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.

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.

Connections to Standards in Engineering

PLTW curriculum is designed to empower students to thrive in an evolving world. As a part of the design process when developing and updating our curriculum, we focus on connections to a variety of standards. PLTW Environmental Sustainability connects to standards in the following:

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National Consortium for Health Education Standards (2012)

Support Services Pathway

Aseptic Procedures

Standard 2

Support services professionals will adopt work practices that maintain a clean and healthy environment. They will demonstrate best practices to reduce or eliminate pathogenic organisms.

1.1	2.1	2.2	2.3	2.4	3.1	3.2	3.3	3.4	4.1	4.2	4.3	4.4
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Biotechnology R & D Pathway

Contributions of Biotechnology to Health and the Human Condition

Standard 1

Biotechnology R & D professionals will understand that biotechnology products are based on molecular biology of disease and health; the quality of life through finding a cure for genetic, environmental and behavioral diseases, chronic conditions, industrial enzymes and new diagnostic tools; and legal and ethical issues to protect and preserve the quality of life, with emphasis on social and diversity issues.

1.1	2.1	2.2	2.3	2.4	3.1	3.2	3.3	3.4	4.1	4.2	4.3	4.4
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Academic Foundations

Standard 2

Biotechnology R & D professionals will be knowledgeable in the fundamentals of mathematical concepts, statistics, genetics, organic chemistry, biochemistry, cell biology, molecular biology and microbiology.

1.1	2.1	2.2	2.3	2.4	3.1	3.2	3.3	3.4	4.1	4.2	4.3	4.4
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Introduction to Biotechnology Knowledge Areas and Techniques

Standard 3

Biotechnology R & D professionals will be introduced to the following recombinant DNA and genetic engineering, bioprocessing (producing recombinant DNA products on a large scale for profit), monoclonal antibody production, separation and purification of biotechnology products, nanotechnology, bioinformatics, genomics, proteomics and transcriptomics.

1.1	2.1	2.2	2.3	2.4	3.1	3.2	3.3	3.4	4.1	4.2	4.3	4.4
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National Consortium for Health Education Standards (2012)

Laboratory Protocols and Procedures

Standard 4

Biotechnology R & D professionals will understand the principles of solution preparation such as molarity, pH, and dilution; sterile techniques such as inoculum development and transfer; knowledge of contamination control; and measurement and calibration of nstruments such as micropipettes and pH meters. They will maintain a sanitary, safe and hazard free laboratory environment. Employees will be adept at teamwork, oral and written communication skills, problem solving, emergency lab response, and biosafety protocols.

1.1	2.1	2.2	2.3	2.4	3.1	3.2	3.3	3.4	4.1	4.2	4.3	4.4
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Product Design and Development

Standard 5

Biotechnology R & D professionals will have the knowledge of how the product is designed, and what is involved in its development and subsequent production, including the laboratory procedures and regulatory requirements. The employee will have a general understanding of the entire process in order to know how their scope of work contributes to the result including; R & D at the lab bench level, both pre-clinical trials, clinical trials (3 phases), product license application, regulatory process for clinical trials (current Good Manufacturing Practices [cGMPs], and Good Laboratory Practices [GLPs]) for production (cGMPs, GLPs).

1.1	2.1	2.2	2.3	2.4	3.1	3.2	3.3	3.4	4.1	4.2	4.3	4.4
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Bioethics

Standard 6

Biotechnology R & D professionals are not isolated from the social effect of their products in our society. Science, technology and society are intertwined. Biotechnology R & D employees will be conversant with the larger ethical, moral and legal issues related to biotech research, product development and use in society.

1.1	2.1	2.2	2.3	2.4	3.1	3.2	3.3	3.4	4.1	4.2	4.3	4.4
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Common Core Standards for Mathematics

Building Functions

Build a Function That Models a Relationship Between Two Quantities

CCSS.MATH.CONTENT.HSF.BF.A.1.A

Determine an explicit expression, a recursive process, or steps for calculation from a context.

