Modified Educational Transfer Plan (mETP)

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Stanford, Luthy Lab
mETP Type
Subject Area: Science 9-12
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Understanding The Nitrogen Cycle and Using Design Thinking to Reduce the "Dead Zone".

0. Abstract

My mentor, Negin Ashoori, PhD, from the Luthy Group in the Civil and Environmental Engineering department at Stanford University, researches the removal of pollutants from stormwater passed through different media, such as wood-chips, sand, and biochar, identifying the various types of bacteria that carry out microbial remediation to improve the management of stormwater runoff. From this research, the Luthy Group helps to develop stormwater treatment regimes that can include buffer zones around drains and plant habitats for the phytoremediation of the toxins in stormwater runoff near recharge ponds. The biogeochemistry of nitrogen, which is taught in high school in the nitrogen cycle, is almost entirely dependent on the reduction-oxidation (redox) reactions primarily mediated by microorganisms. Understanding the nitrogen cycle is a challenging concept for most high school students. Yet, because of the nitrogen cycle's relevance to air, water and soil quality, it is often considered one of most important nutrient cycles. Nitrogen is essential for the synthesis of nucleic acids and proteins— two important macromolecule polymers of life. The world's population has more than doubled in the last 50 years and the *Green Revolution* of growing more food for the additional 3.5 billion people to be fed has lead to delivering more nitrogen and phosphorous compounds via fertilizers to agricultural fields. This move from nitrogen-limited agriculture and landscaping to nitrogen excess has had profound effects on our environment, especially water quality. Eutrophication, for instance, is caused when nitrogen and other nutrient compounds of the fertilizers are washed from the field when it rains after they have been applied. The nutrients are transported from the field to nearby waterways and leads to several negative impacts on the affected ecosystem, and is often a direct result of nitrogen loading from agriculture and landscaping. This ETP is a series of student activities utilizing NGSS *Crosscutting Concepts* and *Science and Engineering Practices* to help students engage in a deeper understanding of the nitrogen cycle, its relevance to sustaining life, as well as the threat unlimited nitrogen loading poses to aquatic, terrestrial, and atmospheric ecosystems. Innovating methods to reduce fertilizer runoff often use many of the same means to promote, contain, and control microbial action that the Luthy group employs to deal with stormwater runoff. Engaging students in evidence, data, argument, models, systems, as well as having them come at the nitrogen cycle from the perspectives of structure and function, scale and proportion, cause and effect, energy and matter promises to help them gain a deeper understanding of the nitrogen cycle and a greater realization of the challenges and means available for feeding an ever expanding human population without the complete destruction of the natural environment.

I. Standards Connection to NGSS or Common Core

1. Focal Standard:

AP Environmental Science Big Idea 2: The Living World

011 - Biogeochemical Cycles

Biogeochemical cycles move required nutrients through the abiotic and biotic spheres on our planet. Matter on the Earth is conserved so producers must receive required nutrients through the water cycle, carbon cycle, nitrogen cycle, phosphorus cycle, and sulfur cycle.

AP Environmental Science Big Idea 3: Population

0115 - Human Population Impacts

The model of the ecological footprint increasing with development of technology.

AP Environmental Science Big Idea 4: Land & Water Use

0115 - Human Population Impacts

The pros and cons of industrial agriculture including: monocropping, irrigation, and the use of pesticides, fertilizers, and GMOs.

California Content Standard 6b: Students know how to analyze changes in an ecosystem resulting from changes in climate, human activity, introduction of nonnative species, or changes in population size.

NGSS HS-LS2-6: Evaluate claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem.

