Algae Based Engineering Education

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Introduction of the Project

- 3 Year Project funded by the NSF titled "Algae Grows the Future" for developing STEM activities entwined with the Humanities and Social Sciences

- Innovative initiative between the Center for Aquatic Sciences at Adventure Aquarium in Camden, New Jersey

Globally Conscious Topics

NAE GRAND CHALLENGES FOR ENGINEERING
NATIONAL ACADEMY OF ENGINEERING

United Nations Millennium Development Goals

- Create 'Global Engineers'
  - Energy
  - Clean Water
  - Environment
  - Food
  - Global Health
  - Education
 - Poverty
  - Security

Objectives

- Develop hands on activities that focus on engineered applications of algae for freshman engineering students and K-12 educators and students
- Develop lesson plans, website and videos
- Develop algae games for K-12 educators and students

Why Algae?

- Algae are very diverse and found almost everywhere on the planet. They play an important role in many ecosystems.

- Algae are simple microbes that can range from the microscopic (microalgae), to large seaweeds (macroalgae), such as giant kelp more than one hundred feet in length.

- Algae can be grown using water resources such as brackish-, sea-, and wastewater unsuitable for cultivating agricultural crops.

- Most microalgae grow through photosynthesis – by converting sunlight, CO_2 and a few nutrients, including nitrogen and phosphorous.

- Rich in lipids (35%) and proteins (45%)
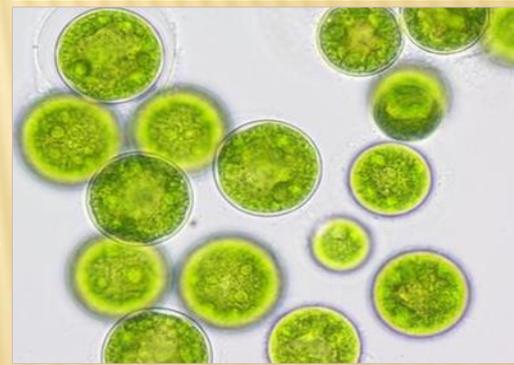
Algae Derived Biofuel

| Crop	Oil yield (L/ha)	Land area needed (M ha)[a]	Percent of existing US cropping area[a]
Corn	172	1540	846
Soybean	446	594	326
Canola	1190	223	122
Jatropha	1892	140	77
Coconut	2689	99	54
Oil palm	5950	45	24
Microalgae[b]	136,900	2	1.1
Microalgae[c]	58,700	4.5	2.5

[a] For meeting 50% of all transport fuel needs of the United States.
[b] 70% oil (by wt) in biomass.
[c] 30% oil (by wt) in biomass.

