



Integrating Humanities with Engineering Fundamentals

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Abstract

At the 2015 United Nations Sustainable Development Summit, a set of sustainable development goals was formed and adopted by world leaders. These goals, which were set to be achieved in a fifteen-year period, address pressing universal issues, including climate change, social inequalities, poverty, and clean water access. The field of engineering is regarded as an essential part of addressing world issues. The humanities, however, are often considered to be dichotomous with the field of engineering. A bridge between engineering and humanities must be built, for they are incontestably intertwined. Engineering, by its very nature, is based around creativity and moving the world forward. Too often, engineering courses teach only equations and figures, overlooking how these fundamentals relate to the world and its people. In an effort to empower and prepare the next generation of engineers to create sustainable solutions to global issues, the Algae Grows the Future team at Rowan University, with funding from the National Science Foundation (NSF), has developed a curriculum based around algae. This curriculum utilizes algae-based experiments and lessons to teach foundational engineering principles, emphasize the link between engineering and humanities, and encourage students to pursue creative, conscientious solutions. The curriculum has been designed with adjustable complexity, suiting K-12 and college freshman students, and has been implemented in both middle school and freshman engineering classrooms. Calorimetry experiments allow students to investigate the nutritional benefits of algae-based products and challenge students to consider the application of algae in the fight against world hunger. Gas transfer experiments are used to research the sustainability of algae in the water treatment process. Algae can also be used to generate energy sustainably, as the oils found in some algae species can be used as biofuels. Students will learn about biofuels and will extract algae oils to generate energy within the classroom. While students will be learning principles of math and science, they will also be encouraged to explore the political, cultural, and economic barriers that prevent algae-based solutions from being implemented in many places around the world. The objective of this curriculum is to give students the knowledge to solve sustainable development issues in the future, while also teaching crucial engineering skills and awareness of global issues. The curriculum has been successfully implemented in first-year engineering classes and a middle school classroom and ultimately hopes to teach a generation of future thinkers the impact that engineering can have on solving humanitarian issues around the world.

1.0 Introduction

1.1 Algae Grows the Future

Algae Grows the Future is the name of a team comprised of junior and senior college students that is focused on creating an algae-based curriculum for K-12 and college students. The project is funded by the National Science Foundation (NSF) and was created in partnership with the Center for Aquatic Sciences (CAS) at the Adventure Aquarium. The CAS promotes the understanding and appreciation of aquatic sciences and provides outreach programs for a large population of students in Camden, NJ and surrounding communities [1]. The partnership will allow the Algae Grows the Future project to expand its reach and will provide material for CAS to implement. The theme of algae was selected because of the wide range of applications of algae, ease of growth and maintenance, and accessibility to any classroom. The Algae Grows the Future team aims to promote a high quality engineering education, along with the integration of humanities to improve students' understanding of the connections between the two fields.

1.2 Project Goals

There is a disconnect between the sciences and humanities on both collegiate and societal levels. Oftentimes, those in technical fields, such as engineering, are not trained to deeply consider the impact that their projects will have on culture, government, and philanthropy. It is vital that the technical and humanitarian fields do not exist independently; they must interact. The Algae Grows the Future team at Rowan University has designed a curriculum with adjustable complexity to be implemented in both K-12 and college classrooms. The objective of this project is to promote the integration of engineering and the humanities as early as the first year of schooling. Through algae-based experiments, projects, lessons, and supplemental material, students will solve real-world problems, be exposed to fundamental math and science concepts, be able to explain and advocate for causes they feel strongly about, and be encouraged to be globally-conscious thinkers and creators.

1.3 Algae as a Learning Tool

Algae is a single-celled, photosynthetic organism that is often found in bodies of water. While algae is familiar to many people as the scummy layer on top of a pond or the green coating on a pool, it has a wide variety of applications that could improve the lives of people around the world. The prospect of utilizing algae is growing in many industries, including cosmetics, food and nutrition, biofuels, bioplastics, and more [2]. For example, algae is being added to nutritional food products because of its high protein and vitamin content. Figure 1 shows the versatile industries that utilize algae. Today, the algae industry's market share is estimated at \$8 billion and is expected to increase [3]. The study of algae is exciting and relevant in today's society, and will provide many job opportunities in coming years.