1.1	2.1	2.2	2.3	2.4	3.1	3.2	3.3	3.4	4.1	4.2	4.3	4.4
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CCSS.MATH.CONTENT.HSF.BF.A.1.B

Combine standard function types using arithmetic operations. For example, build a function that models the temperature of a cooling body by adding a constant function to a decaying exponential, and relate these functions to the model.

1.1	2.1	2.2	2.3	2.4	3.1	3.2	3.3	3.4	4.1	4.2	4.3	4.4
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Geometric Measurement and Dimension

Explain Volume Formulas and Use Them to Solve Problems

CCSS.MATH.CONTENT.HSG.GMD.A.3

Use volume formulas for cylinders, pyramids, cones, and spheres to solve problems.

1.1	2.1	2.2	2.3	2.4	3.1	3.2	3.3	3.4	4.1	4.2	4.3	4.4
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Modeling with Geometry

Apply Geometric Concepts in Modeling Situations

CCSS.MATH.CONTENT.HSG.MG.A.1

Use geometric shapes, their measures, and their properties to describe objects (e.g., modeling a tree trunk or a human torso as a cylinder).

1.1	2.1	2.2	2.3	2.4	3.1	3.2	3.3	3.4	4.1	4.2	4.3	4.4
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Quantities

Reason Quantitatively and Use Units to Solve Problems

CCSS.MATH.CONTENT.HSN.Q.A.1

Use units as a way to understand problems and to guide the solution of multistep problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays.

1.1	2.1	2.2	2.3	2.4	3.1	3.2	3.3	3.4	4.1	4.2	4.3	4.4
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Common Core Standards for Mathematics

CCSS.MATH.CONTENT.HSN.Q.A.2

Define appropriate quantities for the purpose of descriptive modeling.

1.1	2.1	2.2	2.3	2.4	3.1	3.2	3.3	3.4	4.1	4.2	4.3	4.4
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CCSS.MATH.CONTENT.HSN.Q.A.3

Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.

1.1	2.1	2.2	2.3	2.4	3.1	3.2	3.3	3.4	4.1	4.2	4.3	4.4
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Common Core English Language Arts Standards

Science and Technical Subjects (9-10)

Key Ideas and Details

CCSS.ELA-LITERACY.RST.9-10.1

Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions.

1.1	2.1	2.2	2.3	2.4	3.1	3.2	3.3	3.4	4.1	4.2	4.3	4.4
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CCSS.ELA-LITERACY.RST.9-10.3

Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks, attending to special cases or exceptions defined in the text.

1.1	2.1	2.2	2.3	2.4	3.1	3.2	3.3	3.4	4.1	4.2	4.3	4.4
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Integration of Knowledge and Ideas

CCSS.ELA-LITERACY.RST.9-10.7

Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words.

1.1	2.1	2.2	2.3	2.4	3.1	3.2	3.3	3.4	4.1	4.2	4.3	4.4
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CCSS.ELA-LITERACY.RST.9-10.9

Compare and contrast findings presented in a text to those from other sources (including their own experiments), noting when the findings support or contradict previous explanations or accounts.

1.1	2.1	2.2	2.3	2.4	3.1	3.2	3.3	3.4	4.1	4.2	4.3	4.4
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Range of Reading and Level of Text Complexity

CCSS.ELA-LITERACY.RST.9-10.10

By the end of grade 10, read and comprehend science/technical texts in the grades 9–10 text complexity band independently and proficiently.

1.1	2.1	2.2	2.3	2.4	3.1	3.2	3.3	3.4	4.1	4.2	4.3	4.4
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Common Core English Language Arts Standards

Science and Technical Subjects (11-12)

Key Ideas and Details

CCSS.ELA-LITERACY.RST.11-12.2

Determine the central ideas or conclusions of a text; summarize complex concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms.

