Climate Change of a Different Nature – Carbon Capture Redesign in Biology

National Science Teachers Association
ASEE Session
November 13th, 2015

Kathy Kennedy
CIESE, Stevens Institute of Technology
I probably shouldn’t have gone to a veterinarian for my nose job.

But as an engineer, I value function over form, and the airflow is actually quite good.

You might be rationing a little. I pity you with your inefficient nostrils.
Agenda:

1. Overview of the Connecting Biology & Engineering Unit: Carbon Imbalance, Algae to the Rescue?

2. Introduction to an Engineering Design Activity embedded within Life Science
CIESE Mission 1988-2015

- Support excellence in teaching and learning of STEM subjects
- Innovative, research-based instructional strategies
- Use of novel technologies
Project Goals

• Increase understanding of engineering concepts
  • Physics and biology teachers
  • High school students
• Infuse curriculum materials with engineering concepts
• Study infusion process and its impact
  • Changes in understanding of engineering concepts
  • Approaches to infusing curriculum materials
  • Differences among educators in the two domains
Project Infuse

Project Partners

- Stevens Institute of Technology
- Purdue University
- Black Hills State University
- UMBC
- UMass Boston
- Karen Peterman Consulting
Science and Engineering in the Framework

**Science**
Finding out about the natural world

**Engineering**
Application of science and mathematics to solve problems that arise from a human need or desire

Science and Engineering
Include both knowledge and practices
Science and Engineering Practices

**Science**
- Ask questions
- Construct explanations

**Both**
- Develop & use models
- Plan & carry out investigations
- Analyze & interpret data
- Use mathematics & computational thinking
- Engage in argument from evidence
- Obtain, evaluate & communicate information

**Engineering**
- Define problems
- Design solutions

**Science and Engineering Practices**
Engineering Infused Bio Module

- Photosynthesis
- Respiration
- Decomposition
- Human impact
- Engineering

Terrestrial carbon cycle
Matter and Energy in Organisms and Ecosystems

Use a model to illustrate how photosynthesis transforms light energy into stored chemical energy.

Develop a model to illustrate the role of photosynthesis and cellular respiration in the cycling of carbon among the biosphere, atmosphere, hydrosphere, and geosphere.

Interdependent Relationships in Ecosystems

Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.

Engineering Design

Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.
Engineering Design Activity

Memorandum - Confidential

To: Engineering department
Date: 4/4/2015
Re: New venture

Goal:
Design and build a small-scale algae farm
• Capture and use the CO$_2$ from a power plant (modeled by a candle)
• Maximize algae growth under classroom conditions
• Practical to scale up for use with a power plant
Considerations

• Type of algae to use (e.g., freshwater or marine, species)

• Optimizing growing conditions
  – Light source and length of “daylight”
  – Medium (water, nutrients in which algae will grow)
  – Open or closed system

• Active or passive systems
Engineering Design Activity

Design
• CO$_2$ collection/delivery device and process
• Algae farm

Modeling
• Physical model
  – Prototype
• Mathematical model
  – Project algae growth
## Analysis

- Predictive – Algae selection

### TABLE 1: Algae Characteristics and Growth Conditions

<table>
<thead>
<tr>
<th>Type of Algae</th>
<th>Growth Rate</th>
<th>Light Intensity (units)</th>
<th>Optimum Temp. (°C)</th>
<th>Medium</th>
<th>Size (μm)</th>
<th>Color</th>
<th>Motility</th>
<th>Cost (per tube)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chlorella vulgaris</td>
<td>0.80</td>
<td>3240</td>
<td>32.5</td>
<td>Fresh water</td>
<td>5-10</td>
<td>Green</td>
<td>Non-motile</td>
<td>$10.40</td>
</tr>
<tr>
<td>Dunaliella salina</td>
<td>0.70</td>
<td>27,000</td>
<td>20-40</td>
<td>High salt water</td>
<td>10-12</td>
<td>Reddish pink</td>
<td>Motile</td>
<td>$7.30</td>
</tr>
<tr>
<td>Haematococcus</td>
<td>0.195</td>
<td>2160</td>
<td>23-25</td>
<td>Low salt water</td>
<td>5-25</td>
<td>Red</td>
<td>Motile</td>
<td>$9.25</td>
</tr>
<tr>
<td>Tetraselmis</td>
<td>0.67</td>
<td>2000</td>
<td>20-27</td>
<td>High salt water</td>
<td>10</td>
<td>Green</td>
<td>Motile</td>
<td>$7.30</td>
</tr>
</tbody>
</table>
Engineering Design Activity

Systems

• Subsystems
  – CO$_2$ capture and delivery
  – Algae containment
• Components
  – Of the subsystems
  – Lighting
  – Medium
• Interactions
Implementing the Module

• Education through real world applications

Photosynthesis → Cellular Respiration → Human Effect

Implementing the Module

• Student centered activities:
  – unified classroom
  – collaboration
  – higher level engagement
  – diversity of solutions
Carbon Capture Design Challenge

• Task: Design a device that can capture CO2 from a candle

• Determine how you will evaluate the effectiveness of this device
• Requirements & Constraints
  – Materials
    • Cans, tubing, tape, clay, aluminum foil, funnels, candles
  – Time
    – Must demonstrate that it captures CO2
      • Through the use of BTB
  – Let’s take 5 minutes to sketch initial ideas BEFORE getting your materials.
CO₂ Capture and/or Transfer

• In the table below, list what you know about the design problem that will be important in creating a successful design. Then list what you need to know about the problem, about carbon dioxide or the materials to create a solution.

• Research the information that you need to know to solve this design problem. In the space below, summarize what you learned from your research.

<table>
<thead>
<tr>
<th>What You Know</th>
<th>Information or Skills You Need</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>
• In the boxes below, make several labeled sketches for possible solutions.
• Build
• Test
• Evaluate
• Redesign
Assessing Engineering

• How do you assess this engineering activity?
Implementing the Module
Teacher Feedback

• **Successes**
  - Increased student engagement
  - Better Understanding
  - Developing team building skills

• **Challenges**
  - Time
  - How to facilitate engineering content
  - Teacher and student feedback is very positive
Carbon Imbalance: Algae to the Rescue?

http://www.ciese.org/engineeringproj.html
Acknowledgment

This work is funded by the National Science Foundation

Grants DRL-1158615 and DRL-0917540

Thank you!
Questions or Comments
Katheryn.Kennedy@stevens.edu