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Determining Water Quality of a Local Water Source with
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Angela Christine Clark-Pohlod

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DETERMINING WATER QUALITY OF A LOCAL WATER SOURCE WITH EIGHTH GRADE STUDENTS

By

Angela Christine Clark-Pohlod

A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
of the degree of

MASTERS OF SCIENCE

Division of Math and Science Education

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ABSTRACT

DETERMINING WATER QUALITY OF A LOCAL
WATER SOURCE WITH EIGHTH GRADE STUDENTS

By

Angela Christine Clark-Pohlod

This study was conducted in a JASON Project class, an eighth grade exploratory course at Laingsburg Middle School. The JASON project includes a unit entitled "Local Field Investigation" that encourages students to study their local watershed. I developed and tested materials to help students become aware of why water is important to our way of life and how we can determine the quality of water in our local area. The objective for this unit, to introduce students to water quality, required development of hands-on laboratory and field activities, as well as of written assessments to determine students' knowledge of the corresponding content. The students were tested prior to the unit and at the conclusion of the unit in the form of a pre- and post-test.

Research was conducted in each of four terms, in rotating 9-week classes, with a new set of students each term. Due to weather restrictions, two of the four class groups used the river site. This thesis compares the two terms that studied the river three times (1st and 4th terms) with those that did not study the river (2nd and 3rd terms).

At the conclusion of this unit, both groups of students, those studying the river and those not studying the river, showed improvement from the pre-test to the post-test. The group that studied at the river did significantly better than the group not studying at the river on the post-test short answer questions.

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INTRODUCTION

This study was conducted in a JASON Project class, an eighth grade, 9-week exploratory course at Laingsburg Middle School. JASON is the title of a project founded by Dr. Robert Ballard, an oceanographer and marine scientist. Dr. Ballard began the JASON Project in the mid-1980's after his discovery of the wreck of the Titanic on the ocean floor. Dr. Ballard received many letters from students showing an interest in the work he was doing. He decided to bring some of the world's scientists into classrooms through this project to allow students to share in their research and discoveries. The JASON project includes a unit entitled "Local Field Investigation" that encourages students to study their local watershed. My goal was to develop a unit that would teach my students about our local water sources and how to determine the water quality of those sources.

Laingsburg is an interesting district, not fully rural and not fully suburban, the town motto being "Where the country and city meet". Children in this district come from varied backgrounds and our middle school goal is to expose them to as many different areas of study as possible to give students a feel for what they may want to study in high school and beyond. As such, the JASON Project is taught only to our eighth grade population and is in a 9-week rotation with Art, Health, Spanish, and Applied Learning (a career/life skills course). Other exploratory courses eighth graders are exposed to are Computers, Physical Education, Band, Choir and Tech Ed (a vocational education/ industrial arts course).

Research was conducted each term in these rotating 9-week classes, with a new set of students each term. All eighth grade students, with the exception of those t

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taking Spanish, were included in this study, a total of 68 students. The four 9-week classes were divided into two study groups, due to weather restrictions, which allowed only two of the four groups to study a river site. This thesis project thus compares the two groups that studied the river three times within their terms (1st and 4th terms) with those that were not able to study the river site (2nd and 3rd terms). The groups that studied the river site will hence be known as the field group and the groups that did not study at the river site will be the classroom group.

Environmental education is not a new idea and there are many aspects of the environment that are covered under this heading. Classes are taught at the middle and high school levels devoted solely to environmental science, but what does that mean? If a course is titled, "Environmental Science", does that mean that the students are out in the environment studying it? Environmental science courses generally cover topics related to ecosystems and how organisms live in their environment, population studies, relationships among living things (such as predation and parasitism), the movement of energy within ecosystems (food chains and food webs), biogeochemical cycles (water cycle, nitrogen cycle, carbon and oxygen cycles), biomes and succession. Environmental issues, such as endangered species, resource use, population growth and pollution (air and water) are often covered. Conservation issues are generally discussed under the context of environmental science, such as conserving land and soil resources, fossil fuels, and other energy resources. Very rarely, however, when studying these topics at the middle school and high school level do we actually take students out into the environment to a field, a river, a lake, or even a parking lot to discover it for themselves. We tell students about how

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organisms interact and how polluted water is, but do we take them outside so they can make these observations for themselves and learn from them? According to Environment-Based Education: Creating High Performance Schools and Students, a report issued in September 2000 by the National Environmental Education & Training Foundation (NEETF), "Using the environment as a context for learning changes student outlook and results in better academic performance across grades K-12 compared with traditional schooling" (Wakefield, 2001). This statement assumes that hands-on learning is taking place. If we involve students in the field, take them out into the environment and let them make observations about the organisms they encounter, let them test water samples or collect leaves to identify, the students can gain a greater knowledge about the environment as a whole.

There is recent research that indicates children are spending less and less time experiencing the world outdoors. The experiences provided by being outdoors helps students see science in context, allowing them to incorporate science as an important part of their lives. Thus with this decrease in time spent outdoors it becomes a teacher's responsibility to help provide "meaningful real-life experiences" (Pfouts, 2000). It is important to teach students about the environment, but it is also important to teach students responsible stewardship of the environment, what they can do to help take care of the environment around them (Moseley, 2000). In teaching students about environmental science it is not always possible to get them outdoors. However, the science will stick with students more if they are involved in doing fieldwork (McLure, 2002), such as observing interactions among organisms in a garden or testing the pH level of a stream or river.

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Constructivism has become a popular term in education within the last several years. This term refers to an educational theory that emphasizes hands-on, activity-based teaching and learning during which students develop their own frames of thought (Johnson, 1996). From the viewpoint of the constructivist learning theory, teaching is about helping students understand how and why scientifically accepted ideas explain and predict what will happen in a given situation (Colburn, 2000). To have students conduct hands-on experiments or activities that allow them to predict an outcome of a situation and then to perform the activity and test their prediction should give these students a better appreciation for and understanding of those scientific principles being presented. The National Science Education Standards define effective science teaching using constructivist tenets as:

> "The Standards call for more than "science as process," in which students learn such skills as observing, inferring, and experimenting. Inquiry is central to science learning. When engaging in inquiry; students describe objects and events, ask questions, construct explanations, test those explanations against current scientific knowledge, and communicate their ideas to others. They identify their assumptions, use critical and logical thinking, and consider alternative explanations. In this way, students actively develop their understanding of science by combining scientific knowledge with reasoning and thinking skills" (Colburn, 2000).

The science education standards describe an effective science classroom as one that probably includes hands-on activities, cooperative learning and demonstrations. Students should be asked to make predictions about what will happen in a lab or activity before the event takes place in order to allow them to access their prior knowledge (Colburn, 2000). By asking students to do this they must think about what they already know about a topic and how it applies to the task at hand. This gets them thinking about the science before they are engaged in a related activity. Another aspect of constructivism is the use of cooperative learning, where students

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work in small groups to help one another master academic material. After students make their predictions or hypotheses about what will happen in a lab or activity it is worthwhile to have them discuss their ideas cooperatively with other students. By explaining their ideas or viewpoints to the rest of the group, students can begin to see problems with their own explanations, pose challenging questions or present alternative viewpoints that often may seem less threatening coming from peers than from an instructor (Colburn, 2000). It is also a good idea to have students discuss labs and activities after completing them to share their outcome. This can lead students to revisit their hypotheses and look for flaws in their own thinking, as well as helping to implant the knowledge gained in the activity more firmly in the student's mind. Lasting knowledge is more likely to occur when students attempt to make sense of new information by applying it to what they already know or perceive they know about a topic (Lord, 1999).

Teaching the middle grades is often set apart from teaching elementary or high school level students due to the major changes occurring in students in the middle grades. "Middle grades teachers are encouraged to become aware of the various stages of physical, cognitive, social, personality, and moral development and keep in mind that the students in their classroom will not all be on the same level" (Muth & Alvermann, 1992). Young adolescents can become restless when asked to sit for long periods of time, which is what they are required to do in most of their classes. By providing activities that allow students to interact with peers and may involve some physical movement teachers can help alleviate some of the student restlessness. Teachers can also provide more hands-on experiences, such as field trips and lab activities to introduce new ideas (Muth & Alvermann, 1992). Students at the middle level are in transition, going from elementary school where they may have had very little experience in exploratory learning or inquiry to high school, where they are expected to know and understand content with the majority of instruction in the form of teacher-led discussions or lecture. At the middle grades students find a combination of these techniques. It is important to train students of this age to not be satisfied with spoon-fed material and to start exploring concepts in a more inquiry-based fashion. Teachers can do this by providing a classroom environment that is open and accepting of student ideas and interests. Providing topics that affect the students and presenting them in such a way that permits further investigation (constructivist approach) will encourage students to participate and enjoy an environment of inquiry. Students typically enjoy lab experiences in which they can follow a procedure and complete the task. This provides them with an opportunity to explore a topic in a hands-on manner and to feel a sense of completion of a task. These types of activities are good, but should include a chance for students to develop hypotheses or predict what they think will happen in the lab and then, after the lab, a chance to show what they learned through written responses, classmate group discussions or full class discussions of the activity. Students are typically hesitant at first to discuss or share their thoughts about a topic, but with the proper classroom environment and time student responses become more detailed and students are less timid about sharing their ideas. Students at this age are constantly asked to think about their future. At this level, they could either embrace or reject science as a career possibility based on their successes or failures. It is important that we give them opportunities to succeed and to enjoy the hands-on activities and the field trips we can provide and we encourage them to interact with their environment (Selover, 2003).

In an attempt to improve the level of environmental education at Laingsburg Middle School this thesis unit was developed using the principles of learning at the middle school, discussed above, as a guide. The focus of this work is issues related to water, including water quality, because water is an important part of our local and global environment. Our nation acknowledged the importance of water quality with the passage of the Clean Water Act of 1972. The purpose of this act was to restore and maintain the chemical, physical, and biological integrity of the nation's waterways. "A generation after the Clean Water Act was passed, about a third of the stream miles and lake acres in the United States are still polluted. Obviously, there is still a great deal more that we need to do" (Outwater, 1996). Part of what we can do to continue to work on improving the water quality of our nation's lakes, rivers and streams is to include water studies in schools. Shirley Ireton, NSTA director of special publications, stated that water quality education is important because "students need to consider environmental quality on their home turf as well as on the global level". Lorraine Loken, the Water Environment Federation's public education manager, notes that public education is important because "the public needs to be more aware of their role in protecting water resources" (Hun, 1999).

The science within this thesis focuses on two main areas, the water cycle and river ecology. The first of these areas, the water cycle, is the process by which water molecules move from the surface of the earth to the atmosphere and back. Heat from

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the sun causes molecules of liquid water from oceans, lakes, moist soil, leaves of plants and the bodies of animals to absorb energy and change to the gas state. This process is known as evaporation. Water molecules, in the form of water vapor, are then carried into the atmosphere by air currents. As the water vapor rises higher in the atmosphere it cools down and changes back into tiny drops of liquid water. This process is known as condensation. The water droplets collect around particles of dust in the air, eventually forming clouds. As more water vapor condenses, the water droplets in the clouds begin to increase in size and become heavier. Finally, the heavy drops of water fall back to Earth as precipitation; rain, snow, sleet, or hail. The precipitation returns to oceans and lakes or to the land. Precipitation that falls on land may soak into the soil and become groundwater or may run off the land, eventually flowing into a river or ocean (Holtzclaw, 2000).

The second area of focus, river ecology, incorporates both biotic (living) and abiotic (non-living) factors. Rivers change constantly, due to erosion, transport, and deposition. River erosion can occur as running water picks up pieces of the land over which it is moving. The speed of the water determines how much land can be moved. Fast-moving water can carry pebbles, large stones, and even boulders, while slower moving water carries mostly sand and silt. When the moving water meets something that slows its flow it causes particles to drop from the water to the riverbed. This process is known as deposition (Martin, 1999). Vegetation along a riverbank can increase the stability of the bank and can decrease erosion. Bank erosion can be caused by removing trees and other plants from the riverbank, by farmers plowing near the riverbank, and by road or building construction. Some effects of bank er

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erosion are increased river turbidity, increased water temperature, increased levels of nutrients and chemicals, and a decreased amount of dissolved oxygen in the water (LaMotte, 2001).

The living organisms found in and around a river can be very diverse, from fishes to raccoons and otters, to algae and plants. However, the most numerous group of river dwellers are invertebrates. These invertebrates live on the rivers bottom, under stones and in the sand and mud. Most of the invertebrates that can be found in rivers are the immature aquatic stages of insects. Many of these freshwater invertebrates require specific ranges of chemical parameters (pH, dissolved oxygen, temperature) to survive. The presence or absence of these organisms in a river, and the diversity of the species found, can be used to indicate the overall ecological quality of the river.

