THE WATERSHED GAME

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Grade Level
High School

Subject area
Biology, Environmental, or Marine Science

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1. **Activity Title:** The Watershed Game: Land Use and Water Quality

2. **Focus:** This lesson plan will assess the influence of land use type on nutrient input into an adjoining estuary

3. **Grade Levels/Subject:** The targeted grade level is 10th grade Life Science

4. **VA Science Standard(s) addressed:**
    a. LS.1: The student will demonstrate an understanding of scientific reasoning, logic, and the nature of science by planning and conducting investigations in which:
        i. dependent variables, independent variables, and constants are identified
        ii. variables are controlled to test hypotheses, and trials are repeated
        iii. data are organized, interpreted, and used to make predictions
    b. LS.5 The student will investigate and understand the basic physical and chemical processes of photosynthesis and its importance to plant and animal life. Key concepts include:
        i. Energy transfer between sunlight and chlorophyll;
        ii. transformation of water and carbon dioxide into sugar and oxygen, and;
        iii. Photosynthesis as the foundation of virtually all food webs.
    c. LS.6 The student will investigate and understand that organisms within an ecosystem are dependent on one another and on nonliving components of the environment. Key concepts include
        i. complex relationships within terrestrial, freshwater, and marine ecosystems;
    d. LS.10 The student will investigate and understand that ecosystems, communities, populations, and organisms are dynamic, change over time, and respond to daily, seasonal, and long-term changes in their environment. Key concepts include:
        i. Eutrophication, climate changes, and catastrophic disturbances.
    e. LS. 11: The student will investigate and understand the relationships between ecosystem dynamics and human activity. Key concepts include:
        i. environmental issues

5. **Learning objectives/outcomes:**
    a. Students will investigate how different land use types (and associated land use practices) influence nutrient input into a river or estuary.
        i. Students will define basic coastal watershed concepts (refer to glossary sheet) including:
            1. Watershed Boundary (Catchment Area)
            2. Land Use/ Land Cover Type
            3. Surface Runoff
            4. Groundwater
            5. Infiltration
        ii. Students will make inferences on types of organisms living in coastal waters and how they might be affected by changes in nutrient supply
        iii. Students will identify differences between three different land use types, discuss why such a land use type may be necessary in a watershed and

hypothesize how this land use type might influence nutrient input into an estuary.

iv. Students will measure the difference between the amount of "precipitation" that falls on a land use type and the amount of "precipitation" that eventually leaves that land use type and enters into the estuary via groundwater or surface runoff
v. Students will identify differences between the concentration of nutrients that is within precipitation as it falls on land and the concentration of nutrients that is within groundwater or surface runoff after it has fallen onto three different land use types.
vi. Students will synthesize what they have learned with assessment activity that requires them to be watershed experts and advise a management official on whether or not a proposed land alteration plan should be implemented.

6. Total length of time required for the lesson

a. 3-classroom sessions (45, 90, 45 minutes)

7. Key words, vocabulary:

a. Primary producer, photosynthesis, eutrophication, fertilizer, nutrients (nitrogen and phosphorous), pollution, land use/ land cover, runoff
b. See the additional Glossary, in this lesson packet.

8. Background (For Teacher)

a. The human population has significantly impacted both the quantity and quality of water that drains from a watershed into an adjoining estuary. Changes in land use from predominately natural vegetation to farmland and urban areas, significantly increases the amount of nutrients (i.e. nitrogen and phosphorous) that enters into waterways via surface runoff or groundwater (Howarth et al. 1991, Cooper and Brush 1993, Basnyat et al. 1999, Bowen and Valiela 2001, Weller et al. 2003). While nutrient input is needed to support a healthy ecosystem in estuaries, rivers or lakes, excessive nutrient input can degrade the system by inducing eutrophic conditions, resulting in poor water quality and affecting organisms at different trophic levels (Livingston et al. 1997, Orth et al. 2006, Murrell et al. 2007, Baptista et al. 2008, Halliday et al. 2008, Selman et al. 2008). As humans continue to inhabit coastal watersheds, it is important to understand how changes in land use are likely to influence coastal ecosystems.

