STEM Unit 3: Engineering the Future (60 Instructional Days)	
Overarching Essential Questions	**Overarching Enduring Understandings**
• What limits an engineer's ability to solve a problem? • Don't most major problems need multiple types of engineering to solve? • What can we learn from past failures in engineering? • How can we as a global community ensure continued progress without depleting our resources beyond their means? • What role will different types of engineers play in our continued development as a global community?	• Engineers apply principles of science and mathematics to develop economical solutions to technical problems. • Sub-disciplines within engineering are meant to specialize in a certain type of problem solving. There is often considerable overlapping among subdisciplines. • Steps can be taken to reduce the impact human society has on the environment. • It is impossible to predict the future, but it is possible to be well prepared for future challenges.

Student Learning Objectives	
What students should be able to do after instruction.	*Evidence Statements*
Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.* [Clarification Statement: Emphasis is on both qualitative and quantitative evaluations of devices. Examples of devices could include Rube Goldberg devices, wind turbines, solar cells, solar ovens, and generators. Examples of constraints could include use of renewable energy forms and efficiency.] [*Assessment Boundary: Assessment for quantitative evaluations is limited to total output for a given input. Assessment is limited to devices constructed with materials provided to students.*]	**HS-PS3-3**
Use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity. [Clarification Statement: Examples of Earth systems to be considered are the hydrosphere, atmosphere, cryosphere, geosphere, and/or biosphere. An example of the far-reaching impacts from a human activity is how an increase in atmospheric carbon dioxide results in an increase in photosynthetic biomass on land and an increase in ocean acidification, with resulting impacts on sea organism health and marine populations.] [*Assessment Boundary: Assessment does not include running computational representations but is limited to using the published results of scientific computational models.*]	**HS-ESS3-6**
Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.* [Clarification Statement: Examples of human activities can include urbanization, building dams, and dissemination of invasive species.]	**HS-LS2-7**
Create or revise a simulation to test a solution to mitigate adverse impacts of human activity on biodiversity.*[Clarification Statement: Emphasis is on designing solutions for a proposed problem related to threatened or endangered species, or to genetic variation of organisms for multiple species.]	**HS-LS4-6**

Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.	**HS-ETS1-1**
Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.	**HS-ETS1-2**
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.	**HS-ETS1-3**
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.	**HS-ETS1-4**

The Student Learning Objectives above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Asking Questions and Defining Problems Asking questions and defining problems in 9–12 builds on K–8 experiences and progresses to formulating, refining, and evaluating empirically testable questions and design problems using models and simulations. • Analyze complex real-world problems by specifying criteria and constraints for successful solutions. (HS-ETS1-1) **Constructing Explanations and Designing Solutions** Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles and theories. • Design a solution to a complex real-world problem, based on scientific knowledge,	**EDD2.D: Weather and Climate** ● Current models predict that, although future regional climate changes will be complex and varied, average global temperatures will continue to rise. The outcomes predicted by global climate models strongly depend on the amounts of human-generated greenhouse gases added to the atmosphere each year and by the ways in which these gases are absorbed by the ocean and biosphere. (secondary to HS-ESS3-6) **ESS3.D: Global Climate Change** ● Through computer simulations and other studies, important discoveries are still being made about how the ocean, the atmosphere, and the biosphere interact and are modified in response to human activities. (HS-ESS3-6) **LS2-C: Ecosystem Dynamics, Functioning, and Resilience** ● Moreover, anthropogenic changes (induced by human activity) in the environment—including habitat destruction, pollution, introduction of invasive species, overexploitation, and climate	**Systems and System Models** • Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales. (HS-ETS1-4) • When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models. (HS-ESS3-6) **Energy and Matter** • Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system. (HS-PS3-3) **Stability and Change** • Much of science deals with constructing explanations of how things change and how they remain stable (HS-LS2-7) **Cause and Effect** • Empirical evidence is required to differentiate