1.1	2.1	2.2	2.3	2.4	3.1	3.2	3.3	3.4	4.1	4.2	4.3	4.4
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CCSS.ELA-LITERACY.RST.11-12.3

Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks; analyze the specific results based on explanations in the text.

1.1	2.1	2.2	2.3	2.4	3.1	3.2	3.3	3.4	4.1	4.2	4.3	4.4
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Integration of Knowledge and Ideas

CCSS.ELA-LITERACY.RST.11-12.7

Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem.

1.1	2.1	2.2	2.3	2.4	3.1	3.2	3.3	3.4	4.1	4.2	4.3	4.4
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Range of Reading and Level of Text Complexity

CCSS.ELA-LITERACY.RST.11-12.10

By the end of grade 12, read and comprehend science/technical texts in the grades 11–12 text complexity band independently and proficiently.

1.1	2.1	2.2	2.3	2.4	3.1	3.2	3.3	3.4	4.1	4.2	4.3	4.4
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Writing History/Social Studies, Science, Technology (9-10)

Text Types and Purposes

CCSS.ELA-LITERACY.WHST.9-10.2

Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes.

1.1	2.1	2.2	2.3	2.4	3.1	3.2	3.3	3.4	4.1	4.2	4.3	4.4
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Common Core English Language Arts Standards

CCSS.ELA-LITERACY.WHST.11-12.2

Write informative/explanatory texts, including the narration of historical events, scientific procedures/experiments, or technical processes.

1.1	2.1	2.2	2.3	2.4	3.1	3.2	3.3	3.4	4.1	4.2	4.3	4.4
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Next Generation Science Standards

Earth and Human Activity

HS.ESS3.4

Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.

1.1	2.1	2.2	2.3	2.4	3.1	3.2	3.3	3.4	4.1	4.2	4.3	4.4
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Engineering Design

HS.ETS1.1

Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.

1.1	2.1	2.2	2.3	2.4	3.1	3.2	3.3	3.4	4.1	4.2	4.3	4.4
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HS.ETS1.2

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

1.1	2.1	2.2	2.3	2.4	3.1	3.2	3.3	3.4	4.1	4.2	4.3	4.4
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HS.ETS1.3

Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.

1.1	2.1	2.2	2.3	2.4	3.1	3.2	3.3	3.4	4.1	4.2	4.3	4.4
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HS.ETS1.4

Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.

1.1	2.1	2.2	2.3	2.4	3.1	3.2	3.3	3.4	4.1	4.2	4.3	4.4
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Matter and Its Interactions

HS.PS1.5

Apply scientific principles and evidence to provide an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs.

1.1	2.1	2.2	2.3	2.4	3.1	3.2	3.3	3.4	4.1	4.2	4.3	4.4
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Next Generation Science Standards

HS.PS1.6

Refine the design of a chemical system by specifying a change in conditions that would produce increased amounts of products at equilibrium.

1.1	2.1	2.2	2.3	2.4	3.1	3.2	3.3	3.4	4.1	4.2	4.3	4.4
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Motion and Stability: Forces and Interactions

HS.PS2.1

Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration.

1.1	2.1	2.2	2.3	2.4	3.1	3.2	3.3	3.4	4.1	4.2	4.3	4.4
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Energy

HS.PS3.3

Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.

1.1	2.1	2.2	2.3	2.4	3.1	3.2	3.3	3.4	4.1	4.2	4.3	4.4
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From Molecules to Organisms: Structures and Processes

HS.LS1.1

Construct an explanation based on evidence for how the structure of DNA determines the structure of proteins which carry out the essential functions of life through systems of specialized cells.

1.1	2.1	2.2	2.3	2.4	3.1	3.2	3.3	3.4	4.1	4.2	4.3	4.4
☐	☐	☐	☐	☐	☐	☑	☐	☐	☐	☐	☐	☐

HS.LS1.2

Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.

1.1	2.1	2.2	2.3	2.4	3.1	3.2	3.3	3.4	4.1	4.2	4.3	4.4
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☑	☑	☐

HS.LS1.3

Plan and conduct an investigation to provide evidence that feedback mechanisms maintain homeostasis.

