

a-g Narrative - Final
Integrated CSTEM Physical Sciences
Learning by Making, Sonoma State University

Course Description

Course Overview:

The integrated *Learning by Making (LbyM)* CSTEM Physical Sciences course fuses investigations of Energy and Matter along with computer science skills to consider solutions to real-world environmental issues. Relevant experiments using sensors that capture real time data are co-constructed by students and instructors. This course includes **80% hands-on teacher supervised lab activities** and 20% skill-building instructional time. The application of scientific practices is central to each lesson and unit of study. Throughout the course, students **develop and use models, plan and conduct investigations and experiments, analyze and interpret the data** collected, and **construct explanations** to demonstrate their understanding of the overarching ideas of **Energy and Matter** across numerous contexts and applications. The integration of computer science and electronics extend opportunities for direct engagement in the science and engineering practices as students develop and **apply mathematics and computational thinking** skills to design, troubleshoot, and refine sensor data-driven experiments. The use of technology extends opportunities for students to explore concepts associated with Waves and Their Applications in Technologies for Information Transfer.

This integrated CSTEM Physical Sciences course provides opportunities for students to deepen their awareness and understanding of crosscutting concepts that occur throughout the natural world. Many of the crosscutting concepts, such as patterns, cause and effect, systems and systems models, energy and matter, as well as structure and function are applied to the physical science, computer science, and electronics lessons.

Extension of Standards.

The integrated structure of this course engages students in the physical sciences discipline while simultaneously addressing related standards and concepts.

- California 2018 Computer Science (CS) Standards are applied as students develop foundational skills needed to conduct and design sensor-driven experiments.
- This integrated CSTEM course applies an understanding of physical sciences to address real-world environmental issues. The California Environmental Principles and Concepts (EP&Cs) are used in applicable lessons for students to consider the human impact on the environmental and ideas for innovative solutions.
- This course addresses Career and Technical Education (CTE) Standards found within the Environmental Resources pathway. Field trips to related local businesses and guest speakers within these industries provide students opportunities for college and career exploration.

The following CS Standards are addressed throughout this course:

9-12.CS.2: Compare levels of abstraction and interactions between application software, system software, and hardware.

9-12.DA.8: Translate between different representations of data abstractions of real world phenomena, such as characters, numbers, and images.

9-12.DA.11: *Refine computational models to better represent the relationships among different elements of data collected from a phenomenon or process.*

9.12 AP.12: Design algorithms to solve computational problems using a combination of original and existing algorithms.

9.12 AP.13: Create more generalized computational solutions using collections instead of repeatedly using simple variables.

9-12 AP.15: Iteratively design and develop computational artifacts for practical intent, personal expression, or to address a societal issue by using events to initiate instructions.

9-12.AP.20: *Iteratively evaluate and refine a computational artifact to enhance its performance, reliability, usability, and accessibility.*

9-12.AP.22: Document decisions made during the design process using text, graphics, presentations, and/or demonstrations in the development of complex programs.

Introduction and Overview:

Students begin by learning foundational computer science skills in preparation for conducting more sophisticated experiments. These foundational units engage students in science and engineering practices as they **use mathematics and computational thinking** skills necessary for coding and computer interactions. Students apply crosscutting concepts of patterns, cause and effect, and systems and system models while they apply mathematics and computational thinking practices as they **plan and carry out investigations**. These investigations provide a rich context to **analyze and interpret the dynamic interchange of data** input from sensors, data processing, and outputs. Students **obtain and evaluate information** from these investigations to **construct explanations** and later in the course **design experiments**. Throughout the investigations, students continue to **ask questions, engage in argument from evidence, and obtain, evaluate, and communicate information**.

Units 0 – 3 engage students in increasingly more sophisticated skills interacting with computer hardware and software, data, sensors, and electronics. These foundational units are followed by a menu of real-world experiments that utilize the physical science disciplinary core ideas to **plan and carry out investigations** and later **construct explanations and design solutions** to relevant environmental issues.