student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (HS-ETS1-2) (HS-ETS1-3) • Design, evaluate, and refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (HS-PS3-3) (HS-LS2-7) **Using Mathematics and Computational Thinking** Mathematical and computational thinking in 9-12 builds on K-8 experiences and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions. ● Use mathematical models and/or computer simulations to predict the effects of a design solution on systems and/or the interactions between systems. (HS-ETS1-4) ● Create or revise a simulation of a phenomenon, designed device, process or system (HS-LS4-6) ● Use a computational representation of phenomena or design solutions to describe and/or support claims and/or explanations. (HS-ESS3-6)	change—can disrupt an ecosystem and threaten the survival of some species. (HS-LS2-7) **LS4-C: Adaptation** ● Changes in the physical environment, whether naturally occurring or human induced, have thus contributed to the expansion of some species, the emergence of new distinct species as populations diverge under different conditions, and the decline–and sometimes the extinction–of some species. (HS-LS4-6) **LS4.D: Biodiversity and Humans** ● Biodiversity is increased by the formation of new species (speciation) and decreased by the loss of species (extinction). (secondary to HS-LS2-7) ● Humans depend on the living world for the resources and other benefits provided by biodiversity. But human activity is also having adverse impacts on biodiversity through overpopulation, overexploitation, habitat destruction, pollution, introduction of invasive species, and climate change. Thus sustaining biodiversity so that ecosystem functioning and productivity are maintained is essential to supporting and enhancing life on Earth. Sustaining biodiversity also aids humanity by preserving landscapes of recreational or inspirational value. (HS-LS4-6) (secondary to HS-LS2-7) **PS3.A: Definitions of Energy** ● At the macroscopic scale, energy manifests itself in multiple ways, such as motion, sound, light, and thermal energy. (HS-PS3-3) **ETS1.A: Defining and Delimiting Engineering Problems** ● Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in	between cause and correlation and make claims about a specific cause and effects. (HS-LS4-6) -- **Connections to Engineering, Technology, and Applications of Science** **Influence of Engineering, Technology, and Science on Society and the Natural World** • New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology. (HS-ETS1-1) (HS-ETS1-3) • Modern civilization depends on major technological systems. Engineers continuously modify these technological systems by applying scientific knowledge and engineering design practices to increase benefits while decreasing costs and risks. (HS-PS3-3)

	such a way that one can tell if a given design meets them. (HS-ETS1-1) (secondary to HS-PS3-3) ● Humanity faces major global challenges today, such as the need for supplies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global challenges also may have manifestations in local communities. (HS-ETS1-1) **ETS1.B: Developing Possible Solutions** ● When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. (HS-ETS1-3) (secondary to HS-LS4-6) (secondary to HS-LS2-7) ● Both physical models and computers can be used in various ways to aid in the engineering design process. Computers are useful for a variety of purposes, such as running simulations to test different ways of solving a problem or to see which one is most efficient or economical; and in making a persuasive presentation to a client about how a given design will meet their needs. (HS-ETS1-4) (secondary to HS-LS4-6) **ETS1.C: Optimizing the Design Solution** ● Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed. (HS-ETS1-2)	

Embedded English Language Arts/Literacy and Mathematics

English Language Arts/Literacy -	
RST.9-10.8	Assess the extent to which the reasoning and evidence in a text support the author's claim or a recommendation for solving a scientific or technical problem. (HS-LS2-7)
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. (HS-ETS1-1) (HS-ETS1-3) (HS-LS2-7)
RST.11-12.8	Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information. (HS-ETS1-1) (HS-ETS1-3) (HS-LS2-7)
RST.11-12.9	Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible. (HS-ETS1-1) (HS-ETS1-3)
WHST.9-12.5	Develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach, focusing on addressing what is most significant for a specific purpose and audience. (HS-LS4-6)
WHST.9-12.7	Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. (HS-PS3-3) (HS-LS2-7) (HS-LS4-6)
Mathematics –	
MP.2	Reason abstractly and quantitatively. (HS-ETS1-1) (HS-ETS1-3) (HS-ETS1-4) (HS-PS3-3) (HS-ESS3-6) (HS-LS2-7)
MP.4	Model with mathematics. (HS-ETS1-1) (HS-ETS1-2) (HS-ETS1-3) (HS-ETS1-4) (HS-PS3-3) (HS-ESS3-6)
HSN.Q.A.1	Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (HS-PS2-6) (HS-PS3-3) (HS-ESS3-6) (HS-LS2-7)
HSN.Q.A.2	Define appropriate quantities for the purpose of descriptive modeling. (HS-PS2-6) (HS-PS3-3) (HS-ESS3-6) (HS-LS2-7)
HSN.Q.A.2	Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-PS2-6) (HS-PS3-3) (HS-ESS3-6) (HS-LS2-7)

Three-Dimensional Teaching and Learning

Coherence with the Circuits unit-

Students' knowledge of AC and DC circuits is developed further and integrated into a bigger picture. Global energy balance is a growing concern and electricity just seems to be a stop along the way anymore. A command of the principles of electricity and its manipulation using programming is more and more considered a necessary skill at the high school level if one expects success at the college level in a technical field. In this unit, students are immersed in the global issue of sustainable energy.

Modeling Systems Using Computer Simulations-

The unit will ask students to begin utilizing peripheral devices as both inputs and outputs. Put into the context of global energy consumption, students will be asked to design a device specific to their chosen field of engineering to aid in lowering our global footprint. This will arguably be the greatest challenge facing humanity in the coming century, as global climate change is not just an inevitability anymore; it's a real problem that demands real solutions.