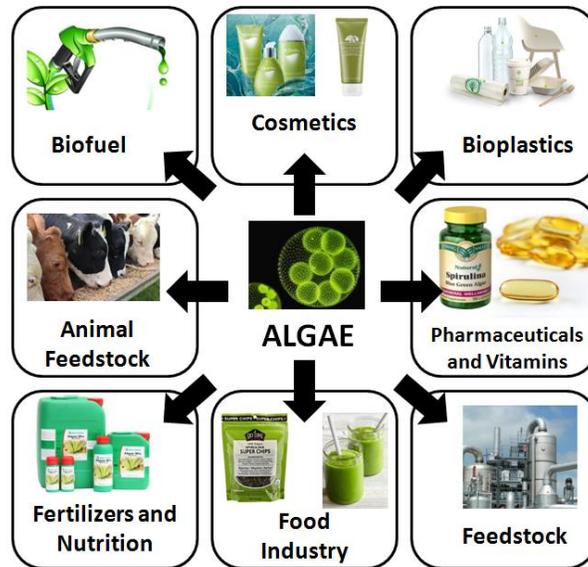


Figure 1: Algae Applications in Industry

Furthermore, algae is a feasible, versatile learning tool. It is easily accessible and low-maintenance, making it ideal for classrooms everywhere. Algae-based experiments are multidisciplinary and incorporate a variety of concepts from engineering, the natural sciences, and humanities. The basic knowledge behind algae innovations can be demonstrated through algae samples grown anywhere, including college labs and K-12 classrooms.

1.4 Globally-Conscious Learning

STEM education is becoming increasingly prominent in elementary and high school classrooms. This trend is exciting and promising, especially for a future of a more diversified engineering community. Engineering provides a unique platform to make an impact on the world. Engineers are responsible for utilizing the scientific principles studied in laboratories, patterns and laws derived by mathematicians, and creativity to develop new products and processes or improve existing ones. These products and processes have an impact on consumers and the environment that surrounds them, both small and large. Thus, it is vital that engineers have a global perspective. It is important to consider economics and efficiency, but the scope of engineering extends beyond cost and industry. Engineers must recognize the effects that their projects will have on culture, humanity, and the environment. Furthermore, it is important for the field of engineering to address global issues, including world hunger, dependency on fossil fuels, limited access to proper healthcare, global warming, and much more.

Promoting global consciousness among students was a key objective in the creation of this curriculum. The experiments and activities were designed not only to teach students principles of engineering and experimentation, but also to encourage the consideration of world needs and to exemplify how engineering and science can be applied to meeting these needs. In today's world, issues including global warming, world hunger, and energy must be addressed, and it is important that the next generation of creators are prepared and excited to tackle these issues.

2.0 Experiments

Experiments were developed to teach concepts of math and science and to promote critical thinking. The experiments were designed with adjustable complexity; they can be made simpler or more complex depending on the classroom level. Specifically, the experiments may be implemented in K-12 and college classrooms. Many of the experiments replicate industrial applications of algae. The experiments were created to be hands-on and exciting for students, with hopes that students will garner interest and enthusiasm for engineering.

2.1 Calorimetry

According to the World Hunger Programme, about 795 million people in the world do not have the proper nutrition to live a healthy and active lifestyle. Furthermore, poor nutrition claims the lives of about 3.1 million children each year [4]. The prospect of algae as a nutritional food source and its potential application in the battle against world hunger is explored through a calorimetry experiment.