Units

Unit 0 – Introduction to *LbyM* Chromebooks

Unit 0 Summary

Unit 0 establishes a critical foundation for understanding the ubiquitous role of technology in science and engineering for research and development. Students use preconfigured Chromebooks throughout the *LbyM* Physical Science CSTEM course. Students will **carry out investigations** of the operating system and text editor to access and customize course-specific folders and files necessary to process data inputs from sensors that will be used in their labs and experiments. This unit serves as an introduction to the hardware and software features of their Chromebooks. Students will **analyze and interpret** communication protocols for system navigation, text editing, and data entry syntax associated with the terminal window (MATE). At the end of this unit, students will understand the file system (Caja) and file naming protocols used throughout the course when they modify and design their own experiments. In addition, students will become familiar with the various applications used for coding (TurtleLogo), the text editor (Pluma), as well as display conventions for hints and warning window. Students will also **investigate, evaluate, and communicate** information regarding innovations in commonly used technologies. Student activities throughout the unit provide format assessment information for teachers. The Double-Dare Challenges at the end of the unit allow students to apply their new skills as they serve as summative assessments for teachers.

Written assignments are embedded within the hands-on labs. Please see the student worksheets uploaded as the course material for this Unit.

NGSS Standard:

PS4.C: *Information Technologies and Instrumentation.*

Laboratory Activities

Unit 0 Assignment – Double Dare Challenges

Students will **obtain, evaluate, and communicate technical information** as they compare and contrast innovations and advantages of components, subcomponents, or software features from commonly used technologies.

1. Students will research cellphone camera information and units of measurement for resolution (Megapixels). They will calculate how many Megapixels make-up the display screen on their computer and compare that data to the resolution of their cellphone camera.
2. Students will research HDMI and USB technology to evaluate their advantages and communicate their uses. Students will then communicate the differences as they compare and contrast these similar innovations.
3. Students will research disk drive technologies to obtain information about hard drives and solid state drives. They will then communicate evaluate the advantages between these innovations as they compare and contrast their various features.
4. Students will research common file types based on their file extensions. Students will then communicate the different file formats as they compare and contrast these commonly used file types.

This series of challenges allow students to apply their new knowledge and skills and also serve as summative assessments for teachers.

Unit 1 – TurtleLogo

Unit 1 Summary

Unit 1 presents students with increasingly more complex challenges for writing coding structures and syntax. TurtleLogo is a computer programming language that produces visual images and geometric patterns based on a basic language structure, geometric commands, and algorithms. Using **mathematics and computational thinking**, students control the movements of the turtle cursor to create visual art images and geometric designs. The crosscutting concepts of patterns and cause and effect are extended to coding skills. Students learn patterns between geometric algorithms and the visual displays they produce. Students experience cause and effect outcomes as they design code to create the desired result and troubleshoot syntax errors. Students explore how research scientists use information from sensors to develop models and real-world simulations. Scientist use, and interact with, technology throughout research and development cycles in multiple ways to obtain information or process data. They use this information to design models or real-world simulations for a variety of purposes such as, making predictions, or communicating information. As a culminating project, students will **develop a visual model** to serve as a simulation of a real-world phenomenon. This project also serves as a summative assessment for this unit.

Students are introduced to ways research scientists are using sensors on animals to collect data, make predictions about their behaviors, design models, and communicate information. The anchoring phenomenon of turtle hatchling migration from sand to sea is used as an engaging context for exploring TurtleLogo and the concept of designing models and simulations. Students obtain and evaluate data regarding survival rates of turtle hatchlings and examine their group migration as a means of individual survival.

Written assignments are embedded within the hands-on labs. Please see the student worksheets uploaded as the course material for this Unit.

NGSS Performance Expectation(s):

PE: HS-LS2-8 *Evaluate evidence for the role of group behavior on individual and species' chances for survival and reproduction.*

Unit 1 Assignment – Turtle Simulation Design

The anchoring phenomenon of turtle hatchling migration from sand to sea is used as an engaging context for exploring TurtleLogo and the concept of **designing models and simulations**. Students are introduced to ways research scientists are using sensors on sharks to collect data, make predictions about their behaviors, design models, and communicate information. The culminating project will allow students to apply their knowledge of TurtleLogo commands and coding skills to design a simulation of turtle hatchling migration and the environmental and human-caused threats turtle hatchlings encounter during their short journey from sand to sea. Students will demonstrate their coding and design skills to create a background image for their simulation using techniques learned in the TurtleArt lessons. Elements of the natural environment such as sand, sea, rocks, and vegetation will be reflected in the background along with potential natural and human-caused hazards such as predators, litter, or plastic objects. They will then apply their coding and algorithm skills to plot a safe migration course for their turtle and account for realistic elements such as the speed of the hatchling moving across the screen and orientation of the turtle cursor. Students will **present their simulations** to their peers and classmates as they **construct explanations** about turtle hatchling migration and **communicate information** about their simulation design challenges. The Turtle Simulation project serves as a performance-based summative assessment for this unit.