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2. Active STEM Learning (and *optional* 21st Century Skill):

- Vocabulary is learned as needed and connected to activities (not in isolation)
- The learning experience starts from students' "developing conceptions" about S, M, and E concepts
- The learning experience is grounded in real-world problems that kids care about
- Students encouraged to touch, manipulate, experiment
- Metacognition – students incorporate thinking strategies
- Students are engaged in learning that is purposeful
- Active STEM learning is transparent- facilitators make relevant connections between content and everyday lives
- Active STEM learning allows students to make observations, engage in the process of inquiry, confirm understandings, connect with peers, and create meaningful artifacts
- Active STEM learning allows students to test ideas, the hallmark of science

21st Century Skills

Students will: Demonstrate knowledge and understanding of society's impact on the natural world (e.g., population growth, population development, resource consumption rate, etc.)

As well as: Demonstrate knowledge and understanding of the environment and the circumstances and conditions affecting it, particularly as relates to air, climate, land, food, energy, water and ecosystems

3. Design Thinking:

Students will use design thinking to develop potential solutions of remediation or prevention of the dead zone or of smaller cultural eutrophication events. To do this, students will need a solid understanding of the nitrogen cycle.

II. Fellowship Connections

1. Fellowship Description:

In my fellowship, the basic idea I am researching is how to improve stormwater quality through filtration and phytoremediation. Phytoremediation is making use of plants to improve environmental conditions. The Luthy Group is working hard at improving stormwater quality so that when this runoff either enters streams, the bay or the ocean, or enters groundwater through percolation ponds, the stormwater is much cleaner than it was when it first picked up and carried toxic pollutants such as petroleum products from rooftops, streets and parking lots. The Luthy group has designed and built a small mesocosm model wetland filtration system that makes use of California native plant species to test the removal of a commonly used chemical additive, benzotriazole. The model filtration system contains pea gravel, sifted sand (sized at .7 - .8 mm), compost and plant, clustered field sedge. Thus far I am incorporating many skills as I work in the lab including: the *scientific method, lab skills, communication skills & technological skills.*

My sponsor, Negin Ashoori, PhD, from the Luthy Group in the Civil and Environmental Engineering department at Stanford University, being an excellent researcher, is superior at managing the lab, helping direct the other personnel working on the project and keeping the whole investigation moving forward. Other work being done by my sponsor includes looking at the removal of pollutants from stormwater passed through different media such as wood chips, sand, and biochar, identifying the various types of bacteria that carry out microbial remediation to improve the management of stormwater runoff, and playing a part in Re-Inventing the Nation's Urban Water Infrastructure (ReNUWIt).

I am being exposed to how the Principal Investigator in a research lab promotes design thinking among the young researchers by setting parameters and constraints on the types of research and methods her lab group uses, and thereby encouraging their creativity within that system. This is exactly what I will imitate with my students in having them do research in my class. I am also learning about the work of environmental engineers and civil engineers.

2. Fellowship Connection to School/Classroom:

Rainwater and stormwater runoff are two underutilized sources of water in urban areas. In California, particularly as one travels from northern California towards southern California, the technique of capturing runoff is of vital importance because of the low average annual rainfall (~15”/year in San Jose, CA as cited by Weather Database), periodic droughts and the likely increase in severity and occurrence of droughts due to climate change and continued population growth. However, depending on how rainwater and stormwater runoff are collected, both can contain pollutants. The goal of the summer research is to improve stormwater quality and usability through the development of a remediation containment system that will reduce/remove contaminants. Thus, this fellowship is very practical in its application outside of academia. Because of this, moving the information and techniques from this summer’s work will allow students to take part at the point of crossover where modeling stormwater remediation meets the expanded use of this technology in and around urban areas. I plan to provide background reading and media materials concerning water, water usage and stormwater contaminants and treatment to help students see the importance of improving runoff water quality. Students will then be shown how to develop a working remediation containment based off this summer’s work. Through the use of design thinking and problem-based learning, students will test the remediation of the water spiked with a non-hazardous pollutant (probably nitrate but other potential contaminants could include salt or phosphate) that has been passed through a filter of their design.