9. Student handouts and other materials needed

a. The handouts required for this lesson includes:
    i. Scrap Paper
    ii. Activity Sheet 1 (Printable Version available in folder)

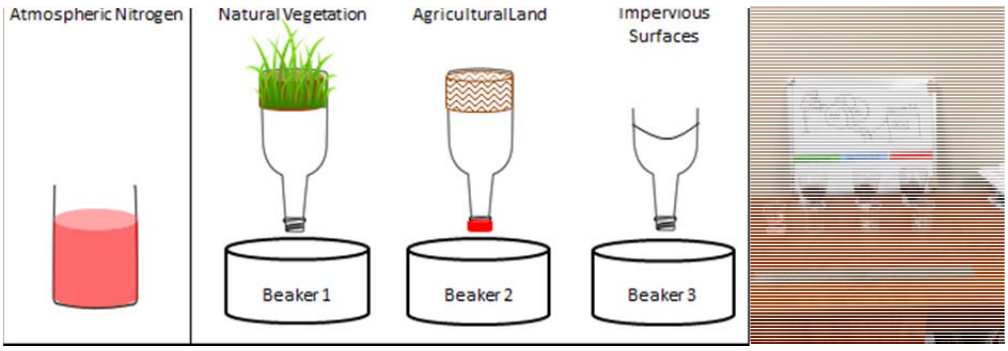
10. Materials & Supplies, AV/Tech Support

a. The materials needed for this lesson include:
    i. 0.5 L water bottles (x3)
    ii. 50 mL beakers (x4)

iii. Water
iv. Colored Powder (i.e. Jello Mix, or Kool-Aid Mix) (1 Packet)
v. Soil
vi. Coffee filter paper (1 piece)
vii. Rubber Bands (x3)
viii. Scissors
ix. Opaque Tape
x. Permanent Marker
xi. Calculator
xii. Ruler
xiii. Playdough
xiv. Watering can

11. Classroom/Lab/Field Setup

a. The instructor has the option to carry out the laboratory portion of this activity
   1. On a small desk placed at the front of the classroom for all students to see or the in. The set up for the experiment is illustrated in Figure 1a and b (one cartoon and one actual) and should take ~20 minutes to set up.
   2. At multiple tables for several lab groups to work on independently. The set up for the experiment is illustrated in Figure 1a and b (one cartoon and one actual) and should take ~20 minutes to set up for each group (i.e. 4 lab groups= ~1 hour set up time for instructor).
      ii. Cut three pieces of opaque tape and write Natural Vegetation, Agricultural Land and Impervious Surfaces on each piece of tape
      iii. Cut 3 water bottles in half
      iv. Place the 3 labels on the top half of the 3 water bottles so that each bottle is labeled as either Natural Vegetation, Agricultural Land or Impervious Surfaces (Figure 1a and b)
      v. Cut three small pieces of coffee filter paper, cover the opening of the water bottle(part where you would normally drink from) with the filter paper and secure with a rubber band
      vi. Place each water bottle in a beaker such that the opening of the water bottle (part where you would normally drink from) is facing the bottom of the beaker (see Figure 1a and b)
      vii. Add powered dye to agricultural bottle.
      viii. Add soil to each of the three bottles
      ix. To create the “impervious surfaces” place bottom half of cut bottle right side up (so that any water poured into this set up is trapped by the plastic bottle bottom and no water should be able to make it through filter) (See Slide 9 in PowerPoint if this is confusing)
      x. To make the “atmospheric nitrogen” supply, fill a beaker with water and add in a small amount of colored powered such that the concentration scale of this beaker is less than 4 according to the nutrient scale provided with this lesson plan (see slide 7 in PowerPoint).



b. Lab Set-up (5 minutes)

i. Hand out Activity Sheet 1 and scrap paper to each student in the classroom.

c. Background Activity- (Day 1-45 minutes)

i. Open up PowerPoint "TheWatershedGame"
ii. Mold your playdough into any land like shape you like. Get Creative! ☺
iii. Indicate to students that your playdough molding represents a piece of land
iv. Pour water from watering can onto playdough mold and have students think about question presented in slide 3 of the attached power point presentation (What do you notice about the flow of water over your land (playdough) molding?). Once students have answered this question correctly, you can proceed to slide 4 which state the actual definition of a watershed.
v. Slide 5-
    1. Prompt students to think about how it's not just water that runs off land and enters into stream or river but that water will have "stuff" in it that will also be transported to stream or river (i.e. runoff). Have students hypothesize what kind of "stuff" may be carried by water into nearby stream/river. Have them think about where their waste goes and how that waste consists of elements such as nitrogen and phosphorous (This important for "Ecosystem Response" slides).
    2. Explain to students that some runoff infiltrates soils and may enter groundwater.
vi. Slide 6- Ask broad question "How what might is running off of the land impact what is living in the water". Before students begin answering this question, ask students to list out some of the organisms that they might expect to be living

in a nearby stream or river. Generally speaking one might expect to see different types of phytoplankton, zooplankton, and fish.
vii. Slide 7- Pay particular attention to phytoplankton. Explain that phytoplankton are tiny marine plants. Since they are plants they photosynthesize and as a result require sunlight, co2, and nutrients (i.e. nitrogen and phosphorus) to do so. Allow students to make the connection that runoff from land they discussed earlier contains the nutrients that phytoplankton require to grow.