Unit 2 – Going with the Electron Flow

Unit 2 Summary

Unit 2 uses electrical energy as a context for understanding how energy is converted from one form to another. Students engage in the performance expectation **HS-PS3-3** as they configure the BasicBoard and Arduino system to control LEDs wired to digital pins. They learn the polar nature of LEDs, their physical characteristics, and how to measure voltage and resistance throughout the system. Students also explore the performance expectation **HS-PS2-6** while they examine the molecular-level structure and function of the BasicBoard's materials and design to communicate scientific and technical information in relation to its purpose.

This unit builds upon the coding and system design skills presented in the previous unit as it provides an understanding of fundamental properties of electricity and electronic components. Students gain a foundational understanding of the more complex functions, coding, design, and connectivity of system components that will be used to conduct research experiments and labs throughout the *LbyM* course. Students investigate the crosscutting concept of structure and function as it applies to the major system components needed to **plan and carry out investigations** using sensors. They engage in systems and systems thinking as they explore proper connections, wiring, and communications between the computer, the BasicBoard, and the Arduino microcontroller through teacher-guided hands-on lessons and investigations. Students apply core ideas of the design and circuitry of the BasicBoard as they examine the conductive (metals) and non-conductive materials as part of its structure and function. Students **plan and carry out investigations** to understand the concept of electric current as the flow of electrons that are negatively

charged parts of the atom that travel on a path provided by conductive materials. Resistance and the use of resistors is introduced as students **apply mathematical thinking** using Ohm's Law to test and measure connectivity and resistance across various locations on the BasicBoard. They **ask questions** then **construct explanations** regarding the internal design of the BasicBoard based on evidence of its conductivity found using a multimeter. Students wire and configure an Arduino microcontroller onto a BasicBoard and learn how to code and control colored LEDs using digital pins. They learn the polarity of LEDs and how to visually identify the positive and negative legs along with the proper configuration to associated digital pins on the Arduino microcontroller. Students **make predictions, then plan and carry out investigations** as they write Logo code to control additional LEDs they configure on the BasicBoard.

Students' coding skills are expanded within the Logo language as the lessons build from teacher-guided instructions to student-designed experiments to operate and control the LEDs. They learn to understand these interconnected components (computer, BasicBoard, Arduino microcontroller, and LEDs) operate as a system. Finally, students interact with hardware and software as they consider the **flow of energy** through the system and the **structure and properties of matter** within the components.

Written assignments are embedded within the hands-on labs. Please see the student worksheets uploaded as the course material for this Unit.

NGSS Performance Expectations:

HS-PS2-6: *Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.*

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.*

Unit 2 Lab – Using Digital Pins to Control LEDs

This key assignment integrates student-controlled communications (Logo coding) of the Arduino microcontroller and concepts of energy flow through a system. At this phase of the unit, students have **developed a physical model to plan and carry out hands-on investigations**. This lesson builds on previous Unit 2 assignments that resulted in students configuring their Arduino microcontroller and wiring their BasicBoard to include a red LED and a white LED. Students learn how to turn LEDs on and off by coding commands that control digital pins on the Arduino. The introduction of LEDs and their structure and function (polar legs) into the system provides a context for students to apply their understanding of resistance (resistors) and voltage in an effort to protect the LEDs. An LED that lights up provides a visual phenomenon for understanding transference of energy within the system. Throughout this assignment, students **analyze and interpret data** in a series of teacher-led investigations that command different aspects of the Arduino microcontroller and result in various measurable outputs (e.g., such as annotating which digital pin is used to control the different LEDs). Students **carry out these investigations** and record their results. Challenge questions ask students to apply systems thinking as they **construct explanations** for how the various hardware and software components interact with each other. Students engage in **mathematical thinking** as they **argue from evidence** and include measurements of voltage and resistance to support their claims. Students apply their knowledge of energy and matter as they **obtain, evaluate, and communicate information** regarding the transference of energy throughout the system by measuring, annotating, and explaining voltage and resistance at various locations on the BasicBoard and the lighting of LEDs.

