PLTW Engineering
Environmental Sustainability | Course Outline

Imagine a world where:

- there is abundant, healthy food for everyone
- there is a clean, bountiful water supply
- the environment is resilient and flourishing
- there is sustainable, clean energy
- good health is the norm

What can you do to help make our world environmentally sustainable?

Environmental Sustainability (ES) is a high school-level specialization course in PLTW Engineering. In ES, students investigate and design solutions to solve real-world challenges related to clean drinking water, a stable food supply, and renewable energy. Students are introduced to environmental issues and use the engineering design process to research and design potential solutions. Utilizing the activity-, project-, problem-based (APB) teaching and learning pedagogy, students transition from completing structured activities to solving open-ended projects and problems that require them to develop planning, documentation, communication, and other professional skills.

Through both individual and collaborative team activities, projects, and problems, students problem solve as they practice common design and scientific protocols such as project management, lab techniques, and peer review. Students develop skills in designing experiments, conducting research, executing technical skills, documenting design solutions according to accepted technical standards, and creating presentations to communicate solutions.

The course requires a rigorous pace, and it is likely to contain more material than a skilled teacher new to the course will be able to complete in the first iteration. Building enthusiasm for and a real understanding of the role, impact, and practice of environmental sustainability is a primary goal of the course.

ES Unit Summary

Unit 1	Environmental Sustainability for a Better Tomorrow
Unit 2	Ensuring Safe and Abundant Water
Unit 3	Food Security
Unit 4	Renewable Fuels

Unit 1: Environmental Sustainability for a Better Tomorrow

Unit 1 establishes a foundation for the course and introduces students to key aspects of the environment while identifying important global problems. In this course, students learn how the biological engineering of organisms can be used to provide environmentally friendly and sustainable solutions to produce clean, safe drinking water; nutritious food sufficient for a growing world population; and affordable renewable energy. This theme sets the stage for each unit within the course.

Environmental Sustainability for a Better Tomorrow	
Lesson 1.1	Introduction to Environmental Sustainability

Lesson 1.1 Introduction to Environmental Sustainability
In this lesson, students examine current global problems and look specifically at world hunger, a lack of clean water, and the need for renewable energy sources. They complete a design challenge to build a device out of recycled materials. Students explore the diverse field of biological and environmental engineering, reflect on ways that engineers work to help solve environmental sustainability problems, and explore the ethical issues that influence the decisions engineers make.

Unit 2: Ensuring Safe and Abundant Water

This unit begins by establishing context around the extent of the global drinking water challenge. Students build models of natural water systems, investigate how these systems become contaminated, explore how contamination can be prevented, and examine how polluted waters can be purified. Students practice laboratory methods for quantitatively measuring water quality. They investigate the role and effectiveness of biological organisms in cleaning up water polluted with crude oil. The physical, chemical, and biological technologies and processes utilized by waste water treatment plants are explored, with optional field trips to these facilities included. As a culmination project, students apply their knowledge of water issues, water treatment technologies, and the associated role of biological organisms, along with their engineering design experience, to the challenge of designing a small-scale water treatment system for rapid deployment within natural disaster zones.

Ensuring Safe and Abundant Water	
Lesson 2.1	Global Water Crisis
Lesson 2.2	Water Supply
Lesson 2.3	Water Remediation
Lesson 2.4	Disaster Area Water Treatment Design Challenge

Lesson 2.1 Global Water Crisis
In this lesson, students investigate why we need clean water for life, determine how much water we use and for what purposes, and analyze the relationship between a clean, fresh water supply and water demand today and in the future. Students explore the consequences resulting from a lack of a clean water supply by preparing a case study of a country or region in water crisis.

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Lesson 2.2 Water Supply
In this lesson, students investigate the possible contaminants found in water from their case study country in Lesson 2.1 and research the adverse effects they have on the human body if consumed. Students conduct chemical and biological tests to measure water quality of locally available drinking water, a local polluted water source, or a contaminated water sample formulated by the teacher. Students explore where groundwater comes from using groundwater models that simulate the region from their case study. They analyze factors affecting the water and brainstorm ways to mitigate the water problems affecting the area of their case study.

Lesson 2.3 Water Remediation
In this lesson, students design, build, and test a gravity-fed water filtration system that removes silt. Students are introduced to a hypothetical situation in which an oil spill contaminates a public drinking water reservoir. They design, build, and test a two-tiered system that first contains the oil and then physically removes the oil from the water. Students investigate how bacteria can be used to accelerate the biological degradation and cleanup of oil spills from water systems. Then they complete an experiment to test different variables (temperature, agitation, sunlight, etc.) that affect bacteria's ability to consume and degrade the oil. Students learn about different methods used to create clean drinking water and treat sewage water – municipal sewage treatment plants, municipal water treatment ponds, individual home septic systems, and engineered wetlands. Students use phytoremediation to mediate a body of water contaminated with nitrates.

Lesson 2.4 Disaster Area Water Treatment Design Challenge
In this lesson, students return to the case study introduced at the start of the lesson – the area devastated by a natural disaster resulting in contaminated water – and review the design problem. Students design a small-scale water purification system that is capable of producing potable water from a contaminated source in a natural disaster zone. The system must be able to be deployed within a short time period after the disaster. The solution needs to include at a minimum one physical and one biological mechanism.

Unit 3: Food Security

This unit focuses on the genetic modification of plants as a potential solution to food security issues around the globe. Students learn about the structure and function of DNA and the process of protein synthesis. They learn to determine whether familiar food items contain genetically modified organisms (GMOs). They investigate various molecular biology techniques while working through the steps necessary to create genetically modified plants. Through laboratory activities and simulations, students explore Polymerase Chain Reaction (PCR), DNA sequencing techniques, restriction enzyme action, ligation, gel electrophoresis, bacterial transformation, and plant transformation. They work through the beginning steps of the engineering design process and propose a genetic engineering solution to a global food security issue.