1.1	2.1	2.2	2.3	2.4	3.1	3.2	3.3	3.4	4.1	4.2	4.3	4.4
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☑	☐

Next Generation Science Standards

HS.LS1.5

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

1.1	2.1	2.2	2.3	2.4	3.1	3.2	3.3	3.4	4.1	4.2	4.3	4.4
☐	☐	☐	☐	☐	☐	☐	☐	☐	✔	☐	☐	☐

HS.LS1.6

Construct and revise an explanation based on evidence for how carbon, hydrogen, and oxygen from sugar molecules may combine with other elements to form amino acids and/or other large carbon-based molecules.

1.1	2.1	2.2	2.3	2.4	3.1	3.2	3.3	3.4	4.1	4.2	4.3	4.4
☐	☐	☐	☐	☐	☐	☐	☐	☐	✔	☐	✔	☐

HS.LS1.7

Use a model to illustrate that cellular respiration is a chemical process whereby the bonds of food molecules and oxygen molecules are broken and the bonds in new compounds are formed resulting in a net transfer of energy.

1.1	2.1	2.2	2.3	2.4	3.1	3.2	3.3	3.4	4.1	4.2	4.3	4.4
☐	☐	☐	☐	☐	☐	☐	☐	☐	✔	☐	✔	☐

Ecosystems: Interactions, Energy, and Dynamics

HS.LS2.4

Use mathematical representations to support claims for the cycling of matter and flow of energy among organisms in an ecosystem.

1.1	2.1	2.2	2.3	2.4	3.1	3.2	3.3	3.4	4.1	4.2	4.3	4.4
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	✔	☐	☐

HS.LS2.7

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

1.1	2.1	2.2	2.3	2.4	3.1	3.2	3.3	3.4	4.1	4.2	4.3	4.4
✔	✔	✔	☐	☐	☐	☐	☐	☐	✔	✔	✔	☐

Heredity: Inheritance and Variation of Traits

HS.LS3.1

Ask questions to clarify relationships about the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring.

1.1	2.1	2.2	2.3	2.4	3.1	3.2	3.3	3.4	4.1	4.2	4.3	4.4
☐	☐	☐	☐	☐	☐	✔	✔	☐	☐	☐	☐	☐

Next Generation Science Standards

Biological Evolution: Unity and Diversity

HS.LS4.6

Create or revise a simulation to test a solution to mitigate adverse impacts of human activity on biodiversity.

1.1	2.1	2.2	2.3	2.4	3.1	3.2	3.3	3.4	4.1	4.2	4.3	4.4
☑	☐	☑	☐	☐	☑	☐	☐	☐	☑	☑	☑	☐

Earth and Human Activity

HS.ESS3.1

Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity.

1.1	2.1	2.2	2.3	2.4	3.1	3.2	3.3	3.4	4.1	4.2	4.3	4.4
☐	☑	☐	☐	☐	☐	☐	☐	☐	☑	☑	☑	☐

HS.ESS3.2

Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios.

1.1	2.1	2.2	2.3	2.4	3.1	3.2	3.3	3.4	4.1	4.2	4.3	4.4
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☑	☑	☐

Standards for Technological and Engineering Literacy

STEL 1 Nature and Characteristics of Technology and Engineering

STEL-1N

Explain how the world around them guides technological development and engineering design.

1.1	2.1	2.2	2.3	2.4	3.1	3.2	3.3	3.4	4.1	4.2	4.3	4.4
✔	✔	☐	✔	✔	✔	☐	✔	✔	☐	✔	☐	☐

STEL-1O

Assess how similarities and differences among scientific, mathematics, engineering, and technological knowledge and skills contributed to the design of a product or system.

1.1	2.1	2.2	2.3	2.4	3.1	3.2	3.3	3.4	4.1	4.2	4.3	4.4
☐	☐	✔	✔	☐	✔	✔	✔	☐	☐	✔	☐	✔

STEL-1P

Analyze the rate of technological development and predict future diffusion and adoption of new technologies.