Students will be introduced to computer programming through the use of Arduinos. The files that are used to program an Arduino are called 'sketches'. Some ideas of sketches that can be used are:

- Utilize pins as both voltage input and outputs
- Use a sensor to control the dimming of an LED light
- Use a peripheral to control a circuit (e.g., photoresistor, knock detector, push button)
- Write more and more complex functions from scratch to call in the setup or loop

Integration of Engineering-

Students will go through the entire engineering design process in the development of their own devices. They will be responsible for an initial statement of purpose, research and development, designing, testing, and redesigning.

Prior Learning

Physical science-

- Electric circuits can be constructed in order to transfer electrical energy to be converted to other forms of energy.
- Varying the construction of the circuit will change its properties.
- Electric circuits are governed by a series of laws including Ohm's Law, the Power Law and Kirchoff's Laws.
- The amount of energy transfer needed to change the temperature of a matter sample by a given amount depends on the nature of the matter, the size of the sample, and the environment.
- Energy is spontaneously transferred out of hotter regions or objects and into colder ones.

Life Science-

- Ecosystems have carrying capacities, which are limits to the numbers of organisms and populations they can support. These limits result from such factors as the availability of living and nonliving resources and from such challenges such as predation, competition, and disease. Organisms would have the capacity to produce populations of great size were it not for the fact that environments and resources are finite. This fundamental tension affects the abundance (number of individuals) of species in any given ecosystem.

- Photosynthesis and cellular respiration (including anaerobic processes) provide most of the energy for life processes.
- Plants or algae form the lowest level of the food web. At each link upward in a food web, only a small fraction of the matter consumed at the lower level is transferred upward to produce growth and release energy in cellular respiration at the higher level. Given this inefficiency, there are generally fewer organisms at higher levels of a food web. Some matter reacts to release energy for life functions, some matter is stored in newly made structures, and much is discarded. The chemical elements that make up the molecules of organisms pass through food webs and into and out of the atmosphere and soil, and they are combined and recombined in different ways. At each link in an ecosystem, matter and energy are conserved.
- Photosynthesis and cellular respiration are important components of the carbon cycle, in which carbon is exchanged among the biosphere, atmosphere, oceans, and geosphere through chemical, physical, geological, and biological processes.
- A complex set of interactions within an ecosystem can keep its numbers and types of organisms relatively constant over long periods of time under stable conditions. If a modest biological or physical disturbance to an ecosystem occurs, it may return to its more or less original status (i.e., the ecosystem is resilient), as opposed to becoming a very different ecosystem. Extreme fluctuations in conditions or the size of any population, however, can challenge the functioning of ecosystems in terms of resources and habitat availability.
- Humans depend on the living world for the resources and other benefits provided by biodiversity. But human activity is also having adverse impacts on biodiversity through overpopulation, overexploitation, habitat destruction, pollution, introduction of invasive species, and climate change. Thus sustaining biodiversity so that ecosystem functioning and productivity are maintained is essential to supporting and enhancing life on Earth. Sustaining biodiversity also aids humanity by preserving landscapes of recreational or inspirational value.

Part A: How can computers be taught to see and hear?

Concepts	Formative Assessment
• By taking advantage of properties of certain materials, energy can be harnessed and utilized to do work. One way this energy is transferred is through electric circuits. • Specially designed sensors can be added to electrical circuits to harness energy from the environment or other circuits to do work.	*Students who understand the concepts are able to:* • Design and build a circuit that is powered by an Arduino sketch. Test the sketch using the circuit. The circuit should contain some relationship between an input and an output. • Use comments to annotate a sketch and optimize a sketch by using the most efficient code possible. Sketches should be double checked and revised to ensure efficiency.

Part B: What kind of different engineers are there?

Concepts	Formative Assessment
• There are widely varying types of challenges constantly facing society. In	*Students who understand the concepts are able to:*

light of this fact, there are specialties within engineering to properly address all types of challenges. • There is no such thing as a perfect system. Learning from failures is crucial to both the engineering design process and our thriving as a people.	• Use evidence from models and simulations to support explanations for how a certain engineering challenge was met. • Communicate scientific ideas in multiple formats (including orally, graphically, textually, and mathematically) about different engineering disciplines, their past successes and failures, their current major challenges, and their place in society's future.

Part C: What can we do now to ensure that future generations are taken care of?	
Concepts	**Formative Assessment**
• Engineers solve problems systematically. This ensures thorough and efficient results and transcends sub-disciplines. • Today's problems are not necessarily tomorrow's. How we respond to the challenges of today will have an effect on the scope and degree of future challenges. •	*Students who understand the concepts are able to:* • Develop a model based on evidence to illustrate the impact of humans on earth and earth's systems within the context of a certain type of engineering. • Communicate scientific ideas in multiple formats (including orally, graphically, textually, and mathematically) about different engineering disciplines, their past successes and failures, their current major challenges, and their place in society's future. • Construct and revise a solution, based on valid and reliable evidence from a variety of sources (including models, theories, simulations, peer review), to a future challenge faced by engineers within a certain type of engineering. • Design and build a circuit that is powered by an Arduino sketch. Test the sketch using the circuit. The circuit should contain some relationship between an input and an output.