viii. Slide 8-Explain to students that too much nutrient input can have negative impacts on the quality of water. This is because too much nutrients may initiate a phytoplankton to bloom which may:
    1. Decrease oxygen in water as phytoplankton die and decompose
    2. Block sunlight from plants that live on the bottom of river and causes them to die

(http://www.chesapeakebay.net/blog/post/the_abcs_of_habs_how_harmful_algal_blooms_impact_the_bay)

Explain to students that this is why it is important to understand how much nutrients is leaving the land and entering the river or stream

ix. Slide 9-Have students brainstorm what are some common land use types they would expect to see in a watershed. Have them brainstorm how the three land use types outlined in table may affect the amount of nutrients that exit a watershed and enters into its stream or river. Finally, end the class with saying that the next class will explore with a lab how these land types impact how much water makes it to the stream and how much "stuff" (i.e. nutrients) is in the water when it makes it to the stream.

d. Lab Activity-(Day 2-90 minutes)

i. Measure (the instructor) the area of each land use type ($A=pi*radius^2$) and provide that information to students so that they may fill it into their activity sheets
ii. Pour 50ml of "atmospheric nitrogen precipitation" onto "Natural vegetation" land use
iii. Repeat step ii for "agricultural land" and "impervious surfaces"
iv. While atmospheric nitrogen is percolating though different land use types, the instructor may ask students to hypothesize which land cover type will result in the greatest amount of nutrients entering into a river or stream.
v. Have students examine the liquid that percolated through the different land use types and record their observations.
vi. Measure the volume of liquid captured in the container below each bottle and have all students use the nitrogen scale(slide 12 of PowerPoint) to determine nitrogen concentration of water from each land use type.
vii. Have students' record answers both in their individual activity sheets and in a larger sheet that is projected onto the board.

viii. Discussion (20 minutes)

1. Questions to ask when students are observing the water that made it through each land type:
    a. Was the concentration of water that made it through natural vegetation more or less than your initial concentration of atmospheric nitrogen? Why? (It should be less as soils help to filter out some of the nutrients)
    b. Was the concentration of water that made it through agricultural land more or less than your initial concentration

of atmospheric nitrogen? Why? (It should be more due to fertilizer application on agricultural land)

c. Was the concentration of water that made it through impervious surfaces more or less than your initial concentration of atmospheric nitrogen? Why? (It should not have made it through the beaker- Impervious surfaces prevent infiltration and so concentrations of atmospheric nitrogen onto impervious surfaces are incorporated into direct runoff into the estuary).

2. Have students use information in activity sheet to calculate the "Amount of Nitrogen Entering System" from each land use type.
    a. Multiply data in columns 5 and 6 (two highlighted columns) for each row.

ix. Closure/Reflection

The closure/reflection activity will allow the students to think about the communities that they live in. The following questions should be asked to help solidify the concepts taught to them over the past two days of the lesson plan.

a. Are there any other land use types that they see in the watersheds that they live in and how do they think those land use types might affect nutrient runoff?
b. What are possible ways that they could change those land use types to help reduce nutrient runoff within their watershed?
c. Are there other ways that nutrients may enter into a stream or river besides runoff from land (i.e. wastewater treatments plants, CSO's etc)?

e. Breakdown and Clean-up

12. Assessment (Day 3-45 minutes)

i. Provide students with the government official letter in Microsoft Word document titled "Activity Sheet 2". This letter proposes land cover alterations of a nearby smaller watershed and the government officials want the students' opinions on whether or not the proposed land cover alterations are advisable. Have students respond to this letter explaining in their own words how different land use types affect runoff in the watershed and offer their expertise on whether or not the proposed land cover alterations are advisable. Ensure that the students reference the research that they have conducted (i.e. lab activity) when making their suggestions. Inform them, that they are the experts and that is why the government official is requesting their advice on how to develop this new watershed.

13. References

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