IV. Instruction

Overview of Instructional Plan		
Learning Activities	**Estimated Time**	**Description of Student Learning Activity**
1 Pre quiz assessment	**10 min**	Prequiz on nitrogen cycle and eutrophication
Students will be given a pre-quiz to assess their current level of understanding of the nitrogen cycle.		
2 Reading from the textbook	**15 min**	Students will read pages 84-86 on the nitrogen cycle as homework
Students read the assigned textbook pages (84-86).		
3 Guided worksheet	**15 min**	As students read pages 84-86 on the nitrogen cycle, the will complete a homework worksheet
As students read the assigned textbook pages (84-86) they will complete the worksheet.		
4 Article on the predicted size of the Gulf of Mexico "Dead Zone"	**10-15 minutes**	Students will read about the Gulf of Mexico "dead zone". A live link to the article is HERE.
Students will have read the article and completed the worksheet and be prepared to discuss and ask questions concerning the article.		
5 Guided Reading "Dead Zone" article	**15 min**	As students the article they will complete a homework worksheet designed to guide their understanding.
Students will have read the article on 2017 Gulf of Mexico Deadzone and have completed the guided reading worksheet. They will be ready to discuss the article is small, pair and share groups.		
6 Review Design Thinking	**10 minutes**	Teacher will briefly review DT and guide students to develop empathy.

<table>
<tr><td colspan="3">Students will have read the article and record questions about the article for discussion.</td></tr>
<tr><td colspan="3"></td></tr>
<tr><td>7 Taking on the role of a stakeholder</td><td>10-15 minutes</td><td>Students will be assigned a stakeholder to learn about and represent.</td></tr>
<tr><td colspan="3">Students will have read about their specific stakeholder profile and, if time allows, do independent online research to learn more about their perspective.</td></tr>
<tr><td colspan="3"></td></tr>
<tr><td>8 Develop Empathy and develop a POV statement</td><td>15 min</td><td>Students will be assigned a stakeholder different from the one they are playing to interview, complete an empathy map & develop some POV statements.</td></tr>
<tr><td colspan="3">Students will have a list of ways they have connected with the situation of the Dead Zone discussed in the article with the nitrogen cycle. They will hear testimonies from farmers, shrimpers/ fisher people, ecologist and other stakeholders listening for their perspective on the cause, ramifications & treatment or remedies of the dead zone. The will complete the linked empathy map and POV statement(s).</td></tr>
<tr><td colspan="3"></td></tr>
<tr><td>9 Teamwork to ideate/Prototype</td><td>10 -20 min</td><td>Students will be given a few minutes to brainstorm ideas and then develop a draft prototype.</td></tr>
<tr><td colspan="3">When students are done they will have a draft of the prototype</td></tr>
<tr><td colspan="3"></td></tr>
<tr><td>10 Prototype mode sharing</td><td>20 min</td><td>Students will share their prototypes</td></tr>
<tr><td colspan="3">From their ideas, students will design and share their designs with the class, models that will help the situation.</td></tr>
<tr><td colspan="3"></td></tr>
<tr><td>11 Review the nitrogen cycle with this diagram</td><td>10 min</td><td>Teacher will lead students in a brief review of the nitrogen cycle.</td></tr>
<tr><td colspan="3">Students will be able to ask questions concerning the nitrogen cycle. They can fill in this blank nitrogen cycle as a way to study.</td></tr>
<tr><td colspan="3"></td></tr>
<tr><td>12 Develop working model in ecocolumns</td><td>1 class period</td><td>Students will test various filters and continue to advance their prototypes into models.</td></tr>
<tr><td colspan="3">Students will move their designs into functioning models and measure their effectiveness.</td></tr>
<tr><td colspan="3"></td></tr>
</table>

13 Review, share and wrap up	15 - 20 min	Students will have time to reflect on the process and review the content.discuss what was learned through
Students will recommend ways to reduce, prevent or remediate the causes of algal blooms / eutrophication and review the nitrogen cycle and key terms for this lesson.		
14 Summative assessment	10 min	Students will take a brief, 10MC quiz to wrap up the unit
Students will answer 10 multiple choice questions based from this week's work.		