Algae Applications
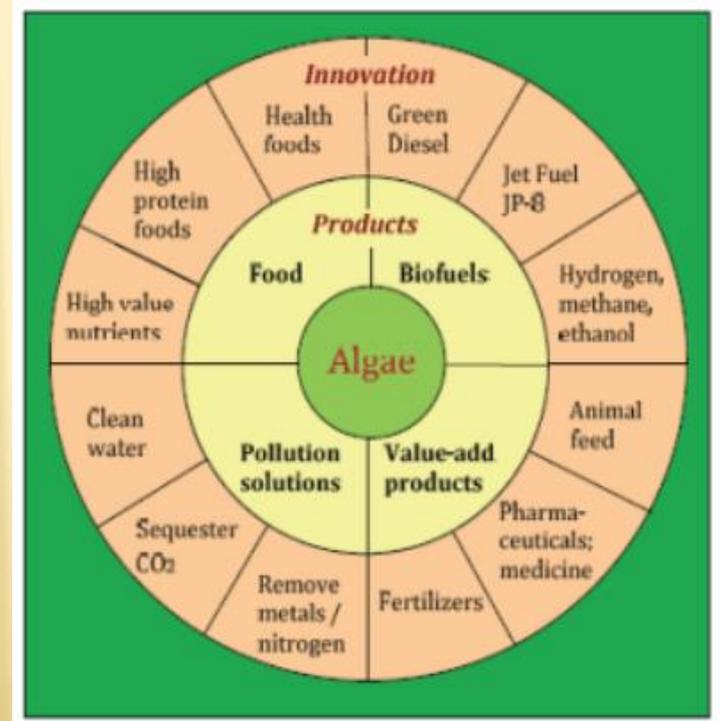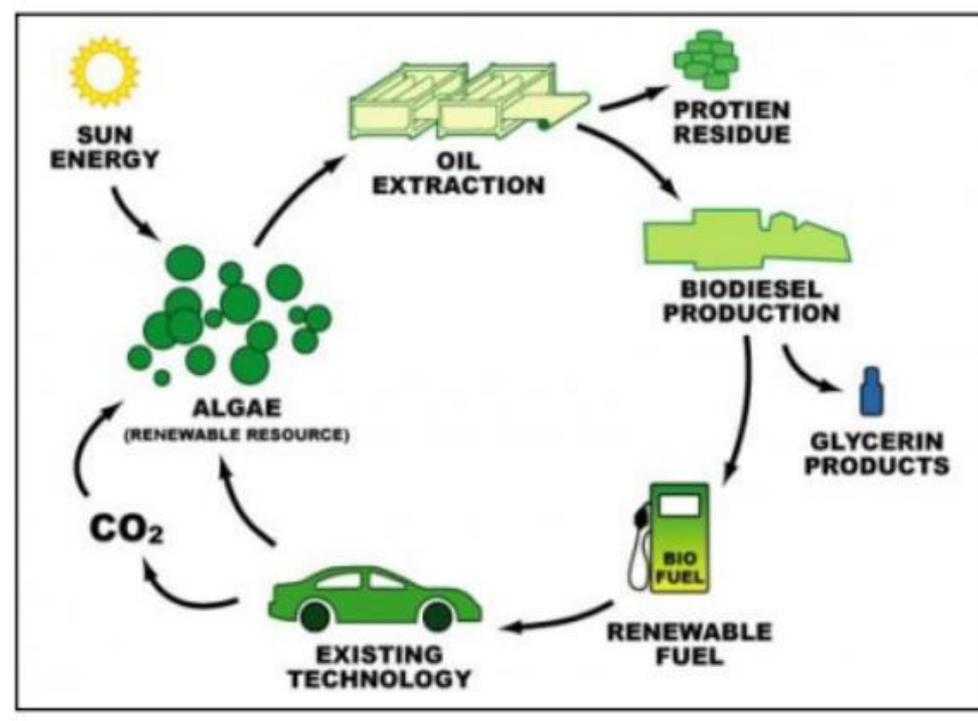
Experiments:

Growth and Development Studies

- Growing Algae
- Photosynthesis Lab
- Gas Transfer Lab
- Dewatering Lab-Jar Test, Centrifuge, Filtration

Applications of Algae

- Biofuels Sodium Alginate Slime
- Cosmetic Engineering
- Calorimetry
- Materials-Surfboards
- Medical - Healing wounds
- Electric battery

Growing Algae
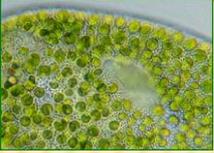
Chlorella vulgaris

Step 1: 50 mL
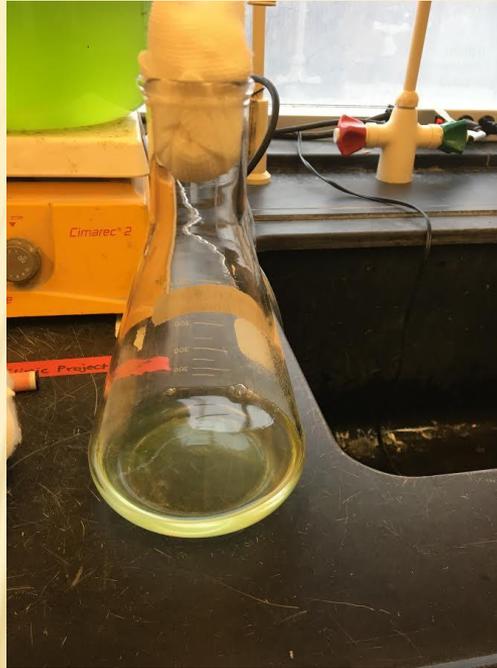
Step 2: 100 mL
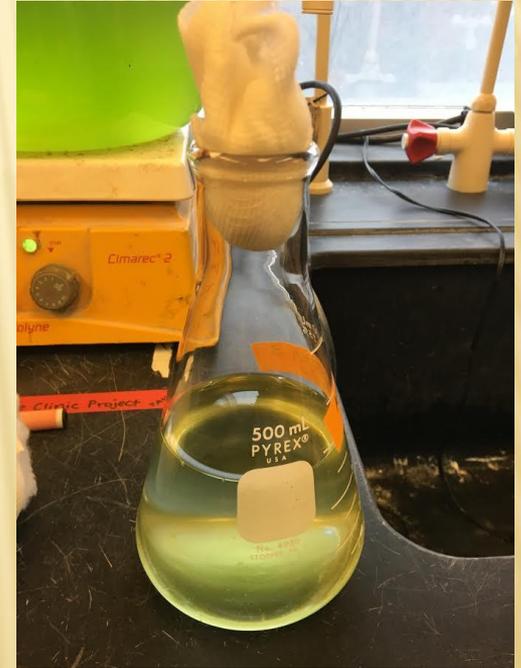
Step 3: 200-300mL