Through the process of calorimetry, the number of calories in a food sample can be determined by measuring energy exchange between a system and its surroundings. Students conduct the calorimetry experiment utilizing an empty, clean soda can as a calorimeter. The soda can is secured on a ring stand and filled with water of a known initial temperature. A food sample is lit on fire with a match and placed beneath the soda can. The final water temperature is measured after the food sample is completely burned. The energy transferred from the burning food to the water is equal to the mass of water multiplied by the specific heat of water multiplied by the change in temperature. The energy calculated is the energy of the food, often referred to as calories.

Students will test several food samples, at least one of these foods being algae-based. For example, there are algae-based chips and nutritional bars. The students will be able to compare the energy content of the food samples, along with their nutritional values, and analyze the nutritional benefits of algae. With the information gathered on the amount of calories within algae, along with the knowledge that algae is high in protein and fats, it can be determined whether or not algae can be used as a viable food source.

2.2 Coagulation and Flocculation through the Jar Test

Coagulation and flocculation is the process of using chemicals to clump together and settle out particles in water, typically used at water treatment plants to remove turbidity and sanitize water. The typical coagulant utilized for this experiment is alum, as it is relatively cheap and works well to clump particles together.

Algae is often one of the lead causes of turbidity in water, since algae is typically distributed evenly throughout water and does not settle out on their own. With the addition of different concentrations of alum to jars containing the same concentration of algae, the optimal dosage of alum needed to coagulate and flocculate the algae within the water samples can be determined.

This experiment offers a hands-on approach for students to learn about the importance of water treatment, and exposes students to potential uses of algae in underdeveloped countries for water treatment. Students will also practice graphing and analyzing data and working with spreadsheets.

2.3 Cosmetics

The cosmetics industry, which includes skin care, topical lotions, and more, had a revenue of over \$62 billion in 2016 [5]. In this massive industry, consumers are attracted to products that are natural and beneficial to health. Algae has a high fatty acid and vitamin content and has the ability to regulate sebum and collagen production, which contribute to firmer, more hydrated skin and the treatment of acne and wrinkles [6]. Algae is therefore a beneficial ingredient in cosmetic products like beauty serums, anti-aging creams, and algal soaps.

In 2011, Women's Health Journal stated that mineral oil hydrocarbons are one of the leading contaminants to the human body [7]. Many cosmetics products contain these hydrocarbons, along with petroleum and questionable chemicals, which are not safe or appealing to conscious customers. By finding substitutes for these ingredients, healthier cosmetic products can be created and the use of nonrenewable resources can be reduced.

In this experiment, students will study and create a common cosmetic product - lip gloss. Lip gloss contains oil, which acts as an emollient to moisturize skin. Students will learn the main components of lip gloss and what purpose each component serves. Then, students make their own lip gloss using algae oil, beeswax, honey, food coloring, and essential oil for scent. This experiment is engaging and exciting for students, as they will be creating a product that they can personalize and bring home to family and friends. Students will be prompted to consider the source of ingredients in everyday products and how the products may be engineered to be more safe and environmentally-friendly.

2.4 The Effect of Alternating Colored Lights on Algae Growth Rate

One of the seventeen Sustainable Development Goals set by the United Nations is to develop "Affordable and Clean Energy" [8]. The negative effects of fossil fuels and shortages of its supply have urged the research and implementation of alternative fuel sources. In order to be a feasible alternative, a fuel source must be environmentally-friendly and economically comparable to existing fuel sources and provide net energy gain [9]. Oil extracted from algae is a desirable feedstock for biofuels, as it can be produced in controlled settings and does not compromise resources needed for other purposes. Since a high volume of fuel is required for transportation, electricity, and other societal functions, it is vital to have access to a large supply of fuel. Therefore, in order for algae oil to be a feasible alternative to fossil fuels, algae must be able to be grown efficiently and quickly.

Studies suggest that a light source with alternating wavelength better stimulates photosynthesis in comparison to a constant wavelength [10]. In this experiment, students will learn about the photosynthetic nature of algae, physics of color, and will study the effect of alternating colored lights on algae growth rate. Through data analysis, students will determine the optimal light

condition for a high algae growth rate. Students will be prompted to consider the prospect of algae as a biofuel and how algae can be grown on an industrial scale.