Modifications: *Teachers identify the modifications that they will use in the unit. The unneeded modifications can then be deleted from the list.(See NGSS Appendix D)*

- *Restructure lesson using UDL principles (http://www.cast.org/our-work/about-udl.html#.VXmoXcfD_UA)*
- *Structure lessons around questions that are authentic, relate to students' interests, social/family background and knowledge of their community.*
- *Provide students with multiple choices for how they can represent their understandings (e.g. multisensory techniques-auditory/visual aids; pictures, illustrations, graphs, charts, data tables, multimedia, modeling).*
- *Provide opportunities for students to connect with people of similar backgrounds (e.g. conversations via digital tool such as SKYPE, experts from the community helping with a project, journal articles, and biographies).*
- *Provide multiple grouping opportunities for students to share their ideas and to encourage work among various backgrounds and cultures (e.g. multiple*

representation and multimodal experiences).

- *Engage students with a variety of Science and Engineering practices to provide students with multiple entry points and multiple ways to demonstrate their understandings.*
- *Use project-based science learning to connect science with observable phenomena.*
- *Structure the learning around explaining or solving a social or community-based issue.*
- *Provide ELL students with multiple literacy strategies.*
- *Collaborate with after-school programs or clubs to extend learning opportunities.*

Leveraging English Language Arts/Literacy and Mathematics

English Language Arts/Literacy-

- Conduct short as well as more sustained research projects to describe energy conversions as energy flows into, out of, and within systems.
- Integrate and evaluate multiple sources of information presented in diverse formats and media to describe energy conversions as energy flows into, out of, and within systems.
- Evaluate scientific text regarding energy conversions to determine the validity of the claim that although energy cannot be destroyed, it can be converted into less useful forms.
- Compare different sources of information describing energy conversions to create a coherent understanding of energy flows into, out of, within, and between systems.
- Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations describing how variations in the flow of energy into and out of Earth's systems result in changes in climate to enhance understanding of findings, reasoning, and evidence and to add interest.
- Cite specific textual evidence of the availability of natural resources, occurrence of natural hazards, and changes in climate and their influence on human activity.
- Use empirical evidence to write an explanation for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity.

Mathematics-

- Define appropriate quantities for the purpose of descriptive modeling of how the quantitative change in energy of one component in a system can be calculated when the change in energy of the other component(s) and energy flows in and out of the system are known.
- Represent symbolically that energy at the macroscopic scale can be accounted for as a combination of energy associated with motions of particles (objects) and energy associated with the relative position of particles (objects), and manipulate the representing symbols. Make sense of quantities and relationships between the energy associated with motions of particles (objects) and energy associated with the relative position of particles (objects).
- Represent the conversion of one form of energy into another symbolically, considering criteria and constraints, and manipulate the representing symbols. Make sense of quantities and relationships in the conversion of one form of energy into another.
- Use a mathematical model of how energy at the macroscopic scale can be accounted for as a combination of energy associated with motions of particles

(objects) and energy associated with the relative position of particles (objects). Identify important quantities representing how the energy at the macroscopic scale can be accounted for as a combination of energy associated with motions of particles (objects) and energy associated with the relative position of particles (objects), and map their relationships using tools. Analyze those relationships mathematically to draw conclusions, reflecting on the results and improving the model if it has not served its purpose.

- Use a mathematical model to describe the conversion of one form of energy into another and to predict the effects of the design on systems and/or interactions between systems. Identify important quantities in the conversion of one form of energy into another and map their relationships using tools. Analyze those relationships mathematically to draw conclusions, reflecting on the results and improving the model if it has not served its purpose.
- Represent symbolically how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity, and manipulate the representing symbols. Make sense of quantities and relationships among availability of natural resources, occurrence of natural hazards, and changes in climate and their influence on human activity
- Use units as a way to understand the relationships among availability of natural resources, occurrence of natural hazards, and changes in climate and their influence on human activity. Choose and interpret units consistently in formulas to determine relationships among availability of natural resources, occurrence of natural hazards, and changes in climate and their influence on human activity. Choose and interpret the scale and the origin in graphs and data displays representing relationships among availability of natural resources, occurrence of natural hazards, and changes in climate and their influence on human activity.
- Define appropriate quantities for the purpose of descriptive modeling of relationships among availability of natural resources, occurrence of