Growing Algae
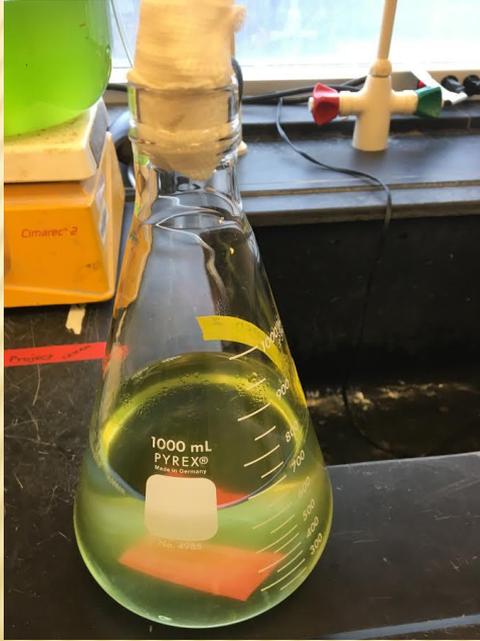
Step 4: 500 mL
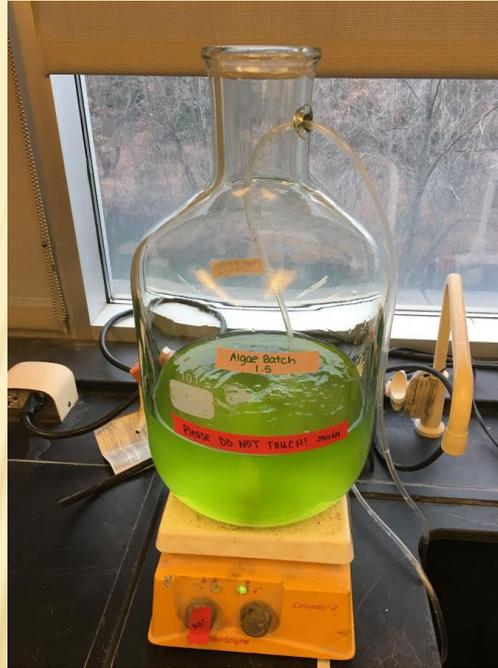
Step 5: 2L and up

Used Environ Shaker to
Mix and Aerate

Algae Growth Studies

- Algae growth was measured periodically with different variables and controls.
- There was four variables and a control group for each variable. The variables were mixing, nitrate, light and heat.
- Data Collection
- Plotting
- Statistics: Error Bars, t-tests
- Comparison of data
- Calculation of growth rates
- Report (Technical Writing)
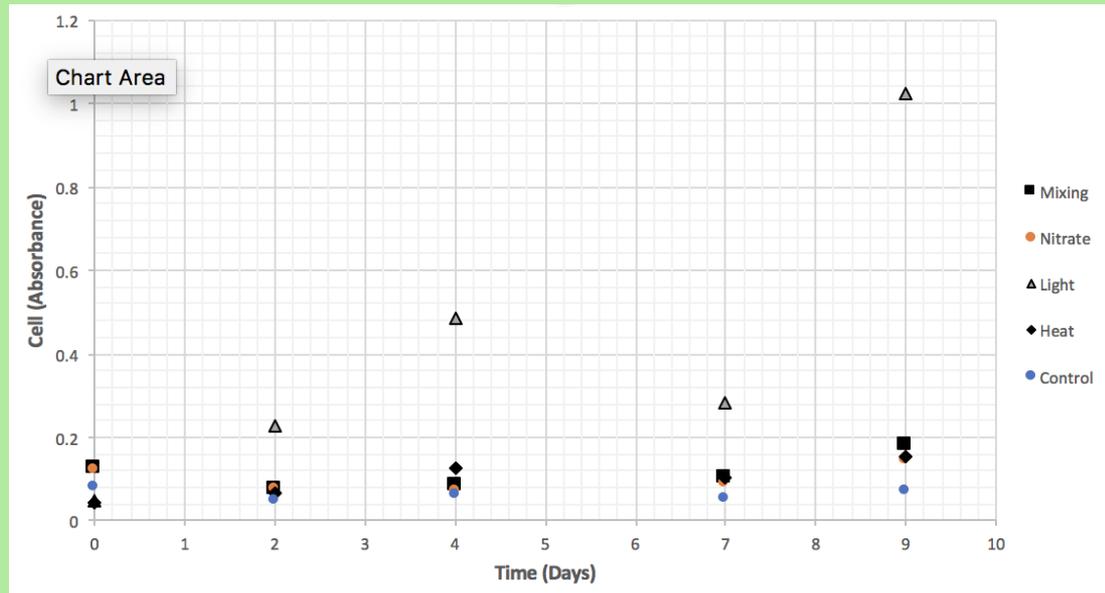
Photosynthesis Lab