2.5 Photosynthesis

In order to understand the relationship between oxygen and carbon dioxide in a biological system, a fundamental understanding of the photosynthetic process is necessary. This experiment is simple, but effective. It will introduce students to the biological concepts behind photosynthesis and the differentiation between light-independent and light-dependent parts of photosynthesis. A sample of algae will be subjected to a light source and the increase in dissolved oxygen will be measured with a dissolved oxygen meter. An increase in dissolved oxygen concentration signifies that the algae is undergoing photosynthesis. After a set amount of time, the algae sample will be placed such that it will not be subjected to any light. Again, the dissolved oxygen will be measured. This procedure will be repeated, and students will analyze the reliance that photosynthesis has on the presence of light.

The United Nations Sustainable Development Goal that best aligns with this experiment is to “Clean Water and Sanitation” [8]. Photosynthesis is a recognized carbon dioxide sequestration mechanism, which is utilized to mitigate accumulation of greenhouse gases in air and water. This experiment will help students understand the process of carbon sequestration and how algae may be used to achieve cleaner water and air.

2.6 The Effect of Light Intensity on Oxygen Production

Similar to the photosynthesis lab described above, this light intensity experiment details how the photosynthetic nature of algae can be used to convert carbon dioxide into oxygen. However, while the photosynthesis experiment focuses solely on the presence of light, this experiment studies the relationship between light intensity, oxygen production, and culture thickness. These variables are important when considering the implementation of algae based carbon sequestration systems in enclosed areas, where these factors can vary.

This experiment was designed to be done virtually, which will expose students to the use of spreadsheets and data interpretation. Given equations that relate light intensity, area exposed to light, culture thickness, and oxygen production, students will construct a spreadsheet that will relate the factors. Then, students will be able to determine how changing a factor, increasing culture thickness for example, may impact photosynthesis. It should be observed that increasing the thickness of an algae culture decreases oxygen production and that increasing light intensity increases oxygen production. To simplify this experiment for younger students, a preconstructed spreadsheet may be provided to students.

2.7 Microtox

Algae grows naturally in bodies of water and is often undesirable in pools and ponds. It can be removed with algaecides, which not only kill algae cells, but may also inhibit the lives of other organisms in the treated area. For example, storm water may cause overflow in a pond treated with algaecides. The overflow may carry harmful chemicals from the pond to plants in the

surrounding area and cause harm. In this experiment, a Microtox 500 Analyzer from Modern Water is used to test the effects of common algaecides on bacteria. The Microtox machine utilizes the bioluminescence of cryogenically frozen bacteria to show the toxicity of aqueous substances by taking a baseline bioluminescence reading of the bacteria, then another reading when the substance is introduced to the bacteria. Microtox readings can determine the percentage removal of the bacteria, or the fraction of the bacteria that the substance has killed. This experiment is intended for a freshman clinic setting in which students will test several algaecides and determine the lethal dose of each. Students will observe how certain chemicals influence cells and will consider how ecosystems can be affected by treatments like algaecides.

3.0 Integration of Humanities

All experiments were designed with the United Nations Sustainable Development Goals and global connection in mind. For example, the jar test experiment encourages students to consider creative methods of purifying water. Additional activities and supplementary material were developed to further engrain the connection between engineering and the humanities.

3.1 Semester Project

While students explore solutions to global problems through the algae experiments, they will be asked to think about how these solutions can work for countries around the world. At the beginning of the curriculum, students will be broken into small groups and each group will be assigned a country. Students will be responsible for researching demographic, political, and economic information about the country, while identifying engineering challenges. At the end of the semester, students will give a presentation detailing how algae-based innovations could be implemented as a solution to solve healthcare, environmental, or materials problems in the assigned country. The project not only encourages students to think about culture in other countries, but also prompts them to think about social barriers that would prevent innovative solutions from being implemented in the country. This project will build upon teamwork and public speaking skills, as well as instill a spirit of creativity, problem-solving, and humanities amongst students.