1. Instructional Plan:

This series of lessons makes the assumption that students are familiar with the format of Design Thinking. See more about how to implement DT into your classroom here.

Order and description of instruction:

Day 1

Students will be given a small pre-quiz about the nitrogen cycle. Then, as homework, they will be assigned to read the textbook (Friedland & Relyea & pages 84-86). This can be done online as an exit ticket.

Day 2

(15 minutes)

Students will make use of the Design Thinking model to develop potential solutions to the Gulf of Mexico dead zone. Students will be given an article on eutrophication. They will read the article and answer the following questions:

Here, following and linked herein, is the reading guide:
Define the following terms: dead zone, hypoxia, NOAA, decomposition, watershed, nonpoint pollution source, runoff.

1. **What are the connections between eutrophication and the nitrogen cycle.**
2. **What are some of the variables that influence the intensity of the 'dead zone' in the Gulf of Mexico?**
3. **Do algae cause a decrease in the dissolved oxygen content in the water? Explain.**

4. **What are the two major nutrients that cause the algal bloom?**
5. **What is the role of the Mississippi River/Gulf of Mexico Watershed Nutrient Task Force?**
6. **Explain how the law and what governing agencies are involved in protecting the watershed and the Gulf of Mexico.**
7. **Who are the players that are either part of the cause or are affected by the issue? What incentives/motivations do each of the players and stakeholders have in relation to the dead zone?**

(5 Minutes)

After individuals complete the article, students will pair up and share their thoughts on the reading and the questions above, paying particular attention to question 7 above. (Pairing A)

This table demonstrates the pairing of students to clarify which students are working together. Group 1 has all the same stakeholders paired together. Group 2 has which stakeholders are paired to interview each other for the empathy map.

Grouping 1	Grouping 2
All A (Farmers)	A's will interview B's
All B (Parks and Rec)	B's will interview A's
All C (Fertilizer Companies)	C's will interview D's
All D (Catchers of the Sea)	D's will interview C's
All E (Gulf Coastline Businesses)	E's will interview F's
All F (EPA and Hypoxia Task Force)	F's will interview E's
All G (Environmental Groups)	G's will interview H's
All H (University Researchers)	H's will interview G's

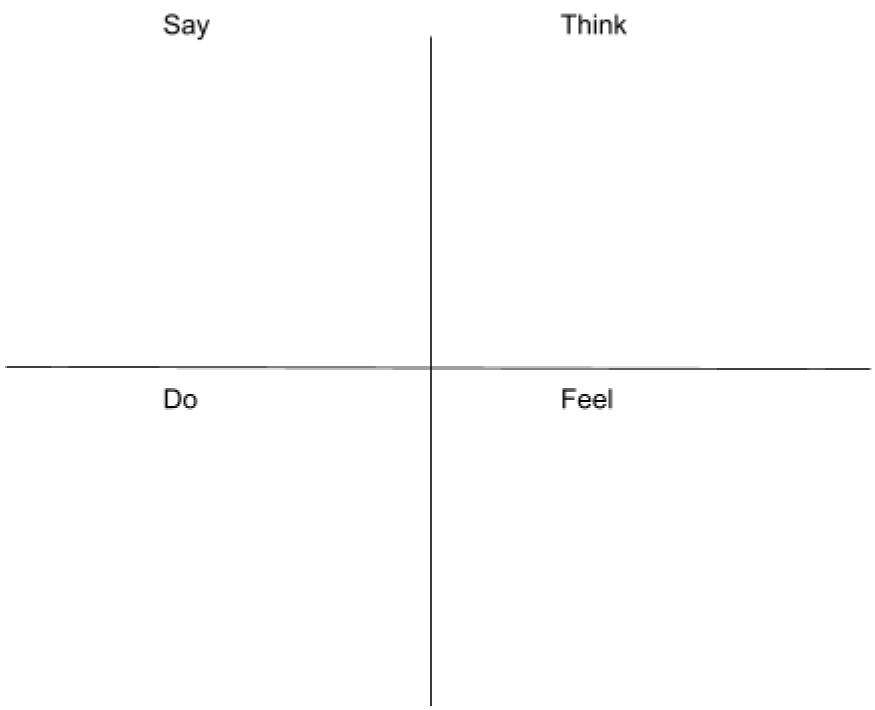
(10 Minutes)