Aquatic organisms need dissolved oxygen to live. Oxygen dissolves readily into water from the atmosphere until the water is saturated. Once dissolved in the water, oxygen diffuses very slowly and its distribution depends on the movement of the aerated water. Oxygen is also produced by aquatic plants, algae, and phytoplankton as a by-product of photosynthesis. The amount of oxygen needed varies by species and stage of life. Generally, dissolved oxygen levels below 3 parts per million (ppm) are stressful to aquatic organisms. Levels of 5 to 6 ppm are generally necessary for growth and activity. Temperature affects the amount of dissolved oxygen in the water, the rate of photosynthesis by aquatic plants, and the sensitivity of organisms to toxic wastes, parasites and disease. Thermal pollution, heated water from industry added to a river, can have damaging effects on a river sy

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system. Nitrogen and phosphorus are nutrients that act as fertilizers for aquatic plants. High levels of these nutrients can cause excessive plant growth, which can lead to water quality problems. Nitrogen enters water through human and animal wastes, decomposing organic matter, and runoff from fertilizers. Phosphorus typically enters water from detergents. Unpolluted water usually has a nitrate level below 4 ppm and phosphate levels higher than 0.03 ppm can contribute to increased plant growth. pH is a measurement of the activity of hydrogen ions in a water sample. The pH scale ranges from 0 to 14. Water samples with a pH between 0 and 6 are considered acidic, those between 8 and 14 are considered basic, and those with a pH of 7 are considered neutral. The optimal pH range for most aquatic organisms is between 6.5 and 8.2. Most natural waters have pH values from 5 to 8.5. Turbidity, which can be affected by erosion of a river, is the measurement of the relative clarity of the water. Turbid water is caused by suspended matter in the water, such as silt, clay, organic and inorganic matter, and microscopic organisms (LaMotte, 2001). The more turbid the water is, the more difficult it may be for sunlight to penetrate to the bottom of the river, causing aquatic plants to die.

A healthy river is more than just clean water. It is a system with many parts, each contributing to the health of the whole. This system includes the plants and animals that live in and around the river, the speed of the water flow, the type of riverbed (sand and silt or rocks and pebbles), and the substances dissolved and carried in the water (Martin, 1999). Humans also play a role in the river system and our actions or lack of action also has an effect on the health of that system.

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The goal of the work reported in this thesis was to give students an awareness of water and their effects on water locally and globally, done by using the constructivist approach, incorporating several hands-on labs and activities and taking field trips to a local river site. The expectation was that students having participated in this study would take away from it not only the knowledge of the subject matter we covered, but, an appreciation of the importance of keeping our water and our environment clean. Students should be able to apply their new knowledge to the outdoor world and take with them a greater appreciation of the world within which they live and a greater appreciation for their responsibility in caring for that world.

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IMPLEMENTATION

My goal in using the JASON project is to help students see "science in action", which they don't always see in the general education science courses. With this goal in mind I developed the water unit to include many labs and hands-on activities to involve students directly, the field group (two of four terms) also took three field trips out to the Looking Glass River (Laingsburg Road crossing) which allowed students to utilize the skills we were learning in class and apply them to the real-world.

This unit was taught each of four nine-week terms of the school year. The study included a total of 68 students who submitted the consent form (Appendix A) distributed across the four classes. The JASON Project curriculum field investigation, upon which my water unit was based, correlates with the following National Science Education Standards for grades 5 through 8:

- Content Standard A: Science as Inquiry
  - Students learn about scientific inquiry and develop the abilities necessary to perform it.
- Content Standard B: Physical Science
  - Students should develop an understanding of properties and changes of matter, motions and forces, and the transfer of energy.
- Content Standard C: Life Science
  - Students should develop an understanding about the structure and function of living systems, reproduction and heredity, regulation and behavior, populations and ecosystems, and the diversity and adaptations of organisms.
- Content Standard D: Earth and Space Science
  - Students should develop an understanding of the structure of the Earth system, Earth's history, and the relationship of Earth to the rest of the solar system.

UNIT OUTLINE

I developed the following unit outline to provide consistency among the four 9-week terms. Because the field investigation portion of the JASON project was not previously emphasized, all activities, labs, and assessments were developed specifically for this water unit.

Pre-test: Concept Map and Short Answer Questions (See Appendix B-I)

I. Introduction to Water – approx. 7 days
   A. Prior Knowledge Assessment
      Free Write: students listen to the sounds of a mountain stream (CD) and write what they know and feel about water for a 10-minute timed session
   B. Fresh water vs. Salt water (Content Standard B, D)
      1. Discuss percentages on earth, density, etc. [Water Notes – Power Point (See Appendix C-I)]
      2. Show visual – "The Earth's Water – A Demo" (See Appendix C-II)
   C. Biological (human) aspects of water (Content Standard C)
      1. How much of the human body is water? [Water Notes – Power Point]
      2. How much water do we need daily? [Water Notes – Power Point]
      3. In what ways do humans use water? [Water Notes – Power Point]
   D. Water as a Solvent (Content Standard A, B)
      1. Experiment: "Solution or Suspension? -- A Disappearing Act" (See Appendix C-III)
      2. Experiment: "Water – Is it Magic?" (See Appendix C-IV)
   E. Water Sources (Content Standard C, D)
      Video: Eyewitness Pond & River (See Appendix C-V)

II. Water Cycle – 9 days
   A. Precipitation (Content Standard C, D)
      1. Short writing activity – prior knowledge/pre-test – students will free write on what they know about precipitation.
      2. Define & Discuss
   B. Evaporation & Condensation (Content Standard B, C, D)
      1. Revisit "Water – Is it Magic?" Experiment (See Appendix C-IV)
      2. Define & Discuss
   C. Water Cycle (Content Standard A, B, C, D)
      1. Video: Bill Nye on the water cycle (See Appendix C-VI)
      2. Activity: "Water Gamble" (See Appendix C-VII)

D. Effect on water quality (Content Standard A, B, C)
   Experiment: "Water Cycle Wonder" (See Appendix C-VIII)
E. Assessment: "The Life of a Water Molecule" (See Appendix B-III) (Content Standard A, B, C, D)

III. Water Quality – 20 days
   A. Glossary of Related Terms (See Appendix C-IX)
      1. Flash Cards
      2. Assessment: Water Quality Vocabulary Quiz (See Appendix B-IV)
   B. Water Testing (Content Standard A, B, C)
      1. Water Source
         Looking Glass River
      2. Pre-field Work
         a. Invertebrate Populations
         b. Dissolved Oxygen [Introduced in Water Notes – Power Point]
         c. Temperature [Introduced in Water Notes – Power Point]
         d. pH [Introduced in Water Notes – Power Point]
            i. Lab: "pHinding pH" (See Appendix C-X)
            ii. Assessment: "Mystery pH" (See Appendix B-V)
         e. Density [Introduced briefly in Water Notes – Power Point]
         f. Turbidity [Introduced briefly in Water Notes – Power Point]
         g. Nitrates
         h. Phosphates
      3. Field Testing
         a. Perform all of the above tests, except 'Density'
         b. Record data on Data Collection Form (See Appendix C-XI)
         b. Macroinvertebrate Collection
      4. Analysis of Data
         a. Review & Discuss Data collected at river site – done at the conclusion of each river visit
         b. Graph data – only done 1st term/out of time 4th term

Post-test: Concept Map and Short Answer Questions (See Appendix B-I)

CLASS NOTES AND DEMONSTRATIONS

Water Notes: Our Water World

The purpose of the water notes (Appendix C-I) was to give students a base of information about water. These notes were given early in each term, generally within the first week of class, and students were asked to copy the notes as we discussed them. As note- taking can be a boring and difficult task for both students and teachers I put the notes into a Microsoft Power Point presentation in an effort to make it more interesting and engaging for the students. The background for the slides got the attention of the students immediately, as I used a photo my husband had taken on one of our vacations of the surf rolling in at Sunset Beach, North Shore, Hawaii. Not many of the teachers in our middle school utilize Power Point or other forms of technology regularly in the classroom. Because of this, students are still fascinated and entertained by the novelty of the technology being used.

The Earth's Water: A Demonstration

The water demonstration (Appendix C-II) was utilized along with the water notes to help students visualize the percentage of the earth's water that is salt water versus that which is fresh water. The bottle was prepared during my summer coursework and passed around during the water notes presentation once we discussed percentages of water on Earth. The salt water was colored green for effect and the fresh water was represented by corn oil, which allowed it to float on top of the salt water.

LABORATORY EXPERIMENTS AND ACTIVITIES

Solution or Suspension? – A Disappearing Act

In this laboratory activity (Appendix C-III) students determined which of five substances (salt, flour, baking soda, sugar, and dirt) dissolve in water, creating a solution, and which stay cloudy, forming a suspension. Students were asked to record their observations about what happened in each beaker of water as they added the appropriate substance.

Water: Is It Magic?

This laboratory activity (Appendix C-IV) asked students to place a Kool-Aid solution into a petri dish, covering the entire surface of the dish, and observe it after 24 hours. Students noted that the water had evaporated and left the Kool-Aid crystals behind. This activity was good support for our discussion of water as a universal solvent and also led nicely into our discussion of the water cycle.

Water Gamble

The objectives of this activity (Appendix C-VII) were to describe the movement and states of water within the water cycle. The activity asked students to move through the water cycle as a molecule of water describing the location (one of nine) they visited and the state of matter they were at each location. Once at a station they recorded their data and drew a picture to represent what they might look like or what they might be "doing" at that location. The student then rolled a die to determine which station they would travel to next. The activity allowed students to see that water travels to many places in the water cycle and through all three states of matter (liquid, gas, and solid).

Water Cycle Wonder

This activity (Appendix C-VIII) demonstrated for students that water is cleaned as it goes through the water cycle. Students used blue food coloring in warm water and created a mini-Earth with ice representing the upper atmosphere. When the water vapor hit the cold atmosphere the water vapor condensed and formed water droplets. Students saw that the drops were not blue, but clear meaning that the food coloring had been left behind when the water evaporated.

LaMotte Green® Water Quality Test Kits

This kit was utilized both in the classroom for pre-field work and at the river for water quality testing. Students took notes on each of the kit tests performed the first time they used them in class. These notes consisted of what the test was for and how to do the test, as well as the results of the test they performed.

Students in the field group, first and fourth terms, utilized the test kits at the river, in addition to the classroom. Students were assigned a specific test to do at the river site and on each trip the students were assigned a new test to perform. Each student had a buddy to work with in the field and reported their data to an assigned recorder who then wrote the data on our "Looking Glass River Data Collection Form" (Appendix C-XI).

pHinding pH

Students were asked to determine the pH of thirteen known substances using both pH paper and cabbage indicator solution (Appendix C-X). Due to the variability of quality of cabbage juice indicator the results for fourth term were different than those of the other terms.

Aside from some time constraint, this lab activity did afford students the opportunity to see that various substances have different pH levels and that pH can range from 1-14. Students also reinforced their learning of acids, neutrals, and bases (learned in 6th grade science) in this activity by reading the background information on pH.

VOCABULARY

Students learned several terms related to water, the water cycle, and water quality as we progressed through this unit. For one set of terms, the water quality vocabulary (Appendix C-IX), students were given small note cards from which they were instructed to create flash cards for the forty terms they were learning. Students wrote one term and definition per card. The term was written on one side of the card and the definition on the other side. This allowed the students to study the terms on their own or with a friend. Students were given time generally at the beginning and/or end of class to work on vocabulary review.

VIDEOS

During the course of each term students watched two videos that helped explain the concepts we were discussing in class. For each video students were given a set of questions to answer from the information presented in the video. These questions are not meant to be difficult, but to keep students focused on the video and to give them a reference for future use.

The first video we watched was "Eyewitness: Pond & River", which presented many aspects of pond and river ecosystems. The video introduced students to several species of macroinvertebrates that live in ponds and rivers, as well as to mammals that live on the banks of rivers. Eyewitness videos, such as this one, present the information to viewers in a way that holds ones attention and keeps them interested. Students respond well to this type of video and stay on task with the video questions (Appendix C-V).

The second video watched was a Bill Nye video on the water cycle. I have used this video for years in my general science class, in which all 8^{th} graders at Laingsburg Middle School are enrolled (~100 students), but chose not to use it there this year and instead used it with the JASON classes. Bill Nye always seems to grab and keep the attention of my eighth grade students. The material is presented in short segments and is broken up by experiments or interesting factoids. This video on the water cycle covers all parts of the water cycle and discusses ways to keep water clean and pollution free. Once again, students respond well to this type of video and stay on task with the video questions (Appendix C-VI).

FIELD WORK – LOOKING GLASS RIVER

During first (October) and fourth (April/May) terms the classes were able to work at the river site on three different dates (see the unit overview for tests done). The first trip out each of those terms we were accompanied by Mr. Chris Klawuhn of the Shiawassee County Health Department Environmental Health Division. Mr. Klawuhn is an environmental health sanitarian whom I contacted over the summer for help in locating a spot to take the students for water collection. Mr. Klawuhn volunteered to help explain proper sampling techniques and to show students equipment that they use at the county to do water testing. He was quite helpful and the students enjoyed having someone "official" out with us. Having Mr. Klawuhn with us gave students the idea that water quality is something that is important and that there are people whose job it is to monitor water quality.

On our river trips students did a visual inspection (looking for trash or other pollutants in and around the water), a biological inspection (looking for aquatic organisms in and around the water), and a chemical inspection (chemical tests to determine the health of the water). We did chemical testing on each trip; however, the first term collected samples and did the testing the next class period back at school. Neither group did a macroinvertebrate collection on their first trip, but both groups collected on the second two dates. First term students brought waders and utilized them for both of the two dates they collected macroinvertebrates. This allowed them to reach the far bank to get a more diverse collection of organisms. Fourth term students brought waders out only on the second of the two dates they collected macroinvertebrates and broke the dip nets I had made. This made collection more difficult for this group, but they still managed to find a many macroinvertebrates.

The chemical tests performed on each visit were for pH, dissolved oxygen, nitrates, and phosphates. Tests for turbidity were also done. Both water and air temperature were recorded on each river trip.

ASSESSMENT

The majority of the assessment done throughout this unit came from questions imbedded within the laboratory activities (See Appendix C) we performed in class. Students were asked to develop a hypothesis for each activity, to perform the activity, and then to answer several questions related to the lab and the stated hypothesis. Some of the questions were basic knowledge and procedure questions, whereas others were used to determine if students could adapt what they had learned from the activity and apply it to a higher level.