1.1	2.1	2.2	2.3	2.4	3.1	3.2	3.3	3.4	4.1	4.2	4.3	4.4
☐	☐	☐	☐	☐	✔	☐	☐	☐	☐	☐	☐	☐

STEL-1Q

Conduct research to inform intentional inventions and innovations that address specific needs and wants.

1.1	2.1	2.2	2.3	2.4	3.1	3.2	3.3	3.4	4.1	4.2	4.3	4.4
☐	✔	☐	✔	✔	✔	✔	✔	✔	☐	✔	✔	✔

STEL-1R

Develop a plan that incorporates knowledge from science, mathematics, and other disciplines to design or improve a technological product or system.

1.1	2.1	2.2	2.3	2.4	3.1	3.2	3.3	3.4	4.1	4.2	4.3	4.4
☐	☐	✔	✔	✔	✔	☐	✔	✔	✔	✔	☐	✔

STEL 2 Core Concepts of Technology and Engineering

STEL-2T

Demonstrate the use of conceptual, graphical, virtual, mathematical, and physical modeling to identify conflicting considerations before the entire system is developed and to aid in design decision making.

1.1	2.1	2.2	2.3	2.4	3.1	3.2	3.3	3.4	4.1	4.2	4.3	4.4
✔	✔	✔	✔	✔	✔	✔	✔	✔	☐	✔	☐	✔

Standards for Technological and Engineering Literacy

STEL-2U

Diagnose a flawed system embedded within a larger technological, social, or environmental system.

1.1	2.1	2.2	2.3	2.4	3.1	3.2	3.3	3.4	4.1	4.2	4.3	4.4
☐	☑	☑	☐	☐	☐	☐	☐	☑	☐	☐	☐	☐

STEL-2V

Analyze the stability of a technological system and how it is influenced by all of the components in the system, especially those in the feedback loop.

1.1	2.1	2.2	2.3	2.4	3.1	3.2	3.3	3.4	4.1	4.2	4.3	4.4
☐	☐	☑	☐	☐	☑	☑	☑	☐	☐	☐	☐	☐

STEL-2W

Select resources that involve tradeoffs between competing values, such as availability, cost, desirability, and waste while solving problems.

1.1	2.1	2.2	2.3	2.4	3.1	3.2	3.3	3.4	4.1	4.2	4.3	4.4
☑	☐	☐	☑	☑	☑	☐	☐	☑	☐	☑	☐	☑

STEL-2X

Cite examples of the criteria and constraints of a product or system and how they affect final design.

1.1	2.1	2.2	2.3	2.4	3.1	3.2	3.3	3.4	4.1	4.2	4.3	4.4
☑	☐	☐	☑	☑	☑	☐	☑	☑	☐	☑	☐	☑

STEL-2Y

Implement quality control as a planned process to ensure that a product, service, or system meets established criteria.

1.1	2.1	2.2	2.3	2.4	3.1	3.2	3.3	3.4	4.1	4.2	4.3	4.4
☐	☐	☐	☑	☐	☐	☐	☑	☐	☐	☑	☐	☐

STEL-2Z

Use management processes in planning, organizing, and controlling work.

1.1	2.1	2.2	2.3	2.4	3.1	3.2	3.3	3.4	4.1	4.2	4.3	4.4
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☑

STEL 3 Integration of Knowledge, Technologies, and Practices

STEL-3H

Analyze how technology transfer occurs when a user applies an existing innovation developed for one function for a different purpose.

1.1	2.1	2.2	2.3	2.4	3.1	3.2	3.3	3.4	4.1	4.2	4.3	4.4
☑	☐	☐	☑	☐	☑	☐	☐	☐	☐	☐	☐	☐

STEL-3I

Evaluate how technology enhances opportunities for new products and services through globalization.