- Uses photosynthesis tank and dissolved oxygen meter .
- Algal photosynthesis uses carbon dioxide, meaning it could be used to remove CO_2 from the air.
- Dissolved oxygen levels are studied as changes occur from photosynthesis and respiration.

$$6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$$
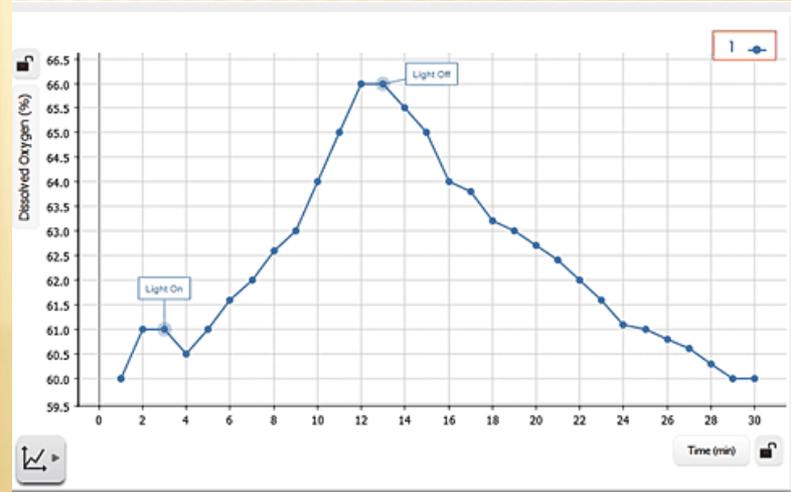
Gas Transfer

- Vital in environmental engineering processes
  - Oxygen transfer for water/wastewater treatment
  - Oxygen transfer for maintaining DO levels in surface waters
  - Oxygen transfer to promote bacterial growth for wastewater treatment

- CO_2 transfer in algae reactors for promoting algae growth
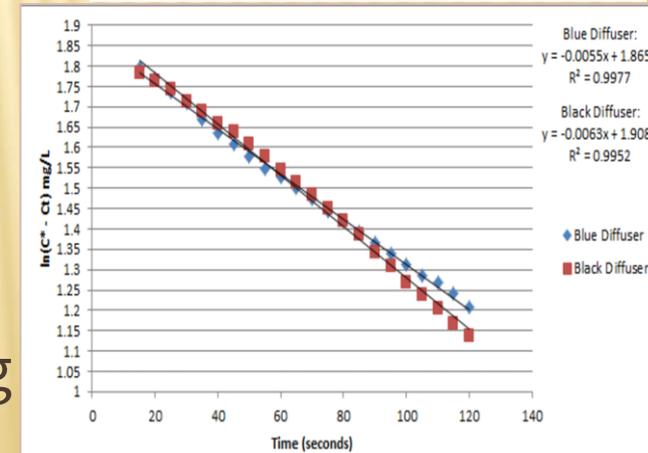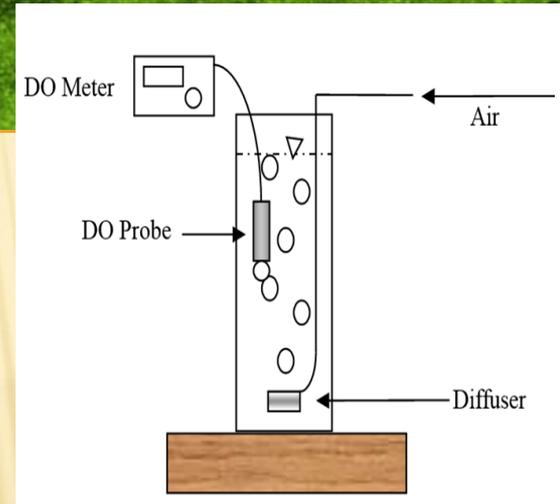
Algae Dewatering