Pre-test

In order to evaluate the progress of the students, a pretest was given at the beginning of the water unit. The pretest was in two parts, a concept map (covering the water cycle) and six short answer questions over all aspects of the unit. The concept map required students to fill in blank ovals by using the rest of the context clues within the map. The pretest (Appendix B-I) was identical to the post-test given at the end of the unit.

The Life and Times of a Water Molecule

This assessment was in the form of a creative written report (Appendix B-III), in which students had to pretend to be a water molecule traveling through the water cycle and describe their movements and state of matter as they went. Overall, students were very creative and had fun with this. They were given about a week and a half to complete a rough draft and a final copy of the report. A grading rubric (Appendix B-III) was given for students to utilize in creating their report. This was assigned all four terms.

Water Quality Vocabulary Quiz

This vocabulary quiz (Appendix B-IV) tested students on twenty of the forty terms they were required to learn related to water quality. Students used flash cards to learn and review the terms. This form of assessment is very basic; the terms and definitions were given and students were required to match them correctly.

Mystery pH

This laboratory activity (Appendix B-V) was used to assess what students had learned about pH in the "pHinding pH" activity (Appendix C-X). Student "pHinding pH" lab papers were graded and returned prior to conducting this activity. Students were able to use the "pHinding pH" lab papers to help them in determining which 6 of 13 substances they had. Some of the substances had food coloring added to them to make the task a little more difficult. All of the six mystery substances were set up the same way each of the four terms. Students could use the pH paper results and the comparison of the indicator solution color to determine what substances they had.

Post-test

The post-test (Appendix B-I) was given in the last week of each 9-week term. Each class was told in advance when the test would be and were given time to review. The post-test was identical to the pre-test given at the beginning of the term. A key to this test can be found in Appendix B-II.

EVALUATION

The majority of the assessment done throughout this unit came from questions imbedded within the laboratory activities we performed in class. The creative writing assignment, *The Life and Times of a Water Molecule* (Appendix B-III), where students were asked to be a water molecule traveling through the water cycle, required a grading rubric (Appendix B-III). The rubric was used to assess that students had gone through the water cycle correctly, had been each of the three states of matter, had visited the minimum six locations required and were creative in their essay.

During "Solution or Suspension? – A Disappearing Act" (Appendix C-III), the objective was to determine which substances really dissolve in water and which are only suspended in it. One of the questions used to determine student comprehension of this concept asked students to explain how a solution and a suspension are different. Student answers were satisfactory. Roughly eighty percent of students could distinguish between a solution and a suspension. One example of a good student response is

> "A solution dissolves completely in the water and you can't see what you mixed anymore. A suspension settles on the bottom and it makes it hard to see through the beaker."

One example of an average student response is

> "A solution's particles are evenly spread and makes the water clearer. A suspension is when the water is cloudy."

One example of a poor student response is

> "A solution floats on the top and when stirred it falls to the bottom and partially dissolves."

The good response to this question shows that the student comprehended the difference between a solution and a suspension and could explain it in their own words. The average response to this question shows that the student only partially comprehended the difference between a solution and a suspension or that they had a difficult time describing the difference in their own words. The poor response to the question shows that the student did not fully comprehend the difference between a solution and a suspension. In the example used above the student did not describe both terms and did not have the proper understanding of what had occurred in the lab activity.

During the "Water: Is It Magic?" lab (Appendix C-IV), the objective was to determine if a solid substance, such as Kool-Aid, once dissolved in water can be recovered. One of the questions asked in the assessment was, "After leaving the petri dish for 24 hours what happened to the water in the dish? What happened to the Kool-Aid?" An example of a good student response is:

> "The water in the petri dish evaporated and the Kool-Aid was left behind."

This student noted that the water had evaporated, a key term, and that the Kool-Aid was still in the petri dish. This response shows that the student could evaluate what had happened and knew the correct terminology to explain what they saw. Approximately fifty percent of students gave good responses to this question.

An example of an average student response is:

> "The water in the dish dried up. The Kool-Aid was left on the bottom of the petri dish."

This student response shows that the student was able to evaluate what had happened in the experiment and could note that the water was no longer in the dish and the

Kool-Aid was still there. However, they did not use the correct term for the property of water that allowed this to happen. Roughly seventeen percent of students gave an average response to this question.

An example of a poor student response is:

> "The Kool-Aid dried out to nothing."

This student response demonstrates a poor understanding of what occurred in the lab. The response makes it sound as if there was nothing at all left in the student's petri dish, which is not an accurate description of what would have been observed. About thirty-three percent of students gave a poor response to this question.

The objectives of the "Water Gamble" activity (Appendix C-VII) were to be able to describe the movement and states of matter of water within the water cycle. The majority of students, approximately ninety percent, did extremely well with describing the state of matter of water throughout the water cycle. One of the questions asked students to give some reasons why water might move in the following ways: from soil to plants, from clouds to lake, from animal to clouds, from animal to soil, and from river to ocean. Students gave a variety of responses to each of these. Roughly seventy-nine percent of students had good responses. Some of the good responses were:

> From soil to plants – "The plants could absorb the water in the soil through their roots."
>
> From clouds to lake – "The clouds would precipitate and rain, snow, hail, or sleet would go into a lake."
>
> From animal to clouds – "Some animals sweat and that evaporates."
>
> From animal to soil – "The animals urinate, which is absorbed by the soil."
>
> From river to ocean – "The river flows out of a delta into the ocean."

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These responses show student thought and consideration for reasons why water moves the way it does through the water cycle. These students were able to take the information they knew about the water cycle and give reasonable explanations for why the water moves from one place to another within the water cycle.

Some examples of poor student responses are:

From soil to plants – "Close to them."

From clouds to lake – "Because the runoff from the rain"

From animal to clouds – "Nature"

From animal to soil – "Location"

From river to ocean – "The water that evaporates can go to a river or ocean."

About twenty-one percent of students gave poor responses. These student responses are either incomplete or show a lack of effort and comprehension about the subject matter. These students appear to have an unclear understanding of why water moves through the water cycle in each of these ways and are unable to give good explanations for this. Some of the one word responses do not give enough detail for the student response to be fully evaluated for comprehension and understanding.

The objective for "Water Cycle Wonder" (Appendix C-VIII) was to determine if water is cleaned as it goes through the water cycle. The final question for this lab was used as an imbedded assessment, "Is water cleaned as it goes through the water cycle? Give reasoning." Some examples of good student responses are:

> "Yes, the water is cleaned when it goes through the water cycle and I know this now because in our lab the water droplets that were on the walls of the cup were clear and clean."

> "The water is cleaned as it goes through the water cycle because the water droplets on the plastic wrap are clear and they are not blue. That is how I know that the water is cleaned during the water cycle."

Some examples of average student responses are:

> "Yes, water is cleaned as it goes through the water cycle because the water was cleaner."

> "Yes it is because the water evaporated onto the cup and condensed."

Some examples of poor student responses are:

> "Yes, water is clean and when it goes through I think that it would be clean enough to drink."

> "Yes, because it is not affected by the bad air."

The good responses to these questions, roughly fifty-three percent, show students clearly grasp the flow of the water cycle and how the simulation done in this lab represented that cycle within our atmosphere. The average responses, roughly twenty-eight percent, showed a concept of how the cycle itself works, but did not show the student tying the lab application to a real-world understanding of how water is cleaned as it cycles through the atmosphere. Roughly nineteen percent of students gave poor responses to these questions. The two examples above both gave the correct answer, that water is cleaned as it goes through the water cycle, however they both went off on unrelated tangents that did not apply to the question or the lab activity at hand.

The "pHinding pH" lab (Appendix C-X) was conducted near the end of each 9-week term and students had experience by then with water testing, including pH. The objective of this lab was to determine the pH value of various substances or solutions using pH paper and an indicator solution, cabbage juice. The question used for assessment was, "You have been monitoring a local stream. The pH of the stream normally ranges from 6-7. Upon testing today, you found the pH to be 4. How will this affect the organisms in the stream?" Some examples of good student responses are:

> "This will affect organisms because they need time to adjust to pH changes and if it went from 6 to 4 then the organisms could die."

> "The pH being lower than normal would mean the water is more acidic and some organisms wouldn't be able to tolerate it and would die."

Some examples of average student responses are:

> "The pH will affect the organisms in the local stream by allowing most of the sensitive organisms that live in the stream to die."

> "Most of the organisms that live in the stream would probably die from the drastic change."

Some examples of poor student responses are:

> "This would affect organisms in the stream because it is getting dirty and more pollution in it."

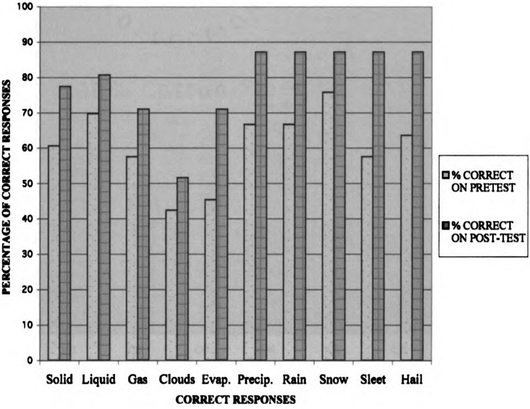
> "I think the affect will make them act different."

The good responses to this question, approximately twenty-one percent, showed that generally students had a clear picture of pH ranges, what is acidic, neutral, and basic and the effect this has on organisms. The first response does not indicate that the pH shift is more acidic, but does indicate that had this occurred more gradually the organisms might be able to adapt physiologically to the change. This showed a conceptual grasp for change over time being more advantageous for these organisms than immediate, dramatic change. The second response showed that the student clearly grasps the concept of this shift being more acidic and that with more acidic water some organisms would not survive. The average responses to the question, approximately forty-six percent, indicate that students know the organisms will die due to the pH change, but gives no further explanation on the matter. There is no discussion of the pH being more acidic or of the neutral range being where the water had been reading previously. The poor responses to the question, approximately thirty-three percent, do not mention pH at all or the demise of organisms. Pollution may very well be a factor leading to the change in pH, but the response should tie in this possibility to make it a better answer. The second of the responses does not indicate how organisms would act differently, only that they would act differently. This answer is very unclear and does not show a grasp of the question or the concept being covered.

The analysis of the overall effectiveness of this water unit was based primarily on pre- and post-test scores. The pre- and post-test (Appendix B-I) were identical and were given to each of the four participating student groups, each 9-week term. The first section of the test was a concept map outlining the water cycle. The second half of the test was a series of six short-answer questions about various aspects of water and the water cycle (question 5).

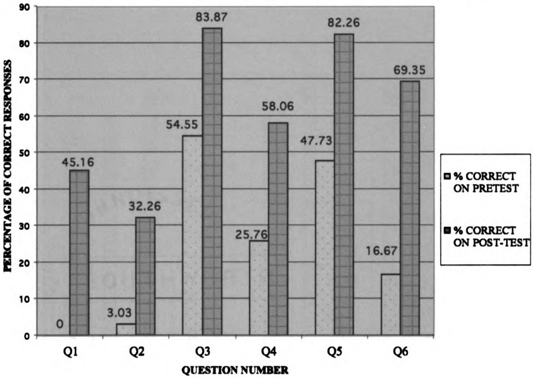
As was expected, both the field group and the classroom group showed an increase in percentage from the pre-test to the post-test. Figure 1 shows the percentage of correct responses by question on the pre- and post-test concept map for the field group.

FIGURE 1 Field Group Pre/Post-test Concept Map Percentage Data



Percentages of correct responses increased for each of the ten questions. The greatest percentage increases were for the "evaporation" response, twenty-six percent, and the "sleet" response, thirty percent. Figure 2 shows the percentage of correct responses on the pre- and post-test short-answer questions by the field group.

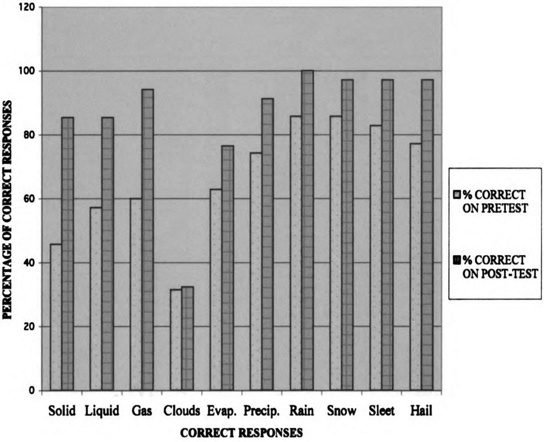
FIGURE 2 Field Group Pre/Post-test Short Answer Questions Percentage Data



This figure also shows the increase in percentage of correct responses from the pretest to the post-test. Percentages of correct responses increased for each of the six questions, most notably question number one, in which student percentages increased by forty-five percent and question number six, in which student percentages increased by fifty-three percent.

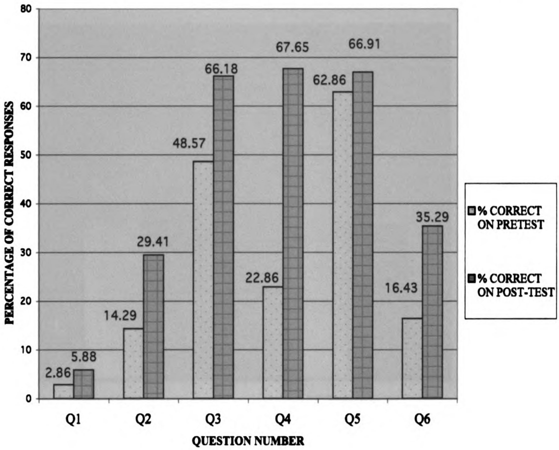
Figure 3 shows the percentage of correct responses by question on the pre- and post-test concept map for the classroom group.