1.1	2.1	2.2	2.3	2.4	3.1	3.2	3.3	3.4	4.1	4.2	4.3	4.4
☐	☑	☐	☐	☐	☑	☐	☐	☐	☐	☐	☐	☐

STEL-3J

Connect technological progress to the advancement of other areas of knowledge and vice versa.

1.1	2.1	2.2	2.3	2.4	3.1	3.2	3.3	3.4	4.1	4.2	4.3	4.4
☑	☐	☐	☐	☐	☑	☑	☐	☐	☐	☐	☐	☐

STEL 4 Impacts of Technology

STEL-4P

Evaluate ways that technology can impact individuals, society, and the environment.

1.1	2.1	2.2	2.3	2.4	3.1	3.2	3.3	3.4	4.1	4.2	4.3	4.4
☑	☑	☑	☑	☑	☑	☐	☐	☑	☑	☑	☑	☐

STEL-4Q

Critique whether existing or proposed technologies use resources sustainably.

1.1	2.1	2.2	2.3	2.4	3.1	3.2	3.3	3.4	4.1	4.2	4.3	4.4
☑	☐	☑	☑	☑	☐	☐	☐	☐	☑	☑	☑	☑

STEL-4R

Assess a technology that minimizes resource use and resulting waste to achieve a goal.

1.1	2.1	2.2	2.3	2.4	3.1	3.2	3.3	3.4	4.1	4.2	4.3	4.4
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☑	☐

STEL-4S

Develop a solution to a technological problem that has the least negative environmental and social impact.

1.1	2.1	2.2	2.3	2.4	3.1	3.2	3.3	3.4	4.1	4.2	4.3	4.4
☐	☐	☐	☑	☑	☐	☐	☐	☐	☐	☐	☐	☐

STEL-4T

Evaluate how technologies alter human health and capabilities.

1.1	2.1	2.2	2.3	2.4	3.1	3.2	3.3	3.4	4.1	4.2	4.3	4.4
☐	☑	☐	☑	☑	☑	☐	☐	☐	☐	☐	☐	☐

Standards for Technological and Engineering Literacy

STEL 5 Influence of Society on Technological Development

STEL-5H

Evaluate a technological innovation that arose from a specific society's unique need or want.

1.1	2.1	2.2	2.3	2.4	3.1	3.2	3.3	3.4	4.1	4.2	4.3	4.4
☐	☐	☐	☑	☐	☑	☐	☐	☐	☐	☐	☐	☐

STEL-5I

Evaluate a technological innovation that was met with societal resistance impacting its development.

1.1	2.1	2.2	2.3	2.4	3.1	3.2	3.3	3.4	4.1	4.2	4.3	4.4
☐	☐	☐	☐	☐	☑	☑	☐	☐	☐	☐	☐	☐

STEL-5J

Design an appropriate technology for use in a different culture.

1.1	2.1	2.2	2.3	2.4	3.1	3.2	3.3	3.4	4.1	4.2	4.3	4.4
☐	☐	☐	☐	☐	☐	☐	☐	☑	☐	☐	☐	☐

STEL 6 History of Technology

STEL-6F

Relate how technological development has been evolutionary, often the result of a series of refinements to basic inventions or technological knowledge.

1.1	2.1	2.2	2.3	2.4	3.1	3.2	3.3	3.4	4.1	4.2	4.3	4.4
☑	☐	☐	☐	☐	☑	☐	☐	☐	☐	☐	☐	☐

STEL-6H

Evaluate how technology has been a powerful force in reshaping the social, cultural, political, and economic landscapes throughout history.

1.1	2.1	2.2	2.3	2.4	3.1	3.2	3.3	3.4	4.1	4.2	4.3	4.4
☐	☐	☐	☐	☐	☑	☐	☐	☐	☐	☐	☐	☐

STEL 7 Design in Technology and Engineering Education

STEL-7W

Determine the best approach by evaluating the purpose of the design.