- Coagulation/Flocculation using chemicals (Trivalent salts Iron & Aluminum)

- Students perform the standard Jar Test experiment with a focus on removal of algae in water using chemicals such as alum or ferric chloride

- Physical treatment using evaporation, centrifugation and filtration
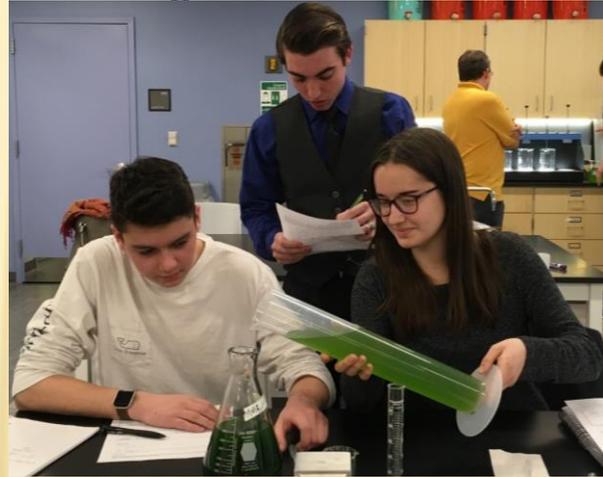
Algae Lipids
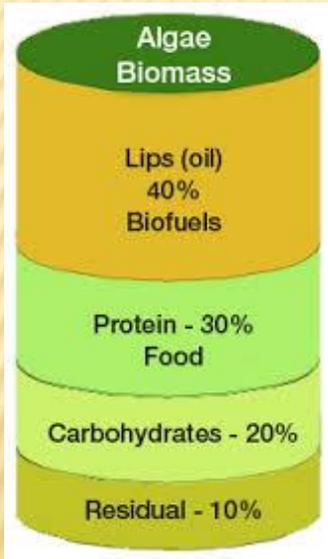
Algal oil is converted into biodiesel through a transesterification process. Oil extracted from the algae is mixed with alcohol and an acid or a base to produce the fatty acid methylesters that makes up the biodiesel.

Algae Biomass
Lips (oil) 40% Biofuels
Protein - 30% Food
Carbohydrates - 20%
Residual - 10%

$$CH_2-OCOCR_1$$
$$CH-OCOR_2 \ + \ 3\,HOCH_3 \ \underset{\longleftarrow}{\overset{Catalyst}{\longrightarrow}} \ CH-OH \ + \ R_2-COOCH_3$$
$$CH_2-OCOR_3$$

$$CH_2-OH \quad R_1-COOCH_3$$
$$CH_2-OH \quad R_3-COOCH_3$$

Triglyceride (parect oil)   Methanol (alcohol)   Glycerol   Methyl esters (biodiesel)

DMF   90% Acetone   Hexane
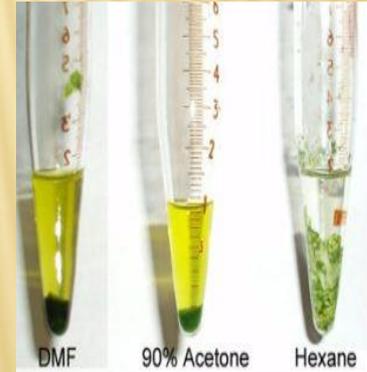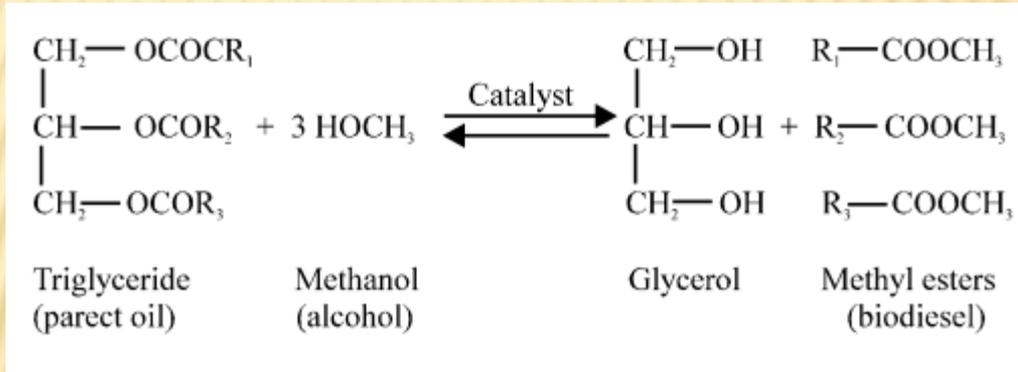
In the cosmetic industry, lipids and oils are often utilized in products.