FIGURE 3 Classroom Group Pre/Post-test Concept Map Percentage Data



Percentages of correct responses increased for each of the ten questions; however, for the "clouds" response the percentage increase from the pre- to post-test was less than one percent. The greatest percentage increases were for the "gas" response, thirty-four percent, and the "solid" response, forty percent. Figure 4 shows the percentage of correct responses on the pre- and post-test short-answer questions by the classroom group.

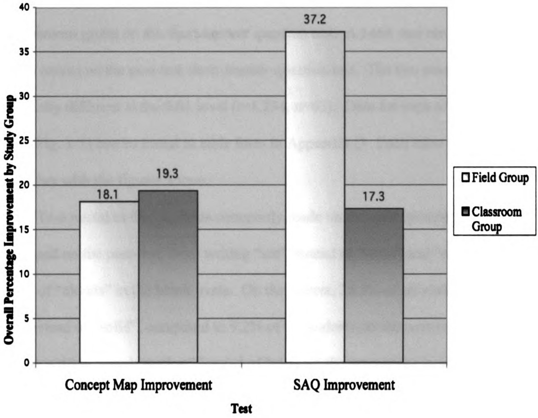
FIGURE 4 Classroom Group Pre/Post-test Short Answer Questions Percentage Data



This figure also shows an increase in percentage of correct responses for each question from the pretest to the post-test. It is interesting to note that on question number one, where the field group improved by forty-five percent, the classroom group only improved by three percent and on question number six, where the field group improved by fifty-three percent, the classroom group only improved by nineteen percent. The classroom group improved, most notably on question number four, by forty-five percent.

Figure 5 compares the overall percentage increase for the two study groups and the improvement in that percentage.

FIGURE 5 Comparison of Overall Improvement from Pre-test to Post-test Percentages by Study Group



The percentages of correct responses increased for both study groups on the concept map and the short-answer question tests from the pretest to the post-test. On the water cycle concept map, the field group percentage increase from the pretest to the post-test was 18.1%. The classroom group had an increase of 19.3%. The field group however, did have a greater increase in percentage from pretest to post-test on the short answer question section of the test. The field group percentage increase from the pre- to post-test was 37.2%, whereas the classroom group increase was only 17.3%.

This figure shows that the classroom group improved by 1.2% more than the field group on the concept map test and that the field group improved by 19.9% more than the classroom group on the short-answer question test. A t-test was run to compare the two means on the post-test short-answer question test. The two means are statistically different at the 0.01 level (t=1.234, n=63). Data for each of the figures above (Fig. 1-5) can be found in table form in Appendix D. Each table corresponds by number with the figures above.

Two mistakes that students commonly made on the concept map, both on the pretest and on the post-test, were writing "ice" instead of "solid" and "condensation" instead of "clouds" in the blank ovals. On the pretest, 26.5% of all students wrote "ice" instead of "solid", compared to 9.2% of all students on the post-test. For students writing "condensation" instead of "clouds" the percentage increased on the post-test. 13.2% of all students tested did this on the pre-test, compared to 26.2% on the post-test. Students understand that ice is a solid and that glaciers are ice, which can explain the mistake on this oval. On the "clouds" oval, students may not have fully read the concept map before writing an answer. They knew by the time they got to that oval that they were being tested on the water cycle, and they knew condensation as a step in the cycle. By not fully reading the context clues one could easily make the mistake of writing the process and not where it occurs. The "clouds" oval was the most missed question on the concept map on both the pretest and the post-test. 63.2% of all students tested missed this on the pretest and 58.5 % of students missed it on the post-test.

On the pre-test, I asked students to make a true effort to answer every question. I told students if they absolutely could not answer the question that I would prefer if they would write "I don't know" instead of leaving the question blank. This helped me in knowing that the students did not accidentally skip a question, but had looked at it and could not answer the question. The number of "I don't know" responses on the pretest concept map totaled 11.1%. On the post-test concept map the "I don't know" response was down to 0.2%. The number of "I don't know" responses on the pre-test short-answer questions was 22.1%. On the post-test these responses were down to 4.6%. Students did still leave some question blank on both the pre- and post-tests. The number of blank questions on the pretest concept map was 6.3% and on the post-test concept map it was 3.5%. On the pretest short-answer questions the number of blank questions was1.2% and the percentage increased to 2.3% on the post-test.

The most common responses on the short-answer questions and the percentage of the overall students tested that gave that response are listed below:

1. Approximately how much water (water-containing liquids) must a human drink daily to replace water lost through bodily excretions and evaporation from skin and lungs? (Content Standard C)
   Pretest – 8 glasses (23.5%)
   Post-test – 2 liters (21.5%) – correct response

2. What percentage of the Earth's water is fresh water? (Content Standard D)
   Pretest – 10% (19.1%)
   Post-test – 3% (27.7%) – correct response

3. Which would contain a greater amount of dissolved oxygen, a river with rapids or a still lake? Explain your choice. (Content Standard B)
   Pretest – River (50%), Lake (30.9%), Same (2.9%)
   Post-test – River (78.5%) – correct response
   Lake (21.5%)

4. Seawater has a pH of about 8.6. Is seawater acidic, basic, or neutral? Explain your choice. (Content Standard B, D)
    Pretest – Acidic (27.9%), Basic (25%), Neutral (7.4%)
    Post-test – Acidic (18.5%)
    Basic (67.7%) – correct response
    Neutral (9.2%)

6. Name three freshwater aquatic invertebrates. (Content Standard C)
    Pretest – Fish (25%), Snails (14.7%), Clams (8.8%)
    Post-test – Mayfly nymph (35.4%)
    Snails (18.5%)
    Damselfly nymph (15.4%)
    - all three are correct responses

Question five (Content Standard B, C, D) related to the basic steps of the water cycle and students were asked to name and describe each of these steps. Student responses included a discussion of evaporation, condensation and precipitation. Fifty-six percent of all students tested answered question five correctly on the pre-test and seventy-four percent answered correctly on the post-test. For question number six, the students were able to name some aquatic macroinvertebrates on the pretest, but could identify many more after the unit. The classroom group identified 3 aquatic macroinvertebrate species on the pretest and 11 on the post-test. The field group identified 5 aquatic macroinvertebrate species on the pretest and 16 on the post-test. Many students did not know what an invertebrate was, making it difficult to then decide on aquatic macroinvertebrates.

CONCLUSION

As was discussed in the introduction, this unit focused on a constructivist approach to teaching middle school students about the environment, specifically water quality. Since research shows that young adolescents can become restless when asked to sit for long periods of time, I chose to provide activities that would allow students to interact with their peers and would involve physical movement both in the classroom and at a river site. It is also important to have students at the middle school level start exploring concepts in a more inquiry-based fashion. The environmental science topics we discussed affect the students and their world so I tried to present them in such a way that would encourage further investigation, an application of the constructivist approach to teaching.

Teaching the water unit was a great experience, both for my students and for me. Although only two 9-week terms of students were able to study at the river, all students had the lab experiences and were able to test water sources from the river or from freshly fallen snow. By testing these water sources, as opposed to simply testing tap water, students were able to make a real-world connection in evaluating the water quality of a real outdoor water source that has not been treated before delivery to us.

In the "Solution or Suspension? – A Disappearing Act" activity (Appendix C-III), students were asked to record their observations about what was happening in beakers as they added substances to them. I was looking for students to describe solutions in a way that showed the substance was dissolving and disappearing and to describe suspensions as a substance creating a cloudy appearance in the water.

Approximately eighty-five percent of the students simply wrote "This is a solution" or "This is a suspension". After the first term group, I gave a bit more guidance as to what I was wanting for observations and students did improve, but some still went with the simplest, most direct option and just stated solution or suspension for their observations. Overall, this activity was effective because students (eighty percent) were able to determine and explain how solutions and suspensions are different.

Students thoroughly enjoyed the "Water Gamble" (Appendix C-VII) activity about the water cycle. This activity was more like a game than any of the other labs and activities that were done. Students rolled a die at each station to determine their path through the water cycle and were able to draw and move about the classroom. Students were able to interact with each other and compare their travels as they were moving around. Some students got frustrated as they continued to roll the die and remain at the same water station. This provided a great learning experience in the post-activity discussion when I asked those students to explain, in terms of the water cycle, why they remained at that one water station for so long. Students were able to look at their path and make logical explanations for their movement through the water cycle.

The "pHinding pH" activity was time consuming and had a few too many steps for my students. First term students did not pay attention to all of my directions or to the procedure and did not finish the lab in one session. Several of the students poured out all of their vials after being told to save them to finish the lab the following day. This created some chaos the next day when the lab needed to be finished and some students had to start from scratch. Students from all of the terms seemed to have some difficultly with this experiment. Terms 2, 3, and 4 all managed to finish the lab, some having to clean up after the bell. However, they did not get all of the coloring done for the data section and thus had to "wing it" the next day, as they had already disposed of all of their vials and no longer had them for reference. This came back to haunt some students when this activity was used to help determine the mystery substances in the assessment activity, "It's a Mystery to Me".

Students had very little knowledge of the freshwater aquatic macroinvertebrates at the start of the water unit; only about seventeen percent of the responses on the pre-test were correct. All students tested could name only a total of six types of macroinvertebrates, combined, on the pre-test given at the start of each term. I introduced students to these organisms by reading short passages from A Guide to Common Freshwater Invertebrates of North America by J. Reese Voshell, Jr. These passages were on the definition of freshwater invertebrates and why they should be studied. This gave students a base of information and gave them an idea of why we were going to be learning about macroinvertebrates. In the classroom group students learned about the macroinvertebrates by taking notes on them and looking at picture cards that the school had purchased for this unit and an enlarged key to life in the river. The field group looked at the picture cards and the key to life in the river and took these out to the river site with them. They familiarized themselves with the organisms prior to the river trips, but were able to use the key and the picture cards to help them identify the organisms they collected in their dip nets. Both student groups were able to identify freshwater aquatic macroinvertebrates on the post-test, but the field group was able to identify a total of five more species than the classroom group.

Combined, students in both groups were able to name a total of eighteen types of macroinvertebrates. Having the hands-on experience of collecting the macroinvertebrates in the field and keying them out gave the field group students an advantage at retaining and remembering the organisms they had found. Students enjoyed these trips to the river and attendance on these days was very high. Students knew what tests they were required to do and they took it seriously and got it done. Some tests took longer than others and thus some students had extra time on their hands, but most handled themselves very well.

The "It's A Mystery to Me" lab activity (Appendix B-V) was used to assess student knowledge gained on pH. In this activity students were instructed to use their findings from the "pHinding pH" activity (Appendix C-X) to help them determine the identity of the six mystery substances they were given. This worked best for the first three terms, but fourth term students were at a disadvantage due to the quality of the cabbage juice indicator. The indicator solution was a new batch and was a blue shade when the "pHinding pH" activity was done and then subsequently changed to a violet color prior to conducting the "It's A Mystery To Me" lab activity. This group had to rely mostly on the pH paper results and other sensory clues, such as smell, to determine the mystery solutions since the indicator solution color change was difficult to use as a guide.

Overall, both the field group and the classroom group improved from the pretest to the post-test. The concept map portion of the test provided many prompters and context clues to help students figure out the answers for the blank ovals. The short-answer question portion of the test required students to complete the more difficult task of applying their knowledge to construct a reasonable response to the questions posed. In repeating this unit in the future, I plan to change the pre- and post-test from two sections, the concept map and the short-answer questions to a longer completely short-answer question format. This is due to the difficulty in determining if students gained knowledge on the information tested on the concept map or if they were simply able to utilize the context clues to determine the answers to the map. I feel that the short-answer questions gave a much better idea of the amount of information learned and the depth to which students comprehended the information covered within the unit.

The classroom group, in this study did better on the water cycle concept map and the field group did significantly better on the short-answer questions. As stated previously, I believe the exposure to the water cycle at the end of the first 9-week term in eighth grade science afforded the classroom group students an advantage on the concept map that the first half of the field group did not have.

As was also previously mentioned, students were given specific instruction on the pre-test to not leave questions blank if they did not know an answer, but instead to write "I don't know". On the pre-test short-answer questions the number of blank responses was 1.2% which increased to 2.3% on the post-test, for the same question set. A possible explanation for this increase is that the statement above was made only prior to the pre-test and not the post-test, thus students left questions completely blank, as opposed to writing that they did not know the answer. Also on the short-answer questions test, question number three asked students to explain why they chose a river with rapids or a still lake as containing a greater amount of dissolved oxygen. Seventy-eight percent of students answered correctly, a river with rapids, on the post-test. Roughly fifty percent of students had a good explanation as to why the river would contain more dissolved oxygen, stating in some way that the water's movement allowed more air to mix with the water creating a greater amount of dissolved oxygen.

