natural environments. Their low performance in science and other areas often stems from lack of exposure to experiences outside of their neighborhoods. Without the outside experience with which to connect their classroom learning, basic concepts seem abstract and unrelated to their world. In this curriculum unit, which culminates in a field-study, students will spend time outside and will have the chance to make a direct and authentic connection to what we are learning and how it affects them personally.

This curriculum unit has several objectives. In my classroom we already focus on respect and responsibility and the students are taught the meaning of stewardship, as it relates to others and to the environment. In this unit, students will learn that use of resources in a sustainable manner is a demonstration of respect and stewardship. Through this curriculum unit, students will see firsthand how important water is. Students will understand the chemistry of water and will actively learn how to determine water quality. They will use technology to record water quality data and to draw conclusions about the health of local bodies of water. Students will understand how human activity affects water quality and will have to use cost-benefit analysis to analyze choices that our society makes to continue activities that obviously damage water quality. Through our study of our local watershed, students will have to create their own viewpoint on the importance of protecting our water supply and will have to determine how they are able to make changes, big or small, to help keep our watershed as unaffected as possible by the activity of humans. Besides learning the chemistry of water and how to determine water health, the biggest objective is that students will learn the importance of sustainability in regards to our natural resources and will see the necessity of their actions in protecting our water supply.

Background

While nearly 75% of the earth's surface is made up of water, most of that water is unavailable for human consumption. Approximately 97% of all water on earth is salt water. While some areas of the world, especially the Middle East, are beginning to remove the salt from saltwater to create freshwater, the process of desalination is costly in regards to both money and energy resources.[1] This means that only about 3% of all water on earth is freshwater. Of the mere 3% of

water that remains as freshwater, most of that, nearly 60% of it, is frozen in the polar ice caps, and therefore, also unusable.[2] This makes only about 1% of all water on earth available for human use. Of that 1%, nearly all of it (99%) is stored as groundwater and the remaining amount is surface water.[3] Because water is so limited, it is important that it is used in ways that are sustainable and that human activity does not damage the relatively little amount of freshwater that is on Earth.

The area of land that drains into a body of water is called a watershed. One of the most important aspects of protecting the health of our bodies of water is to protect the land, or the watershed, that drains into the water. There is the saying that has become much more common now, that "we all live downstream." In addition to pollutants that enter water directly, many other substances that start off as land pollutants ultimately end up as water pollution. There are many human activities that are now causing excessive amounts of water pollution. These pollutants not only endanger the water supply of our cities, but also affect the millions of aquatic organisms living in the water.

One very common pollutant is soil and silt that runs off the land and into the bodies of water, in a process called sedimentation. An increase in sediment deposition can harm aquatic life, such as fish, by clogging their gills and causing other physical damage. Additionally, the suspended particles in the water absorb heat as they float around in the water. With an increase in the water's temperature, the water is not able to hold as much dissolved oxygen. The increase in water temperature, caused by the increase in the amount of sediment in the water, makes it difficult for oxygen-requiring organisms to survive.[4] In cities that are experiencing high growth and a lot of construction, plants and trees are removed. Before the new buildings have been put up, the construction sites are huge areas of dirt with no natural protection against excessive erosion, and artificial protection, such as silt fences, are often poorly installed and inadequate. When it rains, the dirt from the land is easily washed away into the body of water into which the land drains.

Another common source of pollution that originates from watersheds is excess nutrients, in the form of phosphates and nitrates, which are washed into bodies of water. The increase in nutrients in bodies of water is called eutrophication, and while it can happen naturally, human activity on land is causing it to occur at much higher rates. Nitrates and phosphates are found in fertilizers used by both homeowners and farmers. They can also originate from animal feces that have not been properly removed or isolated from the watershed, again by homeowners and farmers. A third source is from household cleaners such as laundry and dish detergent. The danger of excessive nutrients in bodies of water, especially bodies of water that are not flowing quickly, is that just like on land, they cause photosynthetic organisms, like algae and aquatic plants to grow quickly. Soon, the algae form a thick layer on the top of the water, forming what is called an algal bloom. While the algae on the top are receiving plenty of sunlight, the algae underneath the algal bloom are starved for sun and end up dying and sinking to the bottom of the water. As the algae sink to the bottom, they are absorbing additional heat from the sun. Just like