Cosmetics Industry

Benefits of Algae in Skin Care

- Algae are a good source of Omega3 fatty acids, which can treat the following acne, eczema, wrinkling, and dryness.
- Algae regulate the production of sebum, which can prevent skin dehydration.
- Algae aid in the production of collagen, which are essential to firmer skin.
- Algae are rich in essential minerals and vitamins. This helps rejuvenate the skin, prevent skin aging, and repair skin damage.

Experiment

- Make lip gloss using algae oil and other ingredients

- Learn the function of each ingredient

- Students develop a marketing plan for their algae lipgloss

Algae Used as Food Source

- Algae has high potential in the global food industry with its high protein and fat content.
- About 1 of 9 people in the world are undernourished.

- Also feed for aquaculture industry.

- Calorimetry experiment allows students to determine the energy content of various different foods while utilizing principles of energy conservation and energy transfer.
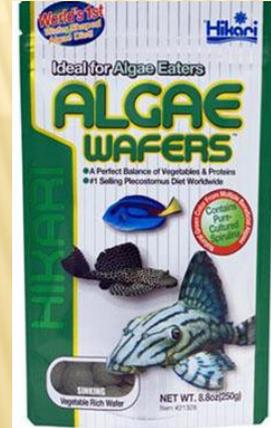
Algae Derived Gel

- Fun experiment that can help show the relationship between algae, chemistry, and engineering for future chemical engineers.
- Sodium Alginate from brown seaweed (kelp) is a polymer of glucose molecules
- When combined with calcium acetate, a non-soluble calcium alginate is formed, creating a gel-like slime
- Typically this product is used in the food industry to create artificial caviar

$$Na(Alginate) + CaCl_2 \rightarrow 2\ NaCl + Ca(Alginate)$$

Ca^{2+} ions

Alginate

Negative charge group
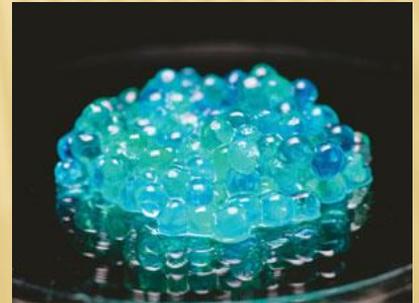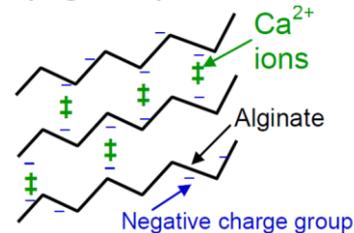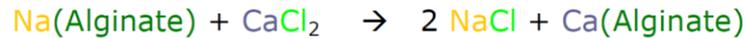
Algae Derived Gel