After discussing the article, each student pair (grouping 1) will be assigned a specific role to develop a deeper understanding of the part their stakeholder plays or cares about the dead zone in the Gulf of Mexico. They will develop empathy statements centered around the issue. Roles of stakeholders can be found here. (grouping 1)

(10 minutes)

Students pairs will be split and the teams will mix and mingle with a member of another group to form a new pair (grouping 2). Each person will briefly be interviewed by the other to gain a deeper appreciation for the position held by the stakeholder they are interviewing. They will develop an empathy map divided into four quadrants like the following based on the interview:

Empathy Map: What did they say, think, feel & do about the issue?



(10 Minutes)

Next: interviewers of the same stakeholders will pair up (grouping 1)and develop Point of View statements (similar to madlib with filling in the blank). Pairs will be different and include those that interviewed the farmers as a pair, those that interviewed the shrimpers as a pair, and so on. These pairs will
develop 2 - 4 statements based on their notes from their interview with the stakeholder.

These statements will be based on the following:

___________(adjective) needs a way to ______________(verb),

because ____________________(unique aspect particular to person).

These statements should be specific to the stakeholder, be interesting making them compelling, and provide an action that can lead to helping resolve the issue.

(20 - 30 Minutes)
Sharing two POV statements for class discussion/suggestions.

(5 Minutes)
Ideate or brainstorm ideas. Students will spend some time thinking of the second pairing stakeholder (Pairing B) and provide possible solutions to their situation that could help in reducing, preventing or remediating the issue of eutrophication.

(5 -10 Minutes)
Students will go back to Pairing B grouping and share their solutions.

DAY 3

(10 minutes)
Review the nitrogen cycle & eutrophication (Show and discuss this image).

(10 minutes)
Students will design a prototype (using supplies offered) to represent their solutions to the dead zone situation based on the individual's need(s). Checklist for prototype here: designing a prototype.

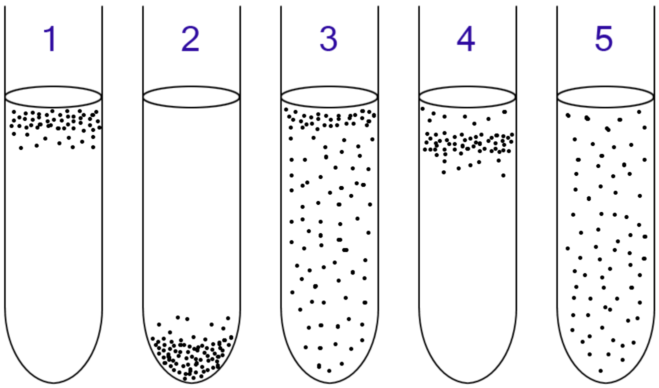
(20 minutes)
Students will share their ideas with the class

(45 minutes)
Students, working in groups of 2-4, will read the attached lab and then begin to assemble filtration columns to test their hypothesis of what will best remove nitrogen compounds from synthetic stormwater. See lab handout here.

Day 4:

(85-90 minute block period)

Review the nitrogen cycle. Review, discuss justification for column design and build working columns. Begin testing water nitrogen levels before and after filtration. Discussion of the following image of the vertical location of colonies of bacteria grown in test tubes of thioglycollate broth.