Unit 3 – Doing Science with Sensors

Unit 3 Summary

Unit 3 increases the complexity and possibilities of the experimental system design with the introduction of light and temperature sensors. Students continue to build their Logo coding skills, technological proficiencies, and conceptual understandings of energy and matter. Knowing how to control, interpret, and experiment with light and temperature sensors are foundational skills students will use throughout the *LbyM* course as the subsequent units focus on application of these STEM competencies that are essential in real-world scientific research. The Unit 3 investigations with sensors provide hands-on phenomena as students explore PS3.A Definitions of Energy (light and thermal), reinforce Unit 2 concepts of PS3.B Transference of Energy, and deepen their understanding of digitized information (PS4.A). In the previous unit, students learned how to use the Arduino to turn LED lights on and off as they investigated changes in voltage as evidence of energy movement through the system. Students are introduced to the OPIC light sensor in the first set of lessons followed by the TMP-36 temperature sensor in the second half of the unit. The introduction of analog sensors requires students to learn the concept of digital versus analog devices and their difference in discrete and continuous values, respectively.

Students begin this unit with a teacher-led discussion about electrostatic discharge and the risks for damaging sensitive electronic equipment including the BasicBoard, Arduino microcontroller, and associated components. Discussion includes the concept of grounding, physical activities that can cause electrostatic discharge, and what students need to do to avoid this. Students must sign an agreement to stay grounded prior to beginning the investigations and experiments in this unit. They examine how information from the sensors is digitized, transmitted in data packets, and converted to measured values. Students **plan and carry out investigations** to understand the structure and function of the OPIC light sensor and how to properly wire and connect it to the BasicBoard and Arduino. Students apply systems thinking as they investigate how visible light is detected as an analog measurement through the OPIC sensor, then is converted to a digital value by the Arduino for input and output within the computer. Light energy is converted to electrical energy that students measure with a multimeter at various locations on the BasicBoard. Students explore cause and effect relationships as they **conduct investigations** to vary the amount of light detected by the sensor, then document and compare the associated analog voltage readings. Students maintain a science notebook as they record data obtained throughout their investigations. Students learn that the Arduino functions as an Analog to Digital Converter (ADC) to provide digital values, or Analog to Digital Units (ADUs) that can be displayed on the computer screen. Students apply systems thinking as they annotate a system model of the flow of information from the OPIC light sensor, to the Arduino, to the computer, then as ADU values displayed on the computer terminal. **Mathematics and computational thinking skills** are applied as students plot the relationship between analog sensor readings and digital BasicBoard outputs. Next, they use the slope-intercept formula to graph their data and **make predictions** of interim values. These artifacts serve as formative assessment tools for teachers. Students learn the use of comparison operators in Logo and how to modify code to make executable decisions based on converted sensor input values. As a culminating lab, students **design and build a night light** (HS-PS3-3) that automatically turns on when the detected light levels reach a predefined value, then turns off once the light levels increase to a different predefined value. This artifact serves as both a formative and summative assessment of students' understanding and skills.

Next, students are introduced to the TMP-36 temperature sensor. The subsequent introduction of the temperature sensors provides a new context and form of energy to reinforce the Arduino lesson series that investigated analog sensor devices, the process to convert analog values to digital units, and how to **analyze, graph, and interpret** the ADU values displayed on the computer terminal. Students learn the structure and function of the TMP-36 temperature sensor, proper wiring and associated Logo coding, and how to visibly recognize its critical features. The use of two temperature sensors increases the cognitive complexity of these concepts, the student investigations, and the data analysis. Students **plan and carry out investigations** to calibrate the temperature sensors for the purposes of modifying the Logo code with relative ADU values for

ambient Celsius temperature and freezing (0°C). They **use mathematical representations to support claims** regarding cause and effect relationships of sensor inputs, ADU values, and voltage readings in various media. Students relate the data values or digital information (PS4.A) to the light and thermal energy that was measured during their investigations. Students **investigate** how real-time sensor data is transmitted and displayed in the aggregate (from all three sensors) in the form of data packets. They learn how to calculate the approximate UNIX Time while they **analyze and interpret** data packets. A train model is used to describe the structure of data packets and the use of a checksum in the Logo code for internal validity of the individual data values obtained at a particular moment in time.