- ## Materials Industry
  - ### Stress, Strain, Young's Modulus, Viscosity
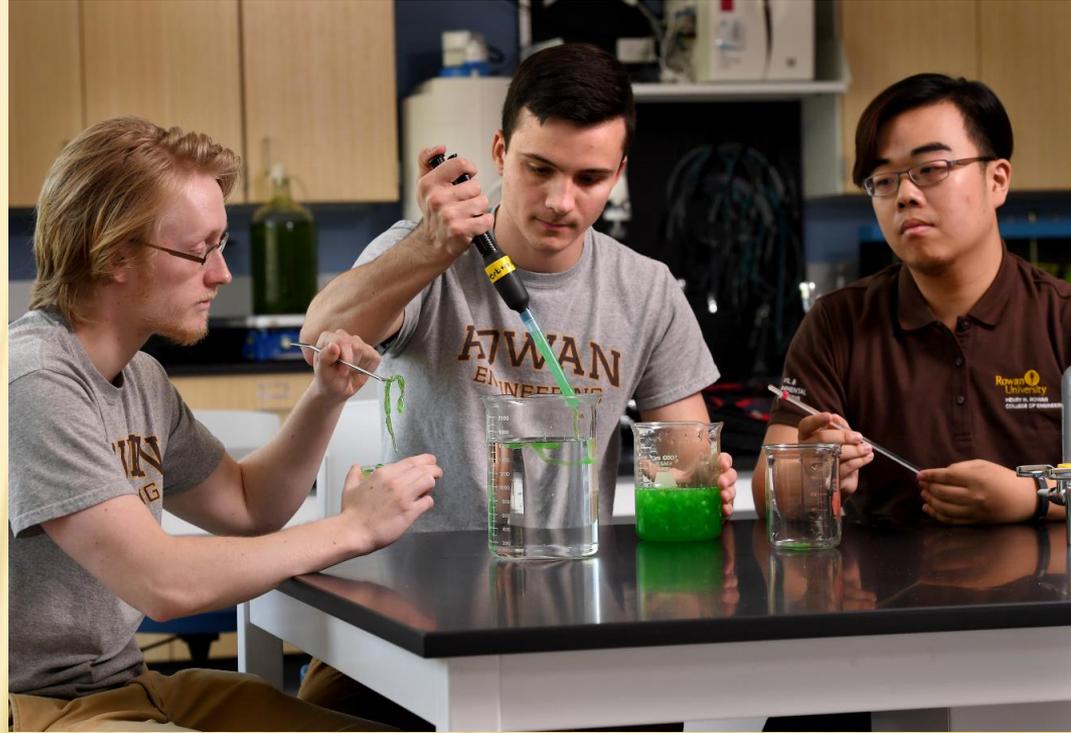
HUMANITIES INTEGRATION

Ethics
Social Injustices Gender Bias
Public Policy
Diversity & Inclusivity   Civilization

Semester Project

Divide teams and assign a state (USA) or a country

Teams research government, religion, society, culture, resources and the status of science & technology

Teams research how algae can help "Grow the Future" of their assigned community. They will identify challenges - both scientific and social that can deter use of algae.

Other Assignments
Movies/Documentaries

Water Wars
Erin Brockovich
Civil Action
Whale Rider
Bhopal Express
Rabbit Proof Fence
Good Intentions
The Hidden Figures
The Wind Rises
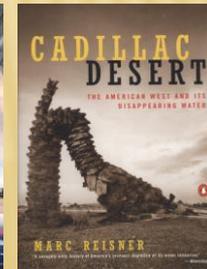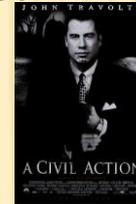
Other Assignments
Select Readings

Dark Lady of DNA
Flint Drinking Water Crisis
Ford Pinto Case Study
Cadillac Desert
An Inconvenient Truth
Billions in Change
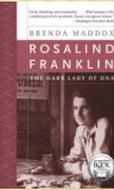
Algae City Game

A mixed-reality game series "*AlgaeCity*" for K-12 students, educators and freshman engineering students is currently under development.


AlgaeCity will allow players to utilize algae for various purposes in the city's day to day functions, including life cycle analyses of various energy sources in comparison to algae-based biofuels, and carbon footprint calculation of various algae product processes, etc

K-12 Outreach

- Teacher Training
- Middle School Pilot Project

- Perfect for project based learning
- Easy link between biological sciences & engineering
- Cost effective experiments
- Hands on visual experiments
- Can map activities to the NJ Next Generation Science Standards

Project Website

- Designed to host future experiment outlines
- Video tutorials for laboratories
- A place students can go to find fun and interesting supplementary material

http://users.rowan.edu/~jahan/sophclinic/slides/algaegrows.html

http://users.rowan.edu/~jahan/hunter/algae_workshop sources.htm

Conclusions and Future Plans

- The ***Algae Grows the Future*** project offers a curriculum that can be easily implemented in freshman engineering courses.

- Elements of the project can also be easily adapted for K-12 students and educators to promote engineering as a career choice.

- Activities are cost effective.

- Students can learn about all branches of engineering and the social sciences while strengthening the skills required for scientific inquiry and experimentation.

ACKNOWLEDGEMENTS