Teaching and Learning Ecology Using a Classroom Algal Photobioreactor

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Highlights Insightful questions were raised regarding the carbon footprint of biofuels and interspecific differences in growth among algae. Students discerned from their studies that biofuels could play an important role in mitigating global and environmental challenges. Their investigations also demonstrated that they too have a future role in shaping and preserving the natural world.

Introduction

The algal photobioreactor laboratory (APBL) is a project-based activity designed to teach about ecology and increase awareness of sustainable biofuel production systems. As described herein, it was introduced in an eighth grade biology class at a Quaker independent school in Wilmington, Delaware. This investigation both increased the students' interest in ecology and sustainable systems thinking and provided hands-on learning opportunities relative to core concepts in environmental science and microbiology. Students increased their facility with the process of scientific investigation and engineering solutions to real-world challenges via hypothesis testing, experimental design, data analysis and modeling, and exploring the downstream implications of their work. APBL also enriched the students' learning experience(s), as the laboratory principles (scientific discovery, ecological stewardship, and sustainability) aligned with the school's core beliefs of environmental conservation and stewardship.

Objectives

Students

- To apply knowledge of the carbon cycle and photosynthesis for growing populations of *Chlorella protothecoide*s.
- To understand the need for finding sustainable alternatives to fossil fuel energy.

Teacher

- Enable students to understand the benefits and disadvantages of growing algae in photobioreactors (return on investment).
- Provide opportunities for students to examine one or more variables involved in growing algae (carbon dioxide, light, and nutrients).
- Align student learning and classroom curriculum to Next Generation Science Standards, specifically:
  - HS- LS 1-5. Use a model to illustrate how photosynthesis transforms light energy into chemical energy.
  - HS-LS 2-5. Develop a model to illustrate the role of photosynthesis and cellular respiration in the cycling of carbon in the biosphere, atmosphere, geosphere, and hydrosphere.
  - HS-LS 2-7. Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.