3.2 Movies/Documentaries

In order to provide examples of real-world engineering ethical challenges, catastrophes, injustices, and gender biases, movies and documentaries can be shown. Some examples include *Erin Brockovich*, *A Civil Action*, and *Bhopal Express*. The movies can be assigned and divided between groups to watch on their own and present to the class or shown to the entire class at once. The instructor can lead a discussion and analyze the movie with students to identify the issue, the consequences of the issue, and how the issue could have been prevented.

3.3 Communication Skills

Oral and written communication skills are incorporated into the curriculum through technical reports, oral-presentations, and reflective essays. Strong communication skills are a necessity in the field of engineering to share statistics, data, experimental findings, and technical information.

Furthermore, it is important for engineers to be able to successfully communicate with other people in other fields of study, including the humanities. A globally conscious engineer that is unable to effectively articulate the humanitarian and environmental implications of projects will not be able to induce change. It is suggested that each experiment is followed by a written report and that reflective essays are assigned occasionally to ensure that students are making a connection between the technical experiments their humanitarian aspects.

3.4 Philanthropy

Philanthropy is the desire to take action or make donations in order to improve that lives of others. Engineering and philanthropy often go hand-in-hand, since engineers work to improve lives both domestically and internationally with buildings and inventions. Educating engineers on philanthropy will prepare them to tackle cultural, financial, and structural issues and barriers within the engineering discipline, which will improve lives of people around the world [11].

Through this curriculum, industrial uses for algae are being researched, such as using algae to create cosmetics, discovering the nutritional value of algae for food production, how different lights affect oxygen production of algae, and more. These applications have the potential to benefit the quality of life for people worldwide, especially those living in impoverished areas. This integration of engineering and philanthropy teaches engineering students that engineering can, and should, be used for good.

3.5 Curriculum Implementation

The Algae Grows the Future Curriculum was implemented in three classrooms in Spring 2017, including two freshmen engineering classes and one seventh grade advanced science class at a local elementary school. Instructors were able to align the curriculum with required teaching goals, and all of the classes were assigned the semester project. In all classes, students came up with innovative ideas based on their knowledge from conducting the algae-based experiments. For the experiments, the seventh grade students were excited to learn about the algae and learned to create graphs using Excel for scientific data, wrote reports for each experiment, and learned laboratory safety. The flexibility of the curriculum allowed the instructor to align the experiments with New Jersey Next Generation Science Standards. The freshman college students learned fundamental skills that would be necessary for success in an engineering curriculum, such as using statistics as a tool for data analysis and using calculus to understand growth rates. The curriculum not only gave the students a basic knowledge of engineering and natural science, it also gave them an ethical foundation for the rest of their academic and career lives.

The curriculum is currently being evaluated through student and teacher surveys and quizzes that are taken by students before and after going through the curriculum. Both quizzes are exactly the same and will be a tool in measuring how much student learned about algae, world issues, and global thinking .

4.0 Website

In order to make the Algae Grows the Future curriculum, including experiments, handouts, instructional videos, and supplemental material, readily available to educators and to promote outreach, a website was developed. The website is intended to expand the implementation of algae-based learning from a local scale to national and global scale. Through the website, the Algae Grows the Future team will continue to update any research progress, add new experimental methods and applications, and encourage other educational programs to share how this curriculum has worked for them and make suggestions as to how to improve and add versatility to the program. The web address is <http://algaegrowsthefuture.wordpress.com>

5.0 Conclusion

Through the Algae Grows the Future curriculum, K-12 and college students are learning fundamental engineering concepts are being trained to consider the humanitarian facet of engineering projects. Projects, such as calorimetry and the creation of algae-based lip gloss, demonstrate how algae-based creations can be used in today's society to be more environmentally friendly, healthy, and improve the quality of life in impoverished communities. Through experiments, lessons, and semester projects, students develop technical skills, as well as communications skills and sense of philanthropy. With this integration of engineering and the humanities, students develop the skills needed to be successful, conscientious engineers.

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