when soil erodes into bodies of water, this causes an increase in the temperature and a subsequent decrease in the amount of dissolved oxygen.[5] Additionally, aerobic bacteria at the bottom of the water begin decomposing the algae, which uses up even more of the now decreasing amounts of the dissolved oxygen. Over time, the body of water becomes unable to support life. In estuaries, where freshwater flows into the ocean, there has been a recent increase in areas called dead zones. These are areas where the oxygen levels are so low that they cannot support aerobic organisms, such as crabs, clams, shrimp and fish. The main cause of these increasing dead zones has been attributed to agricultural fertilizers.[6]

There are countless other pollutants that enter water sources from watersheds. Substances such as oil, copper and zinc from automobile brakes and other metals from car tires commonly accumulate on streets and parking lots. The increased land development in many areas has resulted in large amounts of impervious area. As water drains from these impervious areas, there is no natural buffer to help filter the contaminants, and they are washed quickly into bodies of water. These types of pollutants, fertilizers, dirt and car wastes, often originate from various, unidentifiable sources and are called non-point source pollutants. Non-point source pollutants are often the most common causes of water pollution and are the largest concern in watersheds that are undergoing high amounts of development.[4]

The most important step in protecting water sources in the United States is regular water quality testing. This data allows unsustainable practices within the watershed to be detected. When testing the quality of bodies of water, there are several measurements that are used to indicate the health of the body of water. The first is the temperature of the water. While the temperature changes based on seasons and depth of the water, there are ranges of temperatures that are healthy and of course, some that are unhealthy. Another measurement is turbidity. Turbidity is a measure of the cloudiness of water. Water with high turbidity is extremely cloudy because of the increased number of suspended particles. As stated earlier, increased turbidity causes an increase in temperature, so the two indicators are closely related.

Another measurement is the amount of dissolved oxygen. If there is not enough oxygen, aquatic animals that rely on dissolved oxygen in the water are unable to survive. DO levels are inversely related to water temperature. When the temperature of the water increases, the amount of dissolved oxygen decreases. Cooler water tends to have the highest level of dissolved oxygen, and is therefore indicative of a healthier body of water.

pH is another chemical measure that can be used to determine the quality of bodies of water. The pH scale is a measure of hydrogen ion concentration in water. The pH scale ranges from 1 to 14. A measure of 7 is considered neutral, and this is the pH of pure water. Anything less than 7 is qualified as an acid, and the lower the pH, the stronger the acid. Anything above 7 is considered a base, and the higher the number, the stronger the base. pH is a very important indicator of water health, because it controls the rate of biological and chemical processes that occur in

aquatic habitats. A healthy pH is usually between 6.0 to 8.5. Anything lower than 4.5 and higher than 9.5 will generally kill aquatic organisms.[7]

The pH can be affected by natural sources, including the minerals that are washed into the water from the surrounding soil, and even the plants or trees that grow in the watershed can affect the pH of the surface water in which the watershed drains. Precipitation absorbs carbon dioxide was it falls through the sky, making it slightly acidic. During times of increased precipitation or even during a large snow melt, bodies of water may become slightly acidic. Unnatural changes in pH can be caused by air pollution, specifically sulfuric acid and nitric acid, which can lead to acid rain. Dumping of chemicals directly into bodies of water can lead to lethal pH changes, as well.[8]

The final measure of water quality is a count of specific organisms found in the water at given times. These organisms are referred to as bioindicators, as they are living indicators of environmental health. Benthic macroinvertebrates, invertebrates that tend to be found at the bottom of water sources, provide a more complete picture of fresh water quality than simply measuring the chemical water quality indicators.[9] By measuring chemical water quality, only the current conditions are observable. If there was a significantly harmful event, such as a chemical spill, the chemical itself may have already moved downstream after several weeks time and would not be identifiable through chemical water tests. However, the damage done to the environment would still be evident by measuring the macroinvertebrate population. Several of the benthic macroinvertebrates used to determine water quality are: mayflies, caddisflies and stoneflies.[10]