Written assignments are embedded within the hands-on labs. Please see the student worksheets uploaded as the course material for this Unit.

NGSS Performance Expectations:

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.*

Unit 3 Lab – Build a Night Light

Students continue to build their coding skills as they learn how to use Logo to evaluate arithmetical expressions, Logo words as comparison operators and if statements to make decisions. Students synthesize their knowledge of Logo, the light sensor, light sensor ADU values, and changes of energy through a system to **design and build** a night light (HS-PS3-3). They will apply their new knowledge of arithmetical expressions, comparison operators, and if statements to automatically turn on an LED when the light level detected through the sensor reaches a defined ADU value (an ADU value that signifies a low level of light). The night light system will continue to capture current light values at student-defined intervals. The night light will remain on until the detected light level increases to a student-defined ADU value. Throughout the design and testing phases, students will **ask questions and define problems** they may encounter as they iteratively **design solutions** for their project. Students will **plan and carry out investigations** to determine cause and effect relationships when they adjust the rate at which the Arduino pauses between light sensor readings and the night light's response to changing light levels. Students also have the opportunity to design an anti-night light that turns on the LED in a bright room (higher light values) and off when the room is dark (low light values). The students' night lights **serve as a model or simulation** of how automatic lights operate in the real-world. This project also serves as a summative assessment of student understanding and skills.

Experiment Units

The LbyM experiment units engage students in a series of in-depth hands-on laboratory activities to further investigate concepts of energy and matter. Students apply their skills for controlling and interacting with the system components, sensors, software, and data as they partake in all phases of the scientific process. Their focused investigations on energy and matter are then considered in relation to real-world environmental issues and solutions.

Water and Soil Experiment Unit

Unit Summary

This unit focuses on PEs: HS-PS3-2 and HS-ESS2-5. Students will **develop and use models** to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motions of particles and energy associated with the relative positions of particles. They will then apply this knowledge

to **plan and conduct an investigation** of the properties of water and its effects on Earth materials and surface processes. Properties of water and water molecules are used as a unifying context for this integrated physical science and Earth science unit.

Students begin the unit with an investigation into the phenomenon of the evaporative properties of water at the macroscopic scale in their first experiment. Using two sensors, students **carry out an investigation** to collect temperature data from a stationary sensor that detects ambient temperature and a leashed moisture-protected sensor that has been sprayed with water. Students **observe** temperature changes in real time as water evaporates from the leashed (wet) sensor and **construct explanations** as to how the different components of the evaporative system experiment function together. Students then **analyze and interpret** the comparative data of temperature over time for the two sensors, creating graphs to consider patterns as evidence of macroscopic cause and effect factors. To understand this phenomenon more deeply, the conceptual focus shifts to the microscopic scale as students explore the energy associated with the motion and relative position of particles related to water molecules. Students apply their knowledge of evaporation to **predict** and graph potential changes in temperature given various modifications to the original experiment. To **test their predictions**, students select a modification, rerun the experiment to **obtain additional information**, then **analyze and interpret** their results. Students then synthesize their understanding of energy at the macroscopic and microscopic scales to **develop a model** to illustrate the energy associated with the motion and relative position of particles. They apply systems thinking as they **sketch a model** that represents the flows of energy and matter into, out of, and within the system.

The second half of the units provides an integrated exploration of the conductive properties of water, leading to investigations of the effects of water on Earth materials and surface processes. Students **plan and carry an investigation** to measure the flow of electricity through moist soil. Students construct a soil moisture sensor that enables current to flow into the moist soil. Students **obtain voltage and temperature data** across varying conditions and moisture levels within the soil. Students **analyze and interpret** both the physical components and function of the soil moisture experiment system along with the resulting voltage and temperature data. Next, students **design their own experiments** within given constraints to **obtain additional data** to deepen their understanding of the physical effects water has on soil. Students apply scientific research practices as they explicitly identify the controls and variables for their experiments. They repeat their experiments, document their observations, and graph the data. Next, they **analyze and interpret** the data and **communicate findings and analyses** with their peers. The conceptual focus shifts from a microscopic understanding of the conductive properties of water as measured in soil to a macroscopic view of these implications. Students apply their knowledge to real-world contexts as they **write a report** describing various techniques for using soil moisture measurements to control irrigation in agricultural settings, discussing the benefits and problems with at least two different types of sensors.