1.1	2.1	2.2	2.3	2.4	3.1	3.2	3.3	3.4	4.1	4.2	4.3	4.4
☑	☐	☐	☑	☑	☑	☐	☑	☑	☐	☐	☐	☑

STEL-7X

Document trade-offs in the technology and engineering design process to produce the optimal design.

1.1	2.1	2.2	2.3	2.4	3.1	3.2	3.3	3.4	4.1	4.2	4.3	4.4
☑	☐	☐	☑	☑	☑	☐	☐	☑	☐	☐	☐	☑

Standards for Technological and Engineering Literacy

STEL-7Y

Optimize a design by addressing desired qualities within criteria and constraints.

1.1	2.1	2.2	2.3	2.4	3.1	3.2	3.3	3.4	4.1	4.2	4.3	4.4
☑	☐	☐	☑	☑	☐	☐	☐	☑	☐	☐	☐	☑

STEL-7Z

Apply principles of human-centered design.

1.1	2.1	2.2	2.3	2.4	3.1	3.2	3.3	3.4	4.1	4.2	4.3	4.4
☐	☐	☐	☐	☑	☐	☐	☐	☐	☐	☐	☐	☐

STEL-7AA

Illustrate principles, elements and factors of design.

1.1	2.1	2.2	2.3	2.4	3.1	3.2	3.3	3.4	4.1	4.2	4.3	4.4
☐	☐	☐	☐	☑	☐	☐	☐	☐	☐	☐	☐	☐

STEL-7BB

Implement the best possible solution to a design.

1.1	2.1	2.2	2.3	2.4	3.1	3.2	3.3	3.4	4.1	4.2	4.3	4.4
☐	☐	☐	☐	☑	☐	☐	☐	☑	☐	☐	☐	☑

STEL-7CC

Apply a broad range of design skills to their design process.

1.1	2.1	2.2	2.3	2.4	3.1	3.2	3.3	3.4	4.1	4.2	4.3	4.4
☑	☐	☐	☐	☑	☐	☐	☐	☑	☐	☐	☐	☑

STEL-7DD

Apply a broad range of making skills to their design process.

1.1	2.1	2.2	2.3	2.4	3.1	3.2	3.3	3.4	4.1	4.2	4.3	4.4
☐	☐	☐	☐	☑	☐	☐	☐	☐	☐	☐	☐	☐

STEL 8 Applying, Maintaining, and Assessing Technological Products and Systems

STEL-8N

Use various approaches to communicate processes and procedures for using, maintaining, and assessing technological products and systems.

1.1	2.1	2.2	2.3	2.4	3.1	3.2	3.3	3.4	4.1	4.2	4.3	4.4
☑	☑	☐	☐	☐	☑	☐	☐	☑	☐	☑	☐	☑

Standards for Technological and Engineering Literacy

STEL-8O

Develop a device or system for the marketplace.

1.1	2.1	2.2	2.3	2.4	3.1	3.2	3.3	3.4	4.1	4.2	4.3	4.4
☐	☐	☐	☐	☑	☐	☐	☐	☐	☐	☐	☐	☐

STEL-8P

Apply appropriate methods to diagnose, adjust and repair systems to ensure precise, safe and proper functionality.

1.1	2.1	2.2	2.3	2.4	3.1	3.2	3.3	3.4	4.1	4.2	4.3	4.4
☐	☐	☑	☑	☐	☐	☐	☐	☐	☐	☐	☐	☐

STEL-8Q

Synthesize data and analyze trends to make decisions about technological products, systems, or processes.

1.1	2.1	2.2	2.3	2.4	3.1	3.2	3.3	3.4	4.1	4.2	4.3	4.4
☐	☐	☐	☑	☑	☑	☑	☑	☐	☑	☑	☐	☑

STEL-8R

Interpret the results of technology assessment to guide policy development.

1.1	2.1	2.2	2.3	2.4	3.1	3.2	3.3	3.4	4.1	4.2	4.3	4.4
☑	☐	☐	☐	☐	☐	☐	☐	☐	☑	☑	☐	☐

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