The field study in this curriculum unit will take place in Charlotte, NC. Our school and our students' neighborhoods are in the Mountain Island Lake Watershed, which is part of the Catawba River Basin. In the area in which we live, urban development happened very quickly and has created many problems. Development damaged naturally flowing streams that ultimately feed into the river basin and of course, with the increase in concrete and housing developments, surface run-off and erosion of creek beds has become a large problem. The largest pollutant in the Catawba River today is the silt and soil that erodes from the ground from areas that have been cleared for building.[4]

Fortunately, with the awareness of the dangers of polluting and artificially altering our watershed, Charlotte, NC has taken many steps to protect our area watersheds and the quality of the surface water in the county. One extremely visible improvement has been the creation of greenways, areas of preserved land in urban spaces which also supply land for recreational use, coupled with simultaneous creek restoration projects. A great example is the creation of the Little Sugar Creek Greenway, a pilot project for this dual improvement. Little Sugar Creek is in the heart of a very urban Charlotte area. Since the creek restoration and greenway creation project, which began in 1999, creek beds have been stabilized, more natural meanders have been

added to the creek and two large wetland areas have been added to help filter storm water run-off. Native trees were also added to make the greenway surrounding the creek more appealing to those that are using the greenway, but also to help filter run-off and provide bank stabilization. This has led to increased natural habitats within the stream.[11]

Additionally, the county has increased fines and enforcement for violating erosion control ordinances. In 1987, fines were one hundred dollars per day. Today, they are five thousand dollars per day, per offense.[11]

It is important that government, on the city level, the county level, the state level and the federal level recognize the value of protecting our watersheds and our water resources. It is even more important that citizens have a vested interest in the quality of their own water and the protection of what is arguably our most valuable resource. For, in the words of Milton Friedman, "If government were put in charge of the Sahara Desert, within five years, they'd have a shortage of sand."

Strategies

In order to successfully teach the proposed objectives, many strategies will be utilized.

Simulation Models

The first strategy will be use of watershed models, which I created, and then a writing activity for students to compare what happens on each of the six different watersheds. Using aluminum pans, I will create 6 watersheds that are topographically the same and that contain one river that runs through it and then ends in a pond. Below is a brief description of each of the six watersheds that will be designed:

1. A developed watershed- Concrete will be simulated using wax paper, which water should quickly run off from and buildings will be represented using legos.

2. An undeveloped watershed- Yellow sponges with the green top will be arranged to cover the top of the watershed.

3. A watershed near a farm- Clay will be arranged to represent the farmland and green jello powder will represent the fertilizers that were put down to help crops grow. Cocoa powder will represent the animal wastes.

4. A watershed near a chemical plant- The chemical plant will be created using Legos and the waste produced will be simulated using red kool-aid powder.

5. A watershed with lots of plants and trees- This watershed will look just like watershed #2.

6. A watershed with just dirt- The purpose of this watershed is to demonstrate what happens when construction companies clear out land before building and do not take adequate measures to prevent run-off.

Using a spray bottle, I will make it "rain" on each of the watersheds. Students will then write a short comparison of what happens to the water on each of the watersheds. I will have students compare Watershed 1 to Watershed 2, Watershed 3 to Watershed 4 and finally, Watershed 5 to Watershed 6.[12]

Socratic Seminars

A second strategy that will be used will be Socratic Seminars. It is very important that students begin to formulate their own ideas and opinions regarding new information, rather than just memorizing facts. There are several articles that are included in the bibliography that relate to water quality and pollution and easily allow themselves to be used as the basis for a Socratic Seminar.

Journaling

A third strategy will be journaling. Students will begin their journaling by watching the movie "Water for Life," which was an MTV special for a program for which Jay-Z was a spokesperson and philanthropist. In the video, Jay-Z goes to two different towns in Africa and sees how the lack of clean water sources affect children that are close to my students' ages.[13] This video is usually quite shocking to my students and helps them see the relevance of clean water sources in their own lives. Students will first begin by journaling about their reaction to the video. They will then journal several times a week about how they used water and make observations about ways that they could be more conservative with water.