Investigations take on an even broader view of the effects of water on Earth's surfaces. Students investigate their local watersheds to understand their source of water, its storage, treatment, and release. They also analyze local rainfall data over time, storage capacity, along with historical data of floods and droughts in their area. Students analyze data and visual graphic information of various ground coverings and soils, from open land to hardscapes, to investigate rainwater runoff, absorption by plants, the ground, and atmospheric release through evapotranspiration. They **analyze and interpret** geoscience data to **construct a claim and argument** from evidence relating changes in Earth's surface properties and the availability of water for human use. As a summative assessment, students synthesize the various data models to then present an argument about the effects of the availability of rainwater on human activities. They communicate their ideas through various modes of communication and presentations.

Written assignments are embedded within the hands-on labs. Please see the student worksheets uploaded as the course material for this Unit.

NGSS Performance Expectations:

HS-PS3-2: Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motion of particles (objects) and energy associated with the relative position of particles.

HS-ESS2-5: Analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth's systems.

Unit Lab Activity – Design Your Own Experiment

Students plan and conduct an investigation of the properties of water and its effects on Earth materials and surface processes. They begin by building a soil moisture sensing system that interfaces with the Arduino, BasicBoard, and computer. They assemble a soil moisture sensor using 2 zinc screws inserted through a cardboard base that will rest atop a cup of soil. The zinc screws are wired to the BasicBoard and Arduino along with a leashed temperature sensor. As water is added to the cup of soil, it provides a path to conduct electricity. Students sketch their wiring on a schematic diagram of the soil moisture sensing system. They then add water to the soil and run their initial experiment to **obtain voltage and temperature data** and document their observations. Students **analyze** the initial data and make necessary mathematical modifications to the Logo code to correct for the effect of temperature changes on the soil moisture sensor.

After students have successfully run their initial experiment, they **design their own experiment** within given requirements and constraints. The goal is to design an experiment that provides data that will help them **obtain data to construct explanations** regarding the physical effects that water has on soil. Students **discuss their experiment design ideas** with their peers, verify that each design meets the given requirements and constraints, then **document their predictions**. Within groups, students select one experiment design idea to test. They discuss the needed materials and provide their teacher with a list of additional items they may need. Students practice scientific research protocols as they explicitly identify and document the controls and variables for their experiments. They run their initial experiment, debug the associated computer code as needed, then sketch the resulting data plots. Students then repeat their experiments at least twice, adjusting for their predetermined variables. Students document their observations and compare the results to their previous predictions.

Formative assessment data is collected throughout the investigations as students document their processes and answer questions and present claim, evidence, reasoning statements regarding the properties of water molecules at the microscopic level. At the conclusion of this lesson, students apply their knowledge to real-world contexts to **write a report** describing various techniques for using soil moisture measurements to control irrigation in agricultural settings, discussing the benefits and problems with at least two different types of sensors.

Interactions of Light, Energy and Matter Experiment Unit

Unit Summary

Absorption of electromagnetic radiation (ER) in the form of light provides a unifying context for students to build upon their understanding of energy and matter flows within systems at the macroscopic and microscopic levels. The concepts of reflection, absorption, and transmission are examined as students consider how light

interacts with atoms of various materials and colors along with the resulting flow of energy into, out of, and within the system. The concept of light absorption in the form of heat (thermal energy) is explored using various materials. Students consider rates of absorption related to the materials and their color as an observable property of matter. These foundational concepts of absorption are expanded to include an understanding of photovoltaic energy and energy systems. Solar, or photovoltaic energy, is explored in the second half of this unit with considerations for renewable and non-renewable sources of energy. Students design a photovoltaic system and test the placement of solar panels to maximize the absorption of light energy. Students also examine the effects of electromagnetic radiation on humans in the context of sunburns and X-rays.