Questions based on the observations of each test tube:

1. **The dispersion of the colonies in which test tube(s) represent microbes that require relatively high oxygen levels? (aka obligate aerobes)**
2. **The dispersion of the colonies in which test tube(s) represent microbes that are seemingly not partial to oxygen levels? (aka aerotolerant anaerobes)**
3. **The dispersion of the colonies in which test tube(s) represent microbes that require oxygen levels to be at or near zero? (aka obligate anaerobes)**
4. **The dispersion of the colonies in which test tube(s) represent microbes that prefer oxygen levels to be relatively high but can survive at lower or zero levels of O_2? (aka facultative anaerobes)**
5. **The dispersion of the colonies in which test tube(s) represent microbes that require relatively moderate oxygen levels? (aka microaerophiles)**
6. ***Explain* which test tube and type of microorganism can lead to hypoxia and anoxia in the Gulf of Mexico. Provide a detailed explanation to share with the class.**

KEY:

Test tube 1 = obligate aerobes
(only survive at the surface where O_2 is more abundant)
Test tube 2 = obligate anaerobes
(only survive where O_2 levels are low).
Test tube 3 = Facultative anaerobes
(can use either O_2 or anaerobic pathways for generating ATP but have a much higher metabolic rate in the presence of O_2 and therefore grow more quickly.)
Test tube 4 = Microaerophiles are very sensitive to relatively high amounts of O_2 but still need some O_2 to survive.
Test tube 5 = Aerotolerant microbes do not need O_2 to survive but are not affected by the presence of O_2 levels.

Day 5: (15 Minutes)

Wrap up and possible a quiz assessment.

2. Additional Instructional Context:

This series of lessons are largely centered around the phenomena of eutrophication and the nitrogen cycle. The nitrogen cycle typically falls under a unit that includes ecosystem ecology, the interactions between living and nonliving components that make up an environment. Usually, this unit starts with reviewing the concept of the conservation of energy and matter, including the First and Second Laws of Thermodynamics. Because the concentration of energy is not conserved in an open system as it dissipates, it is considered to be a one way pathway. That is to say, energy/heat is conserved in a system but becomes less concentrated or more spread out, in that system and therefore is less and less useable by components of the system. For example, the amount of energy on Earth (an open system) is constantly moving from more to less concentrated (such as the catabolic reaction in metabolism). If it were not for the Sun, the energy on Earth would eventually be too spread out to maintain chemical reactions required for life to exist. However, in contrast to energy, matter is conserved in the system and the carbon, hydrogen, nitrogen, oxygen, phosphorus and sulfur (as well as all other elements) remain relatively constant. It is under this premise that the nitrogen cycle (as well as the other major chemical cycles such as carbon/oxygen, phosphorus and sulfur) is taught.

Additionally, the hope is to incorporate Design Thinking into helping students learn the nitrogen cycle and develop potential ways to reduce, improve or remediate cultural eutrophication and the Gulf of Mexico dead zone. To read more about the Design Thinking process, click here or here. And an overview document We are all DESIGNERs!.

3. Supply List:

HANDOUTS:

1. Prequiz assessment on the nitrogen cycle
2. Textbook pages 84-86
    a. Worksheet for guiding textbook reading
3. Dead Zone Article
    a. Introduction video on eutrophication
    b. Graphics that go along with the article
    c. Worksheet for guiding article reading
4. List of Stakeholders and a brief description of each
5. Empathy Map / POV statement
6. Criteria for prototype ideas and sharing of the ideas
7. Nitrogen cycle handout to be reviewed by students
8. Blank Nitrogen Cycle handout for testing or review
9. Nitrogen cycle quiz
10. Eco-column filtration testing
11. We are all DESIGNERs!