Service Based Learning Project

A fourth strategy will be for students to create and run a service based learning project within the school. Students will work together to raise money to help provide clean water to children in areas of the world where clean water is scarce. Students will be responsible for educating the rest of the school and for encouraging other students to donate money to this important cause.

Role-play writing assignment

Another strategy to help students learn the material will be a role-playing writing assignment. Students will be given a prompt and will be responding as a selected person/animal that would have a very strong feeling regarding the prompt. The prompt will be that there is a new bill being proposed that farmers will not be allowed to use artificial fertilizers if they are within 50 miles of a surface water source. They will be asked to take a position on the proposed legislation as an imaginary stakeholder. They will either respond from the viewpoint of a traditional farmer, a consumer on a tight budget or as a fish that lives in a water source near a farm.

Cooperative Learning/hands-on activities

Cooperative Learning and hands-on activities will be an integral part of students learning the required objectives, as well. Students will work together in lab groups and will participate in a variety of hands-on labs in order to understand the factors that affect water quality.

Integration of technology

Students will use technology to study water quality. Specifically, they will make use of equipment that measures the water quality indicators, including water temperature, turbidity, pH, dissolved oxygen and nitrate levels. Students will also use digital cameras to capture pictures of surface run-off and to compare surfaces that lead to more pollution, such as concrete and areas without plants and grass. Students will also make use of satellite data to compare water quality measures such as temperature and sizes and frequency of algal blooms.

Foldables

In order for students to keep up with the different measures of water quality, they will create a foldable that summarizes the six different indicators of water quality.

Guest Speakers

Guest speakers from the Catawba Riverkeeper Foundation will be invited to speak at the school.

> "The Catawba Riverkeeper Foundation advocates for and secures protection and enhancement of the Catawba River, its lakes, tributaries and watershed so that it will always sustain the human and wildlife populations that depend on it for life."[14]

Guest speakers from the City of Charlotte Water Quality and Erosion Control office will also be invited to speak to students so that they can hear first- hand how erosion is harming our local water sources and how the government measures and legislates water pollution.

Field Study

All of the strategies above will culminate with a grade level water field study. Students will use the information they have learned regarding the importance of water, especially of unpolluted water sources to participate in a water field study. They will measure the six indicators of water quality in two different local bodies of water. Comparisons will be made between the two bodies of water and students will have to propose explanations for the differences in water quality between the two bodies of water.

Activities

The Hook

At the start of the unit, it will be important to get students excited about water, which can be a difficult thing to accomplish, especially when it comes to middle schoolers. Because of this, I will start the unit by having students generate a list of things that they use water for. We will then watch Jay-Z's video, "Water for Life", which is available on MTV's website. The video chronicles Jay-Z's partnership with the UN as they attack the issues of providing sanitary water to children in developing countries. In the video, Jay-Z goes to two different towns in Africa and sees how the lack of clean water sources affects children that are close to my students' ages. This video is usually quite shocking to my students and helps them see the relevance of clean water sources in their own lives. Students will begin their water journals by reflecting on the movie and how it made them feel to see these children, who are the same age as my students, struggle to simply find water to drink or even just to bathe in. For the remainder of the unit, students will be responsible for journaling about issues related to water use in their daily lives. They will be required to simply list all the times they used water over the course of at least two different days. They will be required to reflect on ways that they waste water or could reduce water usage. They must also journal about their treatment of our local watershed and how their activities or their family's activities may be indirectly contributing to pollution of the environment. Several of the days, students will be given writing prompts to respond to, or current events articles related to water that they will read and respond to.

Students will use the percentages for water's distribution to create a pie chart to allow them to see why it is possible for people to lack water despite the fact that nearly 75% of the earth is water.

Service Based Learning Project

After watching the video, we will chart the distribution of water, showing how it is possible for so many people to be without water. This will be the start of our service based learning project.