The content standards noted previously were covered throughout this water unit. Content Standard A: Science as Inquiry was covered with every lab activity performed and with every trip to the river. The other three standards were also covered during lab activities and river trips. These standards were covered as well on the pre- and post-test. The concept map, over the water cycle, covered content standards B, C, and D. The short-answer questions covered these standards as well (see evaluation for content standard covered by each question). Again, both the field group and the classroom group improved from the pretest to the post-test. I feel that both groups showed improvement due to the in class hands-on labs and activities related to water quality and the water cycle. I believe the field group did better on the short-answer questions due to the added exposure to the material they had by going out to a river and doing sampling. As was previously mentioned, "Using the environment as a context for learning changes student outlook and results in better academic performance across grades K-12 compared with traditional schooling" (Wakefield, 2001). The field group students were able to apply what we did in class to a real-world experience and see the usefulness of what they were learning. I believe the constructivist approach, with hands-on activities, cooperative learning and outdoor river experiences, played a role in these middle school students, specifically those of the field group, becoming more interested in the water topics and helped them to retain the information better over the course of the 9-week term.

APPENDICES

APPENDIX A

14 April 2003

Dear Students/Parents/Guardians,

For the past few years I have been working on a Masters of Science degree through the Division of Science and Mathematics Education at Michigan State University. I am currently collecting data for my thesis. This past summer I redesigned and organized a water quality unit for my JASON Project exploratory course. This unit will include inquiry based laboratory exercises and field research at local water sites, to include data collection and observation of real-world ecological interactions. This unit will be done throughout the nine weeks of the course.

In order to evaluate the effectiveness of this unit, I will be collecting data on pre- and post-tests, inquiry and reflection questions from the laboratory and field experiences and homework, a creative writing assessment, and student portfolios. Some homework responses or sections of laboratory reports and compiled test scores may be used. This work is required of all students independently of my thesis. With your permission, I would like to use data from the above mentioned items for my Master's Thesis. **At no time will any student's name be used in, or connected to the thesis.**

In addition to the above data collection, I also plan to take photographs of the students when we are doing various laboratory and field research activities. These photos may be used to enhance my thesis defense and a possible presentation to other science teachers at a local science conference. As above, no student's name or individual data will be attached to these photographs.

Please complete and return the attached permission form to me by this Friday, April 18, 2003. I am asking to use your student's data from the water quality unit for my thesis. There is no penalty for denying permission to use this data. Your decision will not affect your student's grade in any way. Declining permission in no way exempts the student from doing the same work as everyone else. Declining simply means I will be unable to use his/her classwork in my thesis. Should you choose to withdraw your student from the study after signing the permission form, you may do so at any time. Your privacy will be protected to the maximum extent allowable by law.

Thank you for your time. If you have any questions regarding participant's rights as human subjects for research please contact the Internal Review Board Chairperson, Ashir Kumar, 202 Olds Hall, Michigan State University, East Lansing, MI 48824; the telephone number is (517) 355-2180 and the e-mail is ucrihs@msu.edu. Please contact me at 651-5034 ext. 1017, with any questions or concerns about your child or this study.

Yours, in education,

Angela Clark-Pohlod

Please read the following permission statements carefully and check all that apply:

Data Use:

_____ I give Mrs. Clark-Pohlod permission to use my son/daughter's data collected from the water quality unit to be done in the JASON Project course. Mrs. Clark-Pohlod will not use my son/daughter's name in her thesis and all student data will remain confidential to the maximum extent allowable by law.

_____ I do not wish Mrs. Clark-Pohlod to use my son/daughter's data collected from the water quality unit in her thesis.

Photograph Use:

_____ I give Mrs. Clark – Pohlod permission to use my son/daughter's photograph, taken during laboratory and field research activities, in the presentation of her thesis defense.

_____ I do not wish Mrs. Clark-Pohlod to use my son/daughter's photograph in the presentation of her thesis defense.

Signatures:

Student Name (Printed) ____

Student Signature ____ Date _______

Parent Signature ____ Date _______

*PLEASE NOTE: This consent form was given out each of the four 9-week terms on the following dates: September 3, 2002
November 1, 2002
January 27, 2003
April 14, 2003

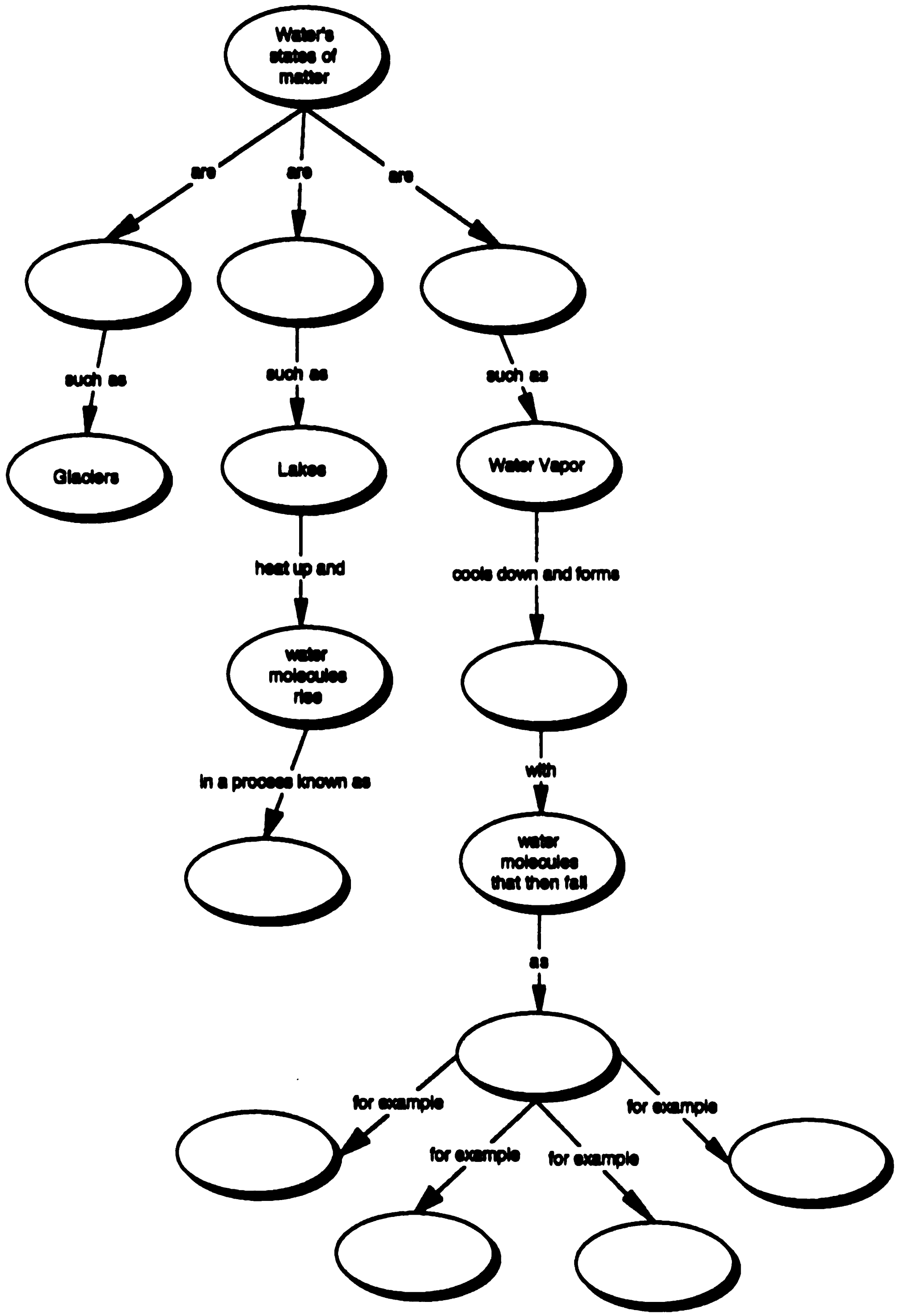
APPENDIX B

Appendix B-I

Clark-Pohlod
JASON Project

Name ____________________
Date __________ Period ________

Water Quality Unit
Pre-/Post-test Concept Map



Water Quality Unit

Pre-/Post-test Short Answer Questions

Answer each of the following questions in complete sentences.

1. Approximately how much water (water-containing liquids) must a human drink daily to replace water lost through bodily excretions and evaporation from skin and lungs?

2. What percentage of the Earth's water is fresh water?

3. Which would contain a greater amount of dissolved oxygen, a river with rapids or a still lake? Explain your choice.

4. Seawater has a pH of about 8.6. Is seawater acidic, basic, or neutral? Explain your choice.

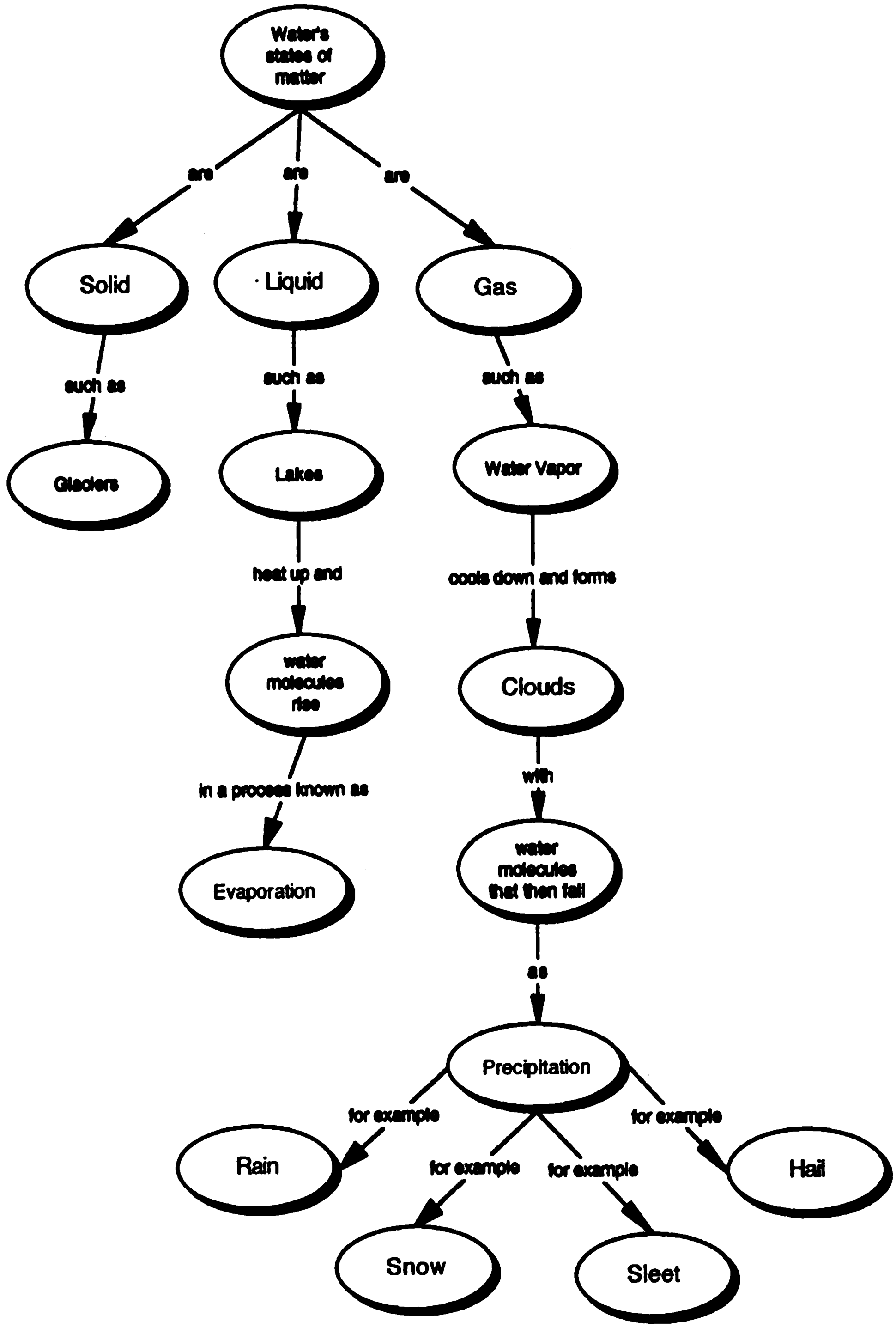
5. List and explain the basic steps involved in nature's water purification system, the water cycle.

6. Name three freshwater aquatic invertebrates.

Appendix B-II

Name Key
Date ______ Period ______

Water Quality Unit
Pre-/Post-test Concept Map



Water Quality Unit
Pre-/Post-test Short Answer Questions

Answer each of the following questions in complete sentences.

1. **Approximately how much water (water-containing liquids) must a human drink daily to replace water lost through bodily excretions and evaporation from skin and lungs?**

   A human must drink approximately 2 liters of water daily to replace water lost through bodily excretions and evaporation from skin and lungs.

2. **What percentage of the Earth's water is fresh water?**

   Approximately 3 percent of the Earth's water is fresh water.

3. **Which would contain a greater amount of dissolved oxygen, a river with rapids or a still lake? Explain your choice.**

   A river with rapids would contain a greater amount of dissolved oxygen than a still lake because the water is being aerated (air is mixed with water at the rapids).

4. **Seawater has a pH of about 8.6. Is seawater acidic, basic, or neutral? Explain your choice.**

   Seawater is basic. The pH scale ranges from 0 to 14 with 0 being the most acidic and 14 being the most basic. A pH value of 7 is neutral.

5. **List and explain the basic steps involved in nature's water purification system, the water cycle.**

The water cycle has three basic steps; evaporation, condensation, and precipitation. Evaporation occurs when water changes from a liquid to a gas. As water evaporates the materials dissolved in water are left behind. As the gas, water vapor, reaches the atmosphere it begins to collect on tiny dust particles and forms clouds. As the clouds form the water vapor begins to get heavy and fall from the cloud as precipitation. Precipitation can be a solid or a liquid. Precipitation can be rain, sleet, snow or hail. The precipitation that falls to the ground can be cleaned by bacterial action in the soil or by filtration through sand and gravel.