The unit begins with a series of lessons and experiments to **investigate** differences in absorption of light using various colored materials and the associated level of thermal (heat) energy produced. Students learn the proper system configuration, wiring, and Logo coding needed to investigate these concepts. Using two leashed temperature sensors individually wrapped in a light and dark color to gather comparative data, students conduct an initial experiment adding an external light source (lamp) to test their set up. Students continue to refine their skills for conducting scientific research. They create a detailed diagram of the experiment set up to describe how the different components of the absorption system work together. They **ask questions** then identify the independent (manipulate) and dependent (respondent) variables to consider what can be changed, controlled, and tested. Students run their initial experiment, **document their observations**, then **analyze and interpret** the data outputs (temperature readings from both sensors) to consider patterns associated with the light and dark materials. Students provide a written explanation of temperature changes over time as they also consider the rate of change. These activities provide teachers with numerous opportunities throughout the lessons to gather formative assessment data of students' understandings. As an extension activity, students adjust the height of the lamp (heat source) and rerun the experiment. They repeat their experiment four times adjusting the distance between the light source (lamp) and the temperature sensors (HS-PS3-3). Students synthesize the comparative temperature data from their experiments to create a graph that displays temperature changes as a function of the lamp height. This activity also serves as a summative assessment tool for teachers.

The foundational understanding of absorption is applied to the real-world context of photovoltaic (solar) energy systems. Students learn about simple power circuits, the photoelectric effect, and optimization techniques. Students build a new experiment system using a solar panel as a sensor. They learn the proper configuration, wiring, and Logo code for their photovoltaic energy system. Students run their solar experiment to test their set up and gather initial data. Teacher-guided lessons explore electromagnetic radiation, in the form of photons, in conjunction with the flow of energy and matter throughout a photovoltaic (solar) energy system. Electromagnetic radiation is examined as lessons present charts of ER energy and associated wavelengths. Students focus on the visible light spectrum and the relationship between color and associated wavelengths. Students learn how photovoltaic energy is converted to voltage within these energy systems (PS3.A). Students experiment with the position of the solar cell and the associated amount of voltage obtained. They apply their understanding of this concept to **design and build a photovoltaic system** that maximizes the power output of the solar cells (HS-PS3-3). Real-world application of solar energy systems is further explored with considerations for renewable and non-renewable sources of energy. Students also consider the effects of electromagnetic radiation on living tissue as they evaluate the validity and reliability of claims in published materials (HS-PS4-4). The unit concludes as students create a presentation of their ideas of absorption and their practical implications in the real-world. Students choose their form of presentation media with given requirements for content. Their presentations serve as a summative assessment for these concepts.

Written assignments are embedded within the hands-on labs. Please see the student worksheets uploaded as the course material for this Unit.

NGSS Performance Expectations:

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.*

HS-PS4-4: Evaluate the validity and reliability of claims in published materials of the effects that different frequencies of electromagnetic radiation have when absorbed by matter.

Unit Lab – Designing a Photovoltaic System

Students **design and build a photovoltaic energy system** to convert electromagnetic radiation in the form of photons to electrical energy as measured by voltage. Students configure their basic experiment system with a wired solar panel. They learn the proper configuration, wiring, and Logo code needed to conduct their experiments. Students test their set up with an initial execution of their experiment. They **document their observations** and **ask questions** to consider the validity of the data outputs. Students **plan and carry out** a series of investigations to investigate the position of the solar cells affects the voltage or power output of the system. They apply this information to design a photovoltaic system that will maximize the amount of energy converted to electrical energy (voltage). Students build their skills for conducting scientific research as they consider ideas for modifying their experiments and controlling identified variables. Students **plan and carry out** their new experiments multiple times to gather comparative data to better understand the relationship between solar cell position and voltage outputs. They **analyze and interpret** the data in various ways including creating charts and graphs. These artifacts serve as formative assessment data for teachers. Students consider the practical implications of their designs in a real-world context for generating the maximum power output. They **synthesize their data and communicate** their understanding of energy and matter flows within a system through individual class presentations. Students presentations also serve as a summative assessment tool for teachers at the conclusion of this unit.