Students will create a program that will be run through homerooms in order to raise money to buy a water pump for a community through UNICEF. A pump costs $703.00 and students will work to encourage other students within the school to donate money to help purchase a pump. Students will break into groups which will be responsible for creating posters to hang around the school. Each group will also be responsible for developing a short commercial for the morning announcements to help advertise the fundraiser. The best commercial from each class will be shown on the announcements in the morning.

At this point, students should understand the value of water and why it must be used in a sustainable way. We will then move on to issues related closer to home, starting with our own watershed.

Watersheds

I will start simply by showing them a picture of a mountain and asking them where the rain will go when it hits the different sides of the mountain. Then, students will be given sections of topographical maps and will have to predict where water will flow, using what they know about topographical maps. Using a map of their neighborhood, they will trace where rainwater goes when it hits their neighborhood. The area that my school is in is part of the Mountain Island Lake Watershed. We will discuss our watershed and then students will predict what substances might pollute the watershed.

This will lead into the activity in which students will observe the models of the six different watersheds and will draw comparisons between each of the three sets of watershed models. Students should see that many substances that pollute the land will also pollute nearby water sources. As it "rains" on the model watersheds, students will write down their observations. They will then be asked to compare #1 (developed land) to #2 (undeveloped, with sponges simulating trees, plants). Hopefully, students will conclude that plants and grass result in less run-off than surfaces such as concrete. Students will compare #3 (near a farm) to #4 (near a chemical plant) and will hopefully conclude that both result in water pollution. At this point, they will not know why fertilizer and animal waste is harmful in water, and they may believe that the chemical plant waste is the only true "pollutant." Lastly, students will compare #5 (areas with lots of plants and trees) to #6 (an area with just soil) and students will hopefully see the amount of sediment that is washed into the water.

Next, students will once again work with their groups and will take pictures of areas on our school grounds where sedimentation is likely to occur. Students will look for areas in which there is little to no ground cover. As a bonus, students can also take pictures of areas that appear to be well protected against sedimentation. They will also be encouraged to look for any other sources of pollution on the watershed that may end up in nearby creeks or streams.

Water Quality Indicators

We will then move on to study the pollutants that are commonly found in river basins and how scientists measure water quality. Students will begin by observing pond water through small, clear "pond view" cubes that I have. They will use jewelry loupes to magnify the pond water and will write down their observations. It is usually shocking to students when they realize how much life is in such a small amount of water. Students will write down questions about what they wonder when they look at the pond water. This is a good time to discuss the importance of all living things, even those that are microscopic and may not be as cute as other organisms that we hear about saving. Have students brainstorm a list of all the things that live in water or depend on things that live in water for their nutrients or for other necessities, such as oxygen.

Nitrates, Phosphates and Eutrophication

This will lead into our study of eutrophication, or excess nutrients in bodies of water, which leads to bodies of water that are not able to support life. Students will be shown several pictures of algal blooms and the resulting fish kills, and told that one of the specific pictures occurred close to home. Students will be given a data table showing the temperature and dissolved oxygen level before and after the fish kill. Using the data, students will speculate what may have caused the fish kill. Students should notice that the temperature increased and the amount of oxygen decreased and will propose ideas for what may have caused these changes in the water. A fake map will be provided showing the body of water with the buildings and businesses near the water, including a large farm that uses fertilizer. Then students will be told that after the investigation, the farmer claims that it is not his fertilizer. He believes that it is household dish detergent and laundry detergent that have caused the fish kill. Provide students with a flow chart showing the chain of events that occurs in eutrophication, leaving out the first step, which is the addition of nitrates and phosphates, often from fertilizer run-off or from household detergents.[15] Students will design their own experiment in order to see who is correct. Depending on the level of the students, the lab can either be previously created by the teacher so that students simply follow the given procedures or you can let students come up with their own way of testing to see who is correct.