6. **Name three freshwater aquatic invertebrates.**

Answers will vary. Some possible freshwater aquatic invertebrates might be caddisfly larva, mayfly nymphs, stonefly nymphs, damselfly nymphs, dragonfly nymphs, midge larva, and rat-tailed maggots.

Appendix B-III

The Life and Times of a Water Molecule

Purpose:

- To describe the movement of water within the water cycle, and
- to identify the states of water as it moves through the water cycle.

Guidelines:

- You will pretend to be a water molecule moving through the water cycle.
  - Write in first person (Me, myself, I)
- This is a creative writing assignment and thus should be imaginative, but must also include facts about the water cycle and how it works.
- You may begin in the state of matter and location/source that you wish.
- You must clearly express where you are (location/source), what state of matter you are in, and what is happening to you in each state of matter. Some questions you may want to consider are:
  - How would you be transported from a puddle on the ground to a cloud up in the atmosphere?
  - What factors in the atmosphere cause you to form into a cloud?
  - If it gets very cold, what happens to a liquid such as water?
  - When water is heated, what state of matter does it change into? Why?
  - If an animal drinks you what are the possible ways you could be reintroduced into the water cycle?
- You will need to include at least **six** locations in your travels. You may only repeat locations/sources twice.
- You will need to be each of the **three** states of matter.
- You must turn in a rough draft ***and*** a typed final copy.
  - The final copy must be *at least* two pages, double-spaced, and 12 point font in black ink
- Spelling and grammar will be graded.

The Life and Times of a Water Molecule
Grading Rubric

Basic Required Elements:	Points Possible	Points Earned
Final Draft Typed/Double spaced/12 point font	3	______
Rough Draft attached to back of final draft	1	______
Correct Spelling/Grammar/Punctuation	3	______
Written in first person	2	______
Six locations/sources used Has no more than two repeated sources	3	______
Text is creative/original/imaginative/accurate	5	______
Subtotal	17	______

Content Requirements:		
All parts of the water cycle are included	4	______
Information is accurate/factual	5	______
Location has been clearly given	6	______
Three states of matter are included	6	______
Proper state of matter is used for each location	6	______
Description of what is happening in each state of matter	6	______
Subtotal	33	______

Total	50	

Appendix B-IV

Water Quality Vocabulary Quiz

Word List:

Acid	Eutrophication	Pathogens
Aneomometer	Fecal Coliform	Phosphates
Base	Habitat	Photosynthesis
Baseline Study	Inorganic	Precipitation
Biodiversity	Invertebrate	Salinity
Compass	Larva	Sediment
Current Speed	Nitrates	Turbidity
Density	Nymph	Water Clarity
Dissolved Oxygen	Organic	Watershed
Ecosystem	pH	Zooplankton

***Directions:** Read the following definitions carefully. Write the term from the list above that best fits the definition in the space provided. Be sure to spell the terms correctly.*

_______________ 1. A measure of the clarity of the water

_______________ 2. A biological agent that can cause a disease

_______________ 3. The environment where a particular plant or animal is normally found

_______________ 4. An immature insect, such as an aquatic mayfly or damselfly; this form does not resemble their adult flying form

_______________ 5. An instrument used to measure the speed of wind

_______________ 6. A study designed to collect critical data to be used for comparison or as a control in a later study

_______________ 7. The amount of oxygen dissolved in water

_______________ 8. The variety of plant and animal species in an environment

_______________ 9. An animal without a backbone

_______________ 10. An area of land that delivers runoff water, sediment, and dissolved substances to surface water bodies, such as rivers and lakes

_______________ 11. Any form of water, such as rain, sleet, or snow, that falls to earth's surface

_______________ 12. The newly hatched, immature, wingless, and often wormlike feeding form of many insects

_______________ 13. A measure of the acidity or alkalinity of a solution

_______________ 14. The solids that settle to the bottom of a liquid

_______________ 15. The speed at which water flows

_______________ 16. A group of organisms together with its environment, seen as a unit

_______________ 17. A substance that produces positively charged hydrogen ions when dissolved in water

_______________ 18. Process by which chlorophyll—containing cells in green plants convert light to chemical energy and synthesize organic compounds from inorganic compounds

_______________ 19. The enrichment of water with nutrients, usually phosphorous and nitrogen, which stimulates the growth of algal blooms and rooted aquatic vegetation

_______________ 20. The mass of an object divided by its volume

Water Quality Vocabulary Quiz
Answer Key

Word List:

Acid	Eutrophication	Pathogens
Aneomometer	Fecal Coliform	Phosphates
Base	Habitat	Photosynthesis
Baseline Study	Inorganic	Precipitation
Biodiversity	Invertebrate	Salinity
Compass	Larva	Sediment
Current Speed	Nitrates	Turbidity
Density	Nymph	Water Clarity
Dissolved Oxygen	Organic	Watershed
Ecosystem	pH	Zooplankton

Directions: *Read the following definitions carefully. Write the term from the list above that best fits the definition in the space provided. Be sure to spell the terms correctly.*

___*Turbidity*____ 1. A measure of the clarity of the water

___*Pathogens*____ 2. A biological agent that can cause a disease

___*Habitat*______ 3. The environment where a particular plant or animal is normally found

____*Nymph*_____ 4. An immature insect, such as an aquatic mayfly or damselfly; this form does not resemble their adult flying form

_*Anemometer*___ 5. An instrument used to measure the speed of wind

*Baseline Study* 6. A study designed to collect critical data to be used for comparison or as a control in a later study

Dissolved Oxygen 7. The amount of oxygen dissolved in water

_*Biodiversity*____ 8. The variety of plant and animal species in an environment

__*Invertebrate*___ 9. An animal without a backbone

__*Watershed*____ 10. An area of land that delivers runoff water, sediment, and dissolved substances to surface water bodies, such as rivers and lakes

_*Precipitation*___ 11. Any form of water, such as rain, sleet, or snow, that falls to earth's surface

___*Larva*_______ 12. The newly hatched, immature, wingless, and often wormlike feeding form of many insects _____*pH*______ 13. A measure of the acidity or alkalinity of a solution

__*Sediment*_____ 14. The solids that settle to the bottom of a liquid

_*Current Speed*__ 15. The speed at which water flows

__*Ecosystem*____ 16. A group of organisms together with its environment, seen as a unit

_____*Acid*______ 17. A substance that produces positively charged hydrogen ions when dissolved in water

_*Photosynthesis*__ 18. Process by which chlorophyll—containing cells in green plants convert light to chemical energy and synthesize organic compounds from inorganic compounds

_*Eutrophication*__ 19. The enrichment of water with nutrients, usually phosphorous and nitrogen, which stimulates the growth of algal blooms and rooted aquatic vegetation

__*Density*_______ 20. The mass of an object divided by its volume

Appendix B-V

It's A Mystery To Me

Objective:

In this activity, you will use your previous knowledge of pH to determine what each of six mystery substances are.

Materials:

Six test solutions in labeled jars (Substances A, B, etc.)
Laminated lab sheet
pH paper
pH indicator solution
6 small test vials
wax pencil
paper towels

Procedure:

1. Read through the entire procedure before beginning this activity.
2. Collect all of your materials, except the pH indicator solution and the test substances.
3. Label each vial, each with a letter A-F.
4. One vial at a time, carefully add 1-2 ml of each test solution to the appropriately labeled vial. Take each vial back to your table.
5. Use one strip of pH paper per vial to test the pH of each substance. Compare the pH paper to the color scale on your laminated lab sheet. Record the pH value in the "pH value determined from pH paper" column of your data table.
6. One vial at a time, carefully add about 3 ml of pH indicator. Gently swirl each vial. Place the vial on the laminated lab sheet and observe the color. Neatly record the color of each substance in the appropriate column of your data table.
7. Using your "pHinding pH" lab, compare today's data to the data previously collected. Determine what each of your mystery substances are and fill in the appropriate column of your data table.
8. Empty the contents of each of your vials into the sink and rinse them thoroughly. Be sure to get the wax pencil off of the vials. Dry them by placing them upside down in your lab basket.
9. Throw away your used pH paper and paper towels.
10. Return your supplies to the back counter or where instructed by your teacher.

Data:

Mystery Substance	pH value determined from pH paper	Solution color with indicator	What is the mystery substance?
A			
B			
C			
D			
E			
F			

It's A Mystery To Me

Answer Key

Data:

Mystery Substance	pH value determined from pH paper	Solution color with indicator	What is the mystery substance?
A	*7*	*color description will vary somewhat by group*	*pH buffer 7*
B	*~8-9*	*color description will vary somewhat by group*	*salt water*
C	*~9*	*color description will vary somewhat by group*	*baking soda & water*
D	*~3-4*	*color description will vary somewhat by group*	*pop*
E	*~3*	*color description will vary somewhat by group*	*vinegar*
F	*~2-3*	*color description will vary somewhat by group*	*lemon juice*

APPENDIX C

Our Water World: What do we need to know?

Water

- There is the same amount of water on the earth today as there was when the earth was formed. The water from your faucet could contain molecules of water that dinosaurs drank!

- 34 billion gallons of water are processed daily by the 56,000 community public water systems in the United States.

Water Facts...

- Water is the only substance found on earth naturally in all three states of matter:
  -Liquid (water) -Solid (ice) -Gas (water vapor)

More Water Facts...

- 80% of the earth's surface is water.

- Of all of the earth's water, 97% of it is oceans or seas (saltwater).

- 2% of the earth's water is frozen and thus unusable.

- 1% of the earth's water is actually suitable for drinking water.

Still More Water Facts...

- A tomato is 95% water.

- An ear of corn is 80% water.

- The human body is 66% water.

Characteristics of Water:

- Water will dissolve more substances than will any other liquid, and is thus called "the universal solvent."

- Water molecules are strongly attracted to one another through their two hydrogen atoms.

- The density of water is ~ 1.000.

Humans and Water:

- Remember, the human body is 66% water.

- A human must consume ~ 2.5 quarts (2.366 liters) of water every day in foods and/or liquids to stay healthy.

Humans and Water: In what ways do humans use water?

Humans use water for...

- Recreational Activities
  - -Boating
  - -Fishing
  - -Scuba Diving
  - -Swimming
- Agriculture
- Industry
- Household activities
  - -Bathing
  - -Toilets
  - -Laundry
  - -Cooking
- Food & Drink

Humans and Water:
How does human use affect the water?

Human Effects on Water...

- Run off from agriculture can add fertilizer, pesticides, herbicides and animal waste to the water

- In suburban areas, chemicals used on lawns, household pesticides, pet wastes, and detergents may end up in the water

Human Effects on Water...

- *Although the practice is much less common today than in the past, factories in urban areas may dump dangerous chemicals into a river.*

- *Anything that is dropped on the ground, poured down the drain or tossed in the trash has the potential to pollute our source of drinking water.*

Humans and Water: Polluting Our Water
How can we tell if the water is polluted?

Water Quality Testing:

- *Visual Inspection*
  - *Look for trash or other pollutants in and around the water*

- *Biological Inspection*
  - *Look for aquatic organisms in and around the water*

- *Chemical Inspection*
  - *Do chemical tests to determine the health of the water*

Chemical Inspection of Water:
What tests can we do?

- *Dissolved Oxygen*

  - *Oxygen is necessary for all aquatic life*

  - *The amount of oxygen required varies according to species and stage of life*

  - *Oxygen is added to water by mixing with the air*

  - *A "DO" concentration of 3ppm or higher is necessary for a healthy environment*

Chemical Inspection of Water:
What tests can we do?

- ***Temperature***

  - ***Affects the percent saturation of dissolved oxygen in the water***

  - ***Most aquatic organisms cannot tolerate even minor changes in water temperature***

  - ***Thermal pollution is the discharge of heated water from industrial operations and runoff from surfaces such as roads and parking lots that artificially increases water temperature***

Chemical Inspection of Water:
What tests can we do?

- ***pH***

  - ***The amount of hydrogen ions in a solution***
    - ***Measures acidity***

  - ***A pH of 6.5 to 8.2 is optimal for most organisms***

  - ***pH is measured on a logarithmic scale, therefore a pH of 5 is ten times more acidic than a pH of 6***

Chemical Inspection of Water:
What tests can we do?

- ***Density***

  - ***In physics, density is the ratio of the mass of a substance to it volume, and it can be calculated by dividing the mass by the volume***

- ***Specific gravity is the ratio of the density of a liquid to the density of distilled water at 4^oC. This measurement can be used to determine salinity***

- ***Most aquatic organisms are adapted to a specific range of salinity***

Chemical Inspection of Water:
What tests can we do?

- ***Turbidity***

  - ***The measurement of suspended particles in the water***

  - ***Soil erosion, urban runoff, algal blooms, and bottom sediment disturbances can increase turbidity***

  - ***High turbidity can inhibit light from reaching aquatic plants and make hunting difficult for visual predators***

Analysis of Testing:
What does it all mean?

Water's Journey...

- ***The water we use every day has a long journey back from the drain to the tap.***

- ***Our everyday activities help shape the health of our local and global water systems.***

Think Globally...

Act Locally!

**These water notes were done in Microsoft Power Point for presentation to students.*

THE EARTH'S WATER: A DEMO TEACHER NOTES

Purpose:

This activity is useful to demonstrate how much of earth's water is fresh water.