4. Bibliography:

1) Article on Eutrophication, and the Dead Zone of the Gulf of Mexico and predicting its size for 2017
http://www.nola.com/environment/index.ssf/2017/06/gulf_of_mexico_dead_zone_2017.html

2) Image of Bacterial Colonies in Test Tubes
https://en.wikipedia.org/wiki/Facultative_anaerobic_organism#/media/File:Anaerobic.png

3) Introduction to Eutrophication and the Dead Zone Video:
https://oceantoday.noaa.gov/happnow_deadzone2015/

<u>Design Thinking Resources:</u>

Developing a POV statement:
http://hci.stanford.edu/courses/dsummer/handouts/POV.pdf

Graphic for Design Thinking Review
http://thinkspace.csu.edu.au/inf536reflections/files/2015/07/pic3-17gum7k.jpg

Additional Informational Resources:

FROM KQED

https://ww2.kqed.org/learning/2017/03/08/should-the-u-s-government-restrict-fertilizer-use-to-improve-water-quality/

https://ww2.kqed.org/quest/tag/eutrophication/

https://www.sciencedaily.com/terms/eutrophication.htm

Climate Change likely to lead to increase in frequency and severity of drought in California

https://www.sciencedaily.com/releases/2015/10/151021161032.htm

https://19january2017snapshot.epa.gov/sites/production/files/2016-09/documents/climate-change-ca.pdf

Labs and other resources:

https://images.nasa.gov/#/details-iss036e035635.html

http://serc.carleton.edu/eslabs/fisheries/7_a.html

7-27-17 Article on increased water pollution:

http://news.nationalgeographic.com/2017/07/water-quality-hypoxia-environment-rain-precipitation-climate-change/

NASA image of Mississippi watershed

https://svs.gsfc.nasa.gov/vis/a000000/a004400/a004493/Mississippi_large.png

USGS Phosphate load in Mississippi watershed

https://water.usgs.gov/nawqa/sparrow/nutrient_yields/total_p-huc8.html

USGS Nitrogen load in Mississippi watershed

https://water.usgs.gov/nawqa/sparrow/nutrient_yields/total_n-huc8.html

EPA Hypoxia information

https://www.epa.gov/ms-htf/hypoxia-101

5. Keywords:

dead zone, hypoxia, NOAA, decomposition, watershed, nonpoint pollution source, runoff, algal bloom, eutrophication, anoxia

IV. Attachments and Handouts

[Prequiz assessment on the nitrogen cycle]
[Textbook pages 84-86]
    [Worksheet for guiding textbook reading]
[Dead Zone Article]
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[Nitrogen cycle quiz]
[Eco-column filtration testing]
[We are all DESIGNERs!]

V. Additional Thoughts

Local issue (along the coast in CA, or in the bay, or in local lakes Vasona, Lexington Reservoir, ….)

Data collected needs to be apply to you final presentation of the remedy for this issue.

Designing Group Work (Book Rachel Lotan) that discusses group thinking.

Excess nutrients leads to input increase...where does the output go and keep the balance? Legume trees fix nitrogen and lead to, Leaves grow fast, leads up to herbivory leads to assimilation of the nutrients into animals.

Look at the big picture of the green revolution and background to why fertilizer are so heavily used
.
Review oxidation reduction of NO_3 converted back to N_2 how to illustrate the movement of electrons, 5 processes of the N cycle could be divided into 5 groups looking at input and output of the nutrients both naturally and anthropogenic.

Add engagement activities will draw from among these topics:
    Role of Microorganisms in the REDOX of nitrogen in

Nitrogen Fixing, Ammonification, Nitrification, Assimilation, Denitrification

Appreciating the nitrogen requirement for the biological macromolecules of nucleic acids and proteins which form the polymers necessary for life.

Appreciating the nitrogen limited vs. nitrogen abundant environments

Green Revolution

Environmental Costs of Excess Fertilizer

Cyanobacteria as an agent to clean water systems of nutrient overload at the expense of dissolved oxygen dependent aquatic biota.

Eutrophication and Sources of Algal Bloom

Gulf of Mexico Dead Zone

Dissolved Oxygen

Plant species as biofilter to provide a habitat which can absorb and reduce nitrogen and phosphorus loading into waterways.

Wood chips, sand and biochar as hosts for microbes with important remediation effects.