World Food Security	
Lesson 3.1	World Food Security
Lesson 3.2	Introduction to DNA
Lesson 3.3	Genetic Engineering
Lesson 3.4	Design a GM Food

Lesson 3.1 World Food Security
factors to global food security issues in relation to the global population residing in developed and developing nations. Students look at current capabilities of biological engineers to solve problems such as food security issues and explore how biological engineering can create genetically modified plants to help address these issues. Students grow biologically engineered soybeans and test both plants and seeds for the introduced gene using a protein-specific immunoassay. Use of genetically modified plants in mitigating food security issues is evaluated.

Lesson 3.2 Introduction to DNA
In this lesson, students extract, collect, and examine DNA from an edible plant, such as a strawberry. Students explore the structural composition of DNA and model the use of DNA to produce proteins. Students simulate Polymerase chain reaction (PCR), gel electrophoresis, and DNA sequencing prior to completing a lab to analyze plant-based DNA to determine the presence of GMOs.

Lesson 3.3 Genetic Engineering
In this lesson, students are introduced to a series of labs where they assemble a real recombinant plasmid containing a resistance gene to the antibiotic kanamycin. The resulting recombinant plasmid is introduced into bacterial cells, where it is copied and expressed. Finally, to analyze the results of the ligation, the resultant DNA is digested with restriction enzymes and run on a gel. Students insert their recombinant plasmid into E. coli cells through the process of bacterial transformation. Once the new gene is inside the bacterial cells, they plate the transformed cells on a media containing the antibiotic kanamycin.
Students analyze the results of specific digestion of both linear and plasmid DNA and demonstrate how restriction analysis can be used to gauge the success of genetic engineering and gene cloning. They use logic to interpret and assemble plasmid maps. Students use what they have learned to design a test to determine what is present in the recombinant plasmid they created.

Lesson 3.4 Design a Genetically Modified (GM) Food
In this lesson, students research a current food security issue that they feel can be addressed with the development of a GM food. They complete a design brief outlining the design problem and justification, as well as identify the design specifications that would need to be considered when creating the solution.

Unit 4: Renewable Fuels

This unit concentrates on the role of biological engineering and biomanufacturing of biofuels from algae and cellulosic plant materials in solving the challenges associated with producing biofuels in a sustainable and environmentally friendly manner. The unit begins by exploring current global energy consumption patterns and then examines futuristic energy consumption models that utilize types of energy other than fossil fuels. Students conduct a household energy audit to contextualize their energy consumption patterns.
They investigate the process of photosynthesis and its role in the formation of both fossil fuels and biofuels. Applying an engineering design process, students are challenged to design, build, and operate bench-top-scale algae bioreactors. Students design monitoring systems and apply standard laboratory processes in quantifying the efficiency of their systems at producing algae and purifying the end products.

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Next, students dive into the production of ethanol from cellulosic plant sources. They investigate the role that enzymes play in this process. Students explore technologies used to produce ethanol and design an ethanol separation and purification system. In the last part of the unit, students are challenged to apply their knowledge of biofuels, engineering design, and biomanufacturing practices as they develop a proposal for a commercial-scale biofuels manufacturing plant.

Renewable Fuels

Lesson 4.1	Challenges of Renewable Energy
Lesson 4.2	Biofuels from Algae
Lesson 4.3	Ethanol Biofuels
Lesson 4.4	Designing a Commercial-Scale Biofuels Manufacturing Plant

Lesson 4.1 Challenges of Renewable Energy
In this lesson, students examine major forms of energy used to power humanity. They compare fossil fuels with renewable biofuels and recognize why renewable energy must become a larger portion of the total energy mix through an examination of national and global energy use data from all major energy sources. Students conduct a family energy audit to determine the amounts and types of energy they consume. Students set up and conduct a closed-system bench-top experiment using Vernier digital probeware to quantitatively measure the amount of carbon dioxide consumed and then mathematically predict oxygen produced during photosynthesis

Lesson 4.2 Biofuels from Algae
In this lesson, students are introduced to the two primary stages of biomanufacturing, upstream and downstream processing. Students are introduced to algae as a biological organism that can be grown in biomanufacturing operations to produce lipids, which can be converted into biofuels. Students calculate and model how much algae-based biodiesel would need to be produced to replace specified amounts of petroleum and then design a bench-top-scale photo-bioreactor for producing algae biofuels using the engineering design process. Students use thin-layer chromatography to model the separation of lipids from the algae cells. Students produce biodiesel from new and used cooking oil. Lastly, students use genomic databases to identify potential genes that could be inserted into specific algal strains to increase lipid production..

Lesson 4.3 Ethanol Biofuels
In this lesson, students investigate the process of fermentation and products made using fermentation. Students investigate and participate in a debate on using feedstocks as a source for ethanol production. Students design, run, and test a bench-top fermentation experiment and an ethanol separation experiment. Students test the effect of inorganic catalysts on the rates of chemical reactions and quantitatively investigate enzyme activity in the fermentation of cellulosic materials.

Lesson 4.4 Designing a Commercial-Scale Biofuels Manufacturing Plant
In this lesson, students apply their knowledge of biofuels, engineering design, and biomanufacturing to develop a plan for a commercial-scale biofuels biomanufacturing plant. They complete a lifecycle analysis of their proposed biofuels biomanufacturing operation and compile their work into a portfolio to present to a set of potential investors in a “Shark Tank” format.

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