Materials:

2-liter plastic bottle
salt
green food coloring
yellow corn oil
water

Procedure:

1. Put a few drops of green food coloring into the bottom of the plastic bottle.
2. Pour water into the container until it is just past the base of the neck of the bottle.
3. Add 2-3 teaspoons of salt to the green water.
4. Slowly add 60 ml of corn oil on top of the salt water in the 2-liter bottle.

Explanations/Discussions:

Explain that the green water represents the water from the oceans on earth, which is salty and cannot be used to drink or to water fresh water plants. Then explain that the corn oil represents the 3% of fresh water available on the earth. This is all of the fresh water available for drinking, plant use and all of our other fresh water needs. This can lead into a discussion of water availability, pollution, etc.

Appendix C-III

Solution or Suspension? - A Disappearing Act

Background:

If a substance has dissolved in water, the solution (the mixture of water and the dissolved stuff) should look the same throughout. The particles will have broken up and will be spread evenly in the water. If the mixture stays cloudy, and the particles hang there and then settle to the bottom, it is a "suspension" rather than a "solution".

Objective:

In this activity, you will determine which substances really dissolve in water and which are only suspended in it.

Materials:

5 small beakers or plastic cups
Wax pencil or Sharpie marker
Spoon or stirring rod
Paper towels
Salt
Flour
Baking soda
Sugar
Dirt

Procedure:

1. Read through the entire procedure before beginning this activity.
2. Label each of the beakers/cups with a different substance from the materials list.
3. Fill the beakers/cups with 200 – 250 mL of cold water.
4. Into each of the appropriately labeled beakers/cups add 1 teaspoon of each substance (salt, flour, baking soda, sugar, and dirt).
5. Stir each of the beakers/cups. Be sure to clean your spoon/stirring rod by wiping it off with paper towel between beakers/cups.
6. Observe what happens in each of the beakers/cups.
7. Record your observations below.

Observations:

Salt/Water Mixture:

Flour/Water Mixture:

Baking Soda/Water Mixture:

Sugar/Water Mixture:

Dirt/Water Mixture:

Data:

Place an "X" in the appropriate column below to indicate whether the substance forms a solution or a suspension when mixed with water:

	Solution?	**Suspension?**
Salt		
Flour		
Baking Soda		
Sugar		
Dirt		

Analysis:

1. **Explain how a solution and a suspension are different.**

2. **Do you think using hot water instead of cold water would have made a difference in the results of this experiment? Explain how you would test this.**

Appendix C-IV

Water: Is it Magic?

Background:

Water can be found as a solid, liquid, or a gas. In its liquid form, many substances, such as salt, sugar, and Kool-aid, when placed in water will seem to disappear. Why is this? Is it magic or is this a special property of water? Water is known as a solvent, which means it is a dissolving agent; therefore substances placed in it will dissolve and form a uniform mixture with the water.

Problem:

Once an item, for example, Kool-aid, is dissolved in water can it be recovered? What property of water would make this possible?

Hypothesis:

____

____

____

Materials:

1 Petri dish base or lid
1 disposable pipette
5 mL sample of Kool-aid mixture
Paper towels

Procedure:

1. The instructor will make a mixture of Kool-aid and water. You should note that the Kool-aid powder is dissolved in the water.
2. Collect your materials.
3. Collect 5 mL of the Kool-aid mixture and place it neatly into the petri dish. Gently swirl the petri dish to coat the full surface of the dish with the Kool-aid mixture.
4. Set petri dish on a paper towel on the counter where the instructor directs you.
5. Leave petri dish for 24 hours.
6. After 24 hours, observe petri dish.
7. Write your observations in the observation section below.

Observations:

Analysis:

1. When the Kool-aid was introduced into the water, how did you know that it had dissolved?

2. After leaving the petri dish for 24 hours what happened to the water in the dish? What happened to the Kool-aid?

3. The water in this experiment began as a liquid. What other state of matter (solid, liquid, gas) was it in this experiment?

Water: Is it Magic?
Key & Teacher Notes

Analysis:

4. **When the Kool-aid was introduced into the water, how did you know that it had dissolved?**

   When the Kool-aid was introduced into the water, I knew it was dissolved because the water turned the color of the Kool-aid and I could no longer see any of the Kool-aid powder in the water.

5. **After leaving the petri dish for 24 hours what happened to the water in the dish? What happened to the Kool-aid?**

   After 24 hours the water in the dish evaporated (dried up, wasn't there, disappeared). The Kool-aid had formed into small crystals and were in the bottom of the petri dish.

6. **The water in this experiment began as a liquid. What other state of matter (solid, liquid, gas) was it in this experiment?**

   The water in this experiment was also a gas when it evaporated out of the petri dish.

TEACHER NOTES:

The Kool-aid to water ratio that worked best was 2 regular-sized packets of Kool-aid mixed into 300mL of warm water. The Kool-aid dissolves fairly completely and after the water evaporates the Kool-aid forms nice crystals.

Appendix C-V

Video Questions: Eyewitness Pond & River

***Directions:** Read ALL of the questions carefully before the video begins. Answer the questions as you watch the video. You do not need to answer in complete sentences. Do NOT talk during the video. You will be given time to compare answers with a partner when the video has ended.*

1. **What percentage of the world's water species live in freshwater?**

2. **At what point does a stream become a river?**

3. **List some adaptations river organisms have to live and survive in their habitat (at least 3 examples).**

4. **What does the presence of caddis fly, mayfly and stonefly larvae tell scientists about the quality of water?**

5. **What river runs through the Grand Canyon?**

6. **What is the ultimate destination of the Nile River?**

7. **What is one of the richest environments on the earth?**

8. **How does the water scorpion breath while underwater?**

9. What characteristics of ponds make them good for breeding and raising young?

10. What is unique about dragonflies' wings?

11. List some mammals that live on or near the banks of rivers.

12. What is the only mammal, other than man, that is known to interfere with the flow of rivers?

13. What is hydroelectricity?

14. What is a "delta"?

15. Write a short paragraph (5 sentences) describing an experience you have had in, on, or around a pond or river.

Appendix C-VI

Video Questions:
Bill Nye the Science Guy: The Water Cycle

Directions:** As you watch the video, please answer each of the following questions. You do not need to use complete sentences, but you do need to write enough information to completely answer the question. Pay close attention so you do not miss any answers. If you should miss one, leave it and try to answer it later. **DO NOT TALK TO YOUR NEIGHBOR TO TRY TO GET AN ANSWER!!!

1. What percentage of Earth is covered by / made up of water?

2. What is another name for the water cycle?

3. When water is heated it forms water vapor, more commonly called steam. What process of the water cycle is this?

4. What are the four (4) types of precipitation?

5. Nifty Home Experiment: What happens to a ziplock bag when it is filled with water and heated in the microwave oven for one minute? How does this simulate the water cycle?

6. What happens to water molecules in boiling water?

7. How does water (in liquid form) go directly from a liquid to a gas or vapor?

8. When water vapor loses energy it cause the water to do which of the following?

Evaporate or Condense

9. What is actually happening when you have a drinking glass that appears to be "sweating"?

10. What does Holly Foley do?

11. What happens when several droplets of water gather together and get too heavy to stay in the clouds?

12. What are five (5) things YOU can do to keep water clean?

13. What is the name of the song at the end of the show?

***Essay:** After the video, read the following question carefully and think about the information you learned in the video and in class about the water cycle. Answer the question using a minimum of five (5) complete sentences.*

14. Explain how and why pollution might affect the water cycle.

Appendix C-VII

Water Gamble

Questions:

- ➡ Where will the water you drink today be tomorrow?
- ➡ What are the different places water can go as it moves through and around Earth?

Hypothesis:

- ➡ ____

  ____

  ____

Objectives:

- ➡ You will be able to describe the movement of water within the water cycle
- ➡ You will be able to identify the states of water as it moves through the water cycle

Materials:

- ➡ Activity Sheet
- ➡ Pen or Pencil
- ➡ Markers
- ➡ Water Station Posters
- ➡ Water Station Dice

Procedure:

1. Read the lab questions above and record your hypothesis in the space provided.
2. You are now a water molecule that will be moving through the water cycle. You will be able to move through nine possible water stations, including clouds, plants, animals, rivers, oceans, lakes, groundwater, soil, and glaciers.
3. You will be assigned a water station to begin at. Once you have made it to your starting station you will determine what state of matter you are in (solid, liquid, or gas) and record it in your data table. Draw an original picture on the water station poster to represent what you look like or what you are doing at this station (remember, you are a water molecule). Write a brief description of your drawing in the data table.
4. Roll the die at your station. You will move to the end of the line of the station indicated on the upward face of the die. If the die says, "STAY", you will go to the end of the line you are currently in. Record your station and state of matter in your data table (do this even if you get "STAY").
5. When you get to the front of the line, draw an original picture on the water station poster to represent what you look like or what you are doing at this station (once again, remember, you are a water molecule).
6. Repeat steps 4 –5 until your data table is complete or your teacher indicates it is time to stop the activity.

Data Table:

Water Station	State of Matter	Explanation of Drawing

Analysis:

1. In your travels through the water cycle did you ever return to a water station you had previously visited? If so, which station did you return to?

2. Give some reasons why water might move in the following ways:
   a. From soil to plants –

   b. From clouds to lake –

   c. From animal to clouds –

   d. From animal to soil –

   e. From river to ocean –

3. In your travels through the water cycle were there any water stations you remained at for 3 or more rolls of the die? If so, which station? Why do you think water would remain in this stage of the cycle so long?

4. As a water molecule, you wake up in a puddle in the parking lot of the local IGA. Explain how you got here and where you might go next (Keep your thoughts to 5 sentences or less…you will have an opportunity to write more later).

Water Gamble
Key & Teacher Notes

Analysis:

3. **In your travels through the water cycle did you ever return to a water station you had previously visited? If so, which station did you return to?**

   Answers will vary

4. **Give some reasons why water might move in the following ways:**
   a. **From soil to plants –** *water is absorbed by plant roots*

   b. **From clouds to lake –** *water condenses and falls into a lake*

   c. **From animal to clouds –** *water is breathed out or evaporated from the body*

   d. **From animal to soil –** *water is excreted through feces and urine*

   e. **From river to ocean – water flows into the ocean**

5. **In your travels through the water cycle were there any water stations you remained at for 3 or more rolls of the die? If so, which station? Why do you think water would remain in this stage of the cycle so long?**

   Answers will vary

6. **As a water molecule, you wake up in a puddle in the parking lot of the local IGA. Explain how you got here and where you might go next (Keep your thoughts to 5 sentences or less…you will have an opportunity to write more later).**

   Responses will vary

Activity adapted from "The Incredible Journey" ©Project WET

Teacher Notes:

- Before this activity can be done dice need to be created for each of the nine water stations. Dice can be made out of square gift boxes, wooden cubes, plastic canvas, etc. See table below for stations and die labels.
- Each water station needs a labeled piece of poster board or butcher paper. This is for students to draw on as they reach that station.

Station	Die side labels	Explanations
Soil	one side plant one side river one side groundwater two sides clouds one side stay	Water is absorbed by plant roots The soil is saturated, so water runs off into river Water is pulled by gravity; it filters into the soil Heat energy added to water; evaporates into clouds Water remains on the surface (puddle)
Plant	four sides clouds two sides stay	Water leaves plant through transpiration Water is used by plant and stays in the cells
River	one side lake one side groundwater one side ocean one side animal one side clouds one side stay	Water flows into a lake Water is pulled by gravity; filters into soil Water flows into the ocean An animal drinks water Heat energy added to water; evaporates into clouds Water remains in the current of the river
Clouds	one side soil one side glacier one side lake two sides ocean one side stay	Water condenses and falls on soil Water condenses and falls as snow onto glacier Water condenses and falls into a lake Water condenses and falls into the ocean Water remains a droplet clinging to dust particles
Ocean	two sides clouds four sides stay	Heat energy added to water; evaporates into clouds Water remains in the ocean
Lake	one side groundwater one side animal one side river one side clouds two sides stay	Water is pulled by gravity; it filters into the soil An animal drinks water Water flows into a river Heat energy added to water; evaporates into clouds Water remains within the lake or estuary
Animal	two sides soil three sides clouds one side stay	Water is excreted through feces and urine Water is respired or evaporated from the body Water is incorporated into the body
Groundwater	one side river two sides lake three side stay	Water filters into a river Water filters into a lake Water stays underground
Glacier	one side groundwater one side clouds one side river three sides stay	Ice melts and water filters into the ground Ice evaporates and water goes into the clouds Ice melts and water flows into a river Ice stays frozen in the glacier

Appendix C-VIII

Water Cycle Wonder

Question:

Is water cleaned as it goes through the water cycle?

Hypothesis:

____

____

____

Materials:

16 oz. clear plastic cup
Food coloring
Warm water
Ice cube
Clear plastic wrap
Rubber Band
Paper towels

Procedure:

1. Read through the procedure entirely before beginning the experiment.
2. Place 3 drops of food coloring into the bottom of the cup.
3. Add approximately 8 ounces of warm water to the cup (about halfway full).
4. Place the cup on paper towel at your table.
5. Carefully stretch an 8-inch square piece of plastic wrap tightly over the cup and secure it with the rubber band.
6. Place an ice cube on top of the plastic wrap.
7. Answer questions 1 & 2 below.
8. Observe.

Analysis:

1. What do you think will happen when the warm vapor from the colored water hits the cooler plastic above it?

2. If drops form on the plastic inside the cup, what color will those drops be? Explain.

3. Describe what you observed during this experiment (in at least 10 – 15 words). Compare your observations to what you know about the water cycle.