The basic set up would be that students use 2 liter bottles with the tops cut off and fill the bottle with pond water containing a small amount of algae. Ideally, students would have a control and two experimental groups: one in which they add dish detergent and one in which they add fertilizer. Keep the bottles under a fluorescent light, and have students measure the temperature and dissolved oxygen in each container, while also recording observations about the amount of algal growth. Students should see an increase in algae and a subsequent decline in the amount of dissolved oxygen as the amounts of nitrates/phosphates increase. After the conclusion of the lab, students should be able to fill in the first step on their flow chart, showing

eutrophication. Some portions of this activity were adapted from the following activity: http://ei.cornell.edu/watersheds/Eutrophication_Experiments.pdf.[16]

Dissolved Oxygen, Turbidity and Water Temperature

While the eutrophication experiment is in progress (it will last for approximately one week), students will be learning about turbidity and dissolved oxygen and how it relates to the health of the body of water. Students will rotate around the room to 5 different samples of water. Each sample will range in the amount of turbidity. As students rotate, they will write down observations about the color and clarity of the water. Each station will have "pre-recorded data," with the temperature and dissolved oxygen levels of the water. When students return to their seats, they will be asked to assign a number value to the clarity of the water, with 1 being the clearest and 5 being the cloudiest. They will then graph the turbidity against the dissolved oxygen levels, the turbidity against the temperature and finally the temperature to the dissolved oxygen levels. Students will then work in groups to research what turbidity is, what causes it and how it affects water quality. Students will then create a one-pager about turbidity, which is simply a one page poster that includes the definition, three pictures related to turbidity, a quote from their textbooks or another source and two to three related words. This activity can simply e be modified to include anything else that a teacher is looking for, and it allows for easy differentiation.

The next topic we will discuss is erosion of soil and its effect on turbidity. We will discuss construction sites and how they have led to making soil and silt the number one polluter of the Catawba River Basin. I am also planning to see if someone from the Water Quality and Erosion Control Office in the City of Charlotte can come speak to the class to discuss the problems and the way that soil erosion is (or is supposed to be) controlled.

pH

Students will learn about pH of water by an inquiry lab in which they will measure the pH of individual liquids, such as orange juice, water and milk. After completing the lab and a reading assignment on pH and water quality, we will play the pH Challenge Game. Each group will be given a random pH level to create and they will have to play around with the amount of each liquid used in order to reach the designated pH. They will then discuss ways that humans affect pH levels of bodies of water and how it affects the organisms living in the water.

Review of chemical water quality indicators

At this point we will have discussed: turbidity, dissolved oxygen, temperature, nitrates/phosphates and pH as the chemical water quality indicators. We will create a flip book foldable to review all the important information about each of these indicators.

Field Study on Water Quality

The purpose of all the previous activities will be to ultimately plan a water field study comparing two different bodies of water in the Charlotte area. One will be in a more rural area and less likely to be affected by construction and human activity. The other one will ideally be closer to recent building developments and will be more likely affected by human activity. One-half of the students will conduct water testing at one of the sites and the other half will conduct testing at the second site. While at the sites, students will be placed into groups and each group will have a designated task. Students will test the temperature, turbidity, dissolved oxygen, nitrate concentration, and the pH of the water. They will also collect samples of macroinvertebrates and we will attempt to classify them and count the frequency of mayflies found in the water. There will not be a huge emphasis on the use of bio-indicators in this project, as our main focus will be the water chemistry. Prior to conducting the water field study, we will have already looked at the sites using aerial photos, maps and satellite images, and students will make predictions about the health of each body of water. Upon returning, the groups will share their data and they will see if their hypotheses were correct.

My hope is that we find at least one of the bodies of water to have unhealthy levels of at least one of the indicators of water quality. Should this be our finding, students will develop a plan of action and will decide on ways that the pollution can be prevented. They will then develop an advertisement campaign to prevent water pollution.

Our final activity will be to have somebody from the Catawba River Keepers come and speak to the kids about the importance of keeping our watersheds as unpolluted as possible.

Resources

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A great magazine all about the ocean, with lots of high interest stories for kids.

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Materials

To create the watersheds:

spray bottle
disposable aluminum pans (6)
florist foam
wax paper
legos
clay
jello powder
cocoa powder
red kool aid powder

sponges (yellow, with a green top)

For the eutrophication lab

2 liter bottles with the top part cut off, 15 per class
liquid dish detergent with phosphates
fertilizer
fluorescent light

Other materials

water quality testing kits
pH strips
liquids of various pH

Notes

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