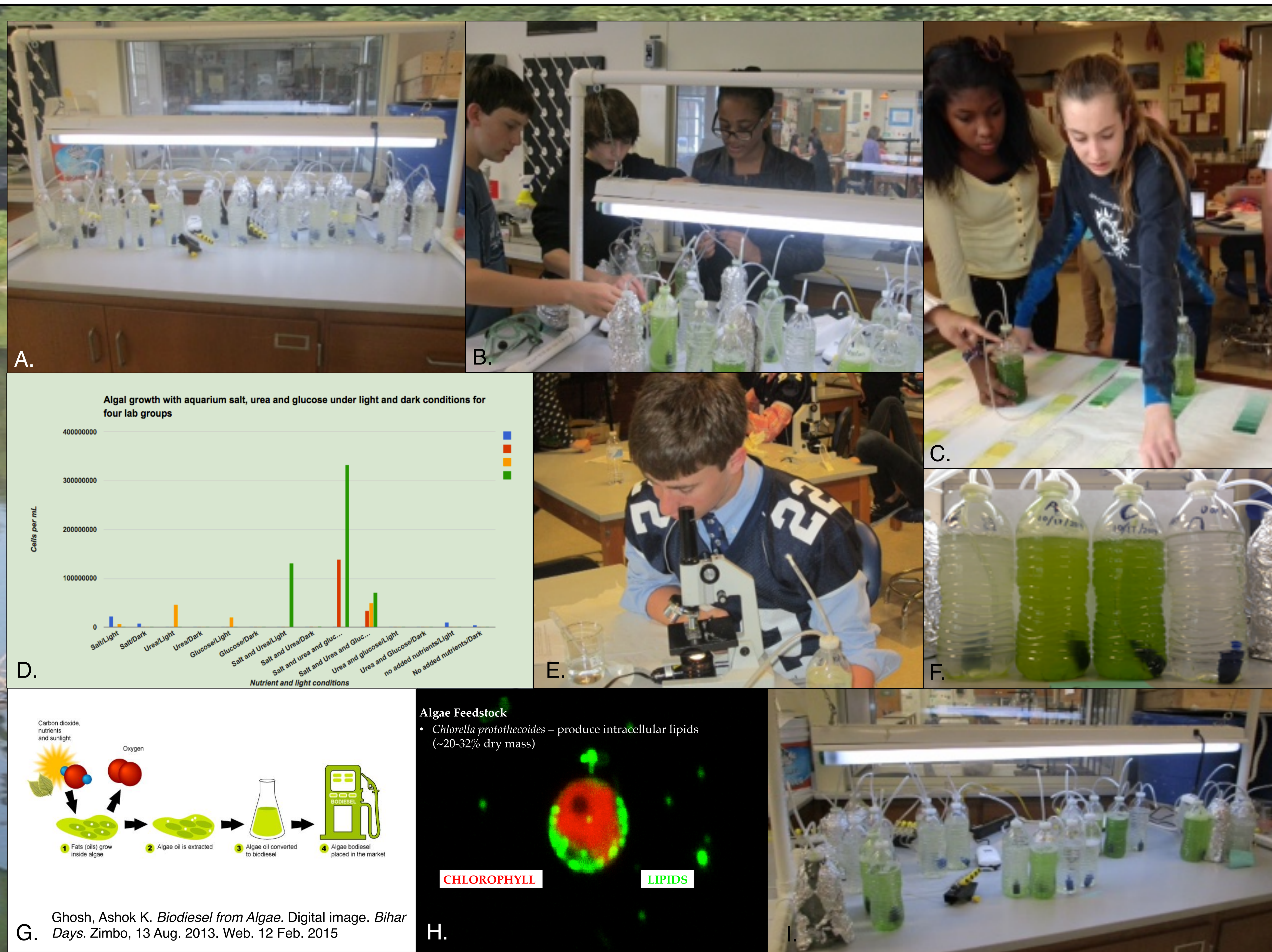

Figure 1. **Day 1-10.** (**A**) Established APBs attached to gang valves and pumps; (**B**) students swirling bottles, maintaining set ups, and checking for color changes; (**C**) Students using commercial paint chips for qualitative observations of algal growth; (**D**) graph of algae growth in various nutrient and light conditions; (**E**) student using hemocytometer to count algae cells per square; (**F**) algae growth after10 days; (**G**) schematic diagram, algae to biodiesel gasoline; (**H**) Lipid content of *C. protothecoides*; and, (**I**) APBs, 5 days

Materials and methods

- Students grew the alga *C. protothecoides* in photobioreactors using laboratory protocols shared by the Boyce Thompson Institute's Curriculum Development Project in Plant Biology Program.
- Using eight nutrient-light combinations, students designed model ecosystems to support optimum algal growth for seven days. Students collaborated in groups of three to choose growth conditions and construct photobioreactors.
- Upon establishing their own "model ecosystems" they observed varying shades of green in their set ups indicating differences in algal population growth by ecosystem.
- Cell concentration per nutrient-light combination was measured using a hemocytometer and spectrophotometer. Students presented data via charts, graphs, and photos, and then prepared a final summary of their findings.

Results

- Students found that more algae grew when aquarium salts and urea were added to the water and that light was necessary for rapid cell growth.
- In small group and whole class conferences, students compared and evaluated their findings.
- Observations, data and questions were shared on Google docs, and they collaborated on how to share their data in charts, graphs, and photos.
- Lastly, each student was required to write an analysis summarizing their findings and reflecting on future implications for biofuels. Questions about the carbon footprint of biofuels, growing algae in darkness, and how different kinds of algae grow in response to the nutrients were raised.

What's next for the students?

- Create a timeline for their entire project, from teacher training and introduction to closing labs and discussions.
- Post a blog on the school website describing their work and how it relates to the school's mission.
- Correspond with scientists at the Boyce Thompson Institute about their lab work, findings, and future implications.
- Revisit biofuel engineering through a new investigation on cellulosic feedstocks and enzyme release of glucose. They will also discuss implications of bioethanol production through studies on DNA, genetic coding for cellulose in plant cell walls.

Conclusions

Through this investigation, students were given the opportunity to experience real-world science. They were able to apply the concepts that they learned in class to environmental problems and grapple logically with solutions proposed by scientists. Students appreciated the level of detail involved, and they expressed interest in chemistry, engineering, and marine ecology as possible careers. They also agreed that this work was important for their futures and that they would support further research on biofuels and bioproducts.

Acknowledgements

Laboratory curricula and classroom materials (creation and/or distribution) were made possible by funding from the National Science Foundation (NSF award no. 1247078) and United States Department of Agriculture (USDA) – National Institute of Food and Agricultures (NIFA; award no. 2011-67009-30055).