4. Is water cleaned as it goes through the water cycle? Give reasoning.

Water Cycle Wonder
Key

Analysis:

1. **What do you think will happen when the warm vapor from the colored water hits the cooler plastic above it?**

   The water vapor will condense on the plastic and form drops

2. **If drops form on the plastic inside the cup, what color will those drops be? Explain.**

   The drops formed on the plastic will be clear because as the water evaporates the food coloring is left behind.

3. **Describe what you observed during this experiment (in at least 10 – 15 words). Compare your observations to what you know about the water cycle.**

   Observations will vary, but students should discuss the they can't see the water vapor leave the colored water, but they see colorless drops form on the inside of the plastic as the water condenses and then these drops will fall as precipitation back into the colored water when they get too heavy to stay on the plastic wrap.

4. **Is water cleaned as it goes through the water cycle? Give reasoning.**

   Yes, water is cleaned as it goes through the water cycle. Some substances are harder to remove from the water than others, but salt and some other toxins are left behind when water evaporates and thus the water is left cleaner than it was before.

Appendix C-IX

Water Quality Glossary

acid: a substance that produces positively charged hydrogen ions (H^+) when dissolved in water.

anemometer: an instrument used to measure the speed of wind.

base: a substance that produces negatively charged hydroxide ions (OH^-) in water and reacts with acids to form salts.

baseline study: a study designed to collect critical data to be used for comparison or as a control in a later study.

biochemical oxygen demand (BOD): a measure of the quantity of oxygen used by microorganisms in the aerobic oxidation of organic matter.

biodiversity: the variety of plant and animal species in an environment.

combined sewer system: sewer system that carries both sanitary wastes and storm runoff to a wastewater treatment plant to be treated and released to a body of water.

compass: a device containing a free-swinging magnetic needle that is attracted to Earth's magnetic North Pole. Used to determine direction of travel.

current speed: the speed at which water flows.

density: the mass of an object divided by its volume.

dissolved oxygen (D.O.): the amount of oxygen dissolved in water.

ecosystem: a group of organisms together with its environment, seen as a unit.

eutrophication: the enrichment of water with nutrients, usually phosphorous and nitrogen, which stimulates the growth of algal blooms and rooted aquatic vegetation.

fecal coliform: bacteria that are found in excrement of warm blooded animals or birds or sewage contamination, occurring naturally in the digestive tract to aid in the digestion of food for human beings and animals.

habitat: the environment where a particular plant or animal is normally found.

impounded: a body of water that is confined, as if in a reservoir.

inorganic: being or composed of matter other than plant or animal.

invertebrate: an animal without a backbone.

larva: the newly hatched, immature, wingless, and often wormlike feeding form of many insects.

metabolic: the chemical process in living cells by which energy is provided for vital processes and activities.

nitrates: one form of nitrogen that plants can take up through their roots and use for growth.

nonpoint source pollution: pollution whose sources cannot be traced to a single point and reach water bodies in runoff.

nymph: an immature insect, such as an aquatic mayfly or damselfly; this form does not resemble their adult flying form.

organic: a living plant or animal containing carbon compounds.

pH: a measure of the acidity or alkalinity of a solution.

pathogens: a biological agent (such as a bacterium or virus) that can cause a disease.

phosphates: an important nutrient for plants to grow and for the metabolic reactions of plants and animals.

photosynthesis: process by which chlorophyll-containing cells in green plants convert incident light to chemical energy and synthesize organic compounds from inorganic compounds.

phytoplankton: microscopic aquatic plants, such as algae, that drift with currents and tides; they are an important source of food for many aquatic organisms; they make their own food from sunlight.

point source pollution: pollution that has discrete discharges, usually from a pipe or outfall.

precipitation: any form of water, such as rain, sleet, or snow, that falls to Earth's surface.

primary productivity: the production of living matter by organisms that make food using sunlight or chemicals. This is usually expressed as grams of carbon per square meter per yard.

salinity: the amount of dissolved salt in water.

secchi disk: a tool for measuring the relative clarity of water.

sediment: the solids that settle to the bottom of a liquid.

separate sewer system: sewer system that carries sanitary wastes (from toilets, washers and sinks) to a wastewater treatment plant to be treated.

turbidity: a measure of the clarity of water.

water clarity: the level of light that penetrates through water.

watershed: the catchment basin or drainage area (both below and above ground) of an entire river system; an area of land that delivers runoff water, sediment, and dissolved substances to surface water bodies, such as rivers or lakes. All watersheds consist of boundaries, a basin and collection areas.

zooplankton: tiny aquatic animals that drift with the currents and tides.

Appendix C-X

pHinding pH

Background:

Water contains both hydrogen and hydroxyl ions. The pH test measures the hydrogen ion concentration of liquids and substances. Each liquid or substance is given a pH value on a scale that ranges from 0 to 14. Pure water has an equal amount of hydrogen and hydroxyl ions, and has a pH of 7. This is considered neutral, neither acidic nor basic. For every one unit (number) change on the pH scale, there is approximately a ten-fold change in how acidic or basic the sample is.

Changes in the pH value of water are important to many organisms. Most organisms have evolved to life in water of a specific pH and may die if it changes even slightly. At extremely high or low pH values, the water becomes unsuitable for most organisms. Immature stages of aquatic insects and young fish are extremely sensitive to pH values below 5. In the U.S., the pH of natural water is usually between 6.5 and 8.5, although wide variations can occur. A change in pH in a stream may mean that pollution is affecting the water.

Objective:

In this activity, you will determine the pH value of various substances or solutions using pH paper and an indicator solution.

Materials:

Various test substances and solutions in labeled jars
Laminated lab sheet
pH paper
pH indicator solution
13 small vials
13 pipettes
Wax pencil/Colored Pencils
Paper towels

Procedure:

1. Read through the entire procedure before beginning this activity.
2. Collect all of your materials, except the pH indicator solution and the test substances and solutions.
3. Label each vial, each one with the name of a different one of the test solutions, with the wax pencil. See the data table for a list of the test solutions.
4. Look at the data table on the following page. Predict the pH of each of the solutions and write your hypothesis in the column labeled "Your pH Hypothesis".
5. One vial at a time, carefully add 1-2 mL of each test solution to the appropriately labeled vial. Take these vials back to your table.
6. Tear off 13 small strips of pH paper (no longer than 5 cm). Using one strip of

pH paper per vial, dip it into the vial. Pull the strip out and compare the color to the pH scale on your laminated lab sheet. Record the pH in the "pH value determined from pH paper" column of your data table.

7. One vial at a time, carefully add 3-5 mL of pH indicator. Gently swirl each vial. Place each vial on the laminated lab sheet and observe the color. Neatly record the color of the solution in the appropriate column of your data table. *Be sure to observe the vials quickly because the color may change or disappear over time.
8. Find the correctly labeled circles in the data section and color them to match the contents of each vial.
9. Empty the contents of your vials into the sink and wash them out using soapy water and the test tube brush. Be sure to get the wax pencil off of the vials. Dry them by placing them upside down on test tube racks.
10. Throw away the pipettes, pH paper strips, and paper towel.
11. Return the wax pencil and laminated lab sheet to your teacher.

<u>Data</u>:

Test Solution/Substance	**Your pH Hypothesis**	**pH value determined from pH paper**	**Solution color with indicator**
Baking Soda			
Bleach			
Coffee			
Distilled Water			
Lemon Juice			
pH Buffer 4			
pH Buffer 7			
pH Buffer 10			
Pop			
Tap Water			
Tomato Juice			
Saltwater			
Vinegar			

Solution color with cabbage indicator:

Baking Soda	Bleach	Coffee	Distilled Water	Lemon Juice
pH Buffer Water 4	pH Buffer 7	pH Buffer 10	Pop	Tap
Tomato Juice	Saltwater	Vinegar		

<u>Analysis</u> (use complete sentences):

1. Which of the substances you tested has the most acidic pH?

2. Which of the substances you tested has the most basic pH?

3. Which of the substances you tested has a neutral pH?

4. Why would bleach not be a suitable environment for living organisms?

5. You have been monitoring a local stream. The pH of the stream normally ranges from 6 – 7. Upon testing today, you found the pH to be 4. How will this affect the organisms in the stream?

Appendix C-XI

Looking Glass River Data Collection Form
Clark-Pohlod

Laingsburg Road Site
Laingsburg Middle School

Date of Test ___________
Time of Test __Morning__

Study Site Profile

1. Color/texture of the water (check all that apply):
   ___ clear ___ tea-colored ___ oily ___ cloudy ___ muddy

   ___ black ___ foamy ___ rusty ___ green ___ gray ___ brown

   ___ other (explain):

   ____

2. Classify your site as one of the following:
   _X_ rural ___ suburban ___ urban ___ nature preserve

3. What is within 10 meters of the water's edge (check all that apply)?
   ___ concrete ___ soil ___ rocks ___ trees ___ other vegetation

   ___ other (explain): ____

4. What land uses do you see around your study area (check all that apply)?
   ___ roads ___ forests ___ houses ___ businesses ___ farms

   ___ mining ___ discharge pipes ___ recreation areas ___ schools

   ___ landfills ___ incinerators ___ industry

   ___ other (explain): ____

5. Would any of the land uses you checked above lead to erosion, potential point or non-point pollution, or increased sediment load in the aquatic site? How might these land uses impact the watershed?

   ____

   ____

6. What kinds of plants/trees do you see around your site? Describe them:
   Ground (grasses and weeds): ____

Understory (shrubs): ____

Canopy (usually trees): ____

Exotic/introduced species: ____

7. What kinds of animals (or evidence of animals) do you see around your aquatic site?

___ aquatic birds ___ terrestrial birds species: _________________

___ small mammals ___ large mammals species: _________________

___ herps (reptiles/amphibians) species: _________________

___ fish species: _________________

___ arthropods species: _________________

___ domestic animals species: _________________

___ other species: _________________

Abiotic Characteristics

1. Weather Observations:

Air Temperature _____°C ___ Open area ___ Sheltered area

Sky Conditions (circle one) clear partly cloudy overcast

Description, type, or drawing of any clouds present: ____________________

____

Current precipitation: ___ none ___ present as ______ (form)

Precipitation in the past 24 hours: ___ none ___ present as ______ (form)

Wind speed (use Wind Scale): ____ mph ___ Open area ___ Sheltered area

Wind direction: __________ (from north, northeast, east, etc.)

2. Water Temperature _____°C

3. pH (circle one): 1 2 3 4 5 6 7 8 9 10 11 12 13 14

4. Current speed: _____ cm/sec

5. Dissolved oxygen (circle one): no O_2 low O_2 medium O_2 high O_2

6. Water clarity/Turbidity: _____ JTU

Macroinvertebrate Study

Species Name	Number of individuals
Mayflies	
Stoneflies	
Damselflies	
Caddisflies	
Crane Flies	
Dobsonflies	
Dragonflies	
Water Beetles	
Midges	
Flatworms/Planaria	
Earthworms	
Scuds	
Water Striders	
Snails	
Leeches	

APPENDIX D

TABLE 1 Field Group Concept Map Percentage Data by Question

Correct Response	Percentage Correct on Pre-test	Percentage Correct on Post-test	Increase of Percentage from Pre- to Post-test
Solid	60.6	77.4	16.8
Liquid	69.7	80.7	11.0
Gas	57.6	71.0	13.4
Clouds	42.4	51.6	9.2
Evaporation	45.5	71.0	25.5
Precipitation	66.7	87.1	20.4
Rain	66.7	87.1	20.4
Snow	75.8	87.1	11.3
Sleet	57.6	87.1	29.5
Hail	63.6	87.1	23.5
Average Percentage Correct	*60.6*	*78.7*	*18.1*

TABLE 2 Field Group Short Answer Questions Percentage Data by Question

Question Number	Percentage Correct on Pre-test	Percentage Correct on Post-test	Increase of Percentage from Pre- to Post-test
1	0.0	45.2	45.2
2	3.0	32.3	29.3
3	54.6	83.9	29.3
4	25.8	58.1	32.3
5	47.7	82.3	34.6
6	16.7	69.4	52.7
Average Percentage Correct	*24.6*	*61.9*	*37.3*

TABLE 3 Classroom Group Concept Map Percentage Data by Question

Correct Response	Percentage Correct on Pre-test	Percentage Correct on Post-test	Increase of Percentage from Pre- to Post-test
Solid	45.7	85.3	39.6
Liquid	57.1	85.3	28.2
Gas	60.0	94.1	34.1
Clouds	31.4	32.4	1.0
Evaporation	62.9	76.5	13.6
Precipitation	74.3	91.2	16.9
Rain	85.7	100.0	14.3
Snow	85.7	97.1	11.4
Sleet	82.9	97.1	14.2
Hail	77.1	97.1	20.0
Average Percentage Correct	*66.3*	*85.6*	*19.3*

TABLE 4 Classroom Group Short Answer Questions Percentage Data by Question

Question Number	Percentage Correct on Pre-test	Percentage Correct on Post-test	Increase of Percentage from Pre- to Post-test
1	2.9	5.9	3.0
2	14.3	29.4	15.1
3	48.6	66.2	17.6
4	22.9	67.7	44.8
5	62.9	66.9	4.0
6	16.4	35.3	18.9
Average Percentage Correct	*28.0*	*45.2*	*17.2*

TABLE 5 Comparison of Overall Improvement of Pre/Post Test Percentages by Study Group

	Field Group	Classroom Group	Overall Improvement of Field Group vs. Classroom Group
Overall Percentage Increase from Pre- to Post-test on Concept Map	18.1	19.3	-1.2
Overall Percentage Increase from Pre- to Post-test on Short Answer Questions	37.2	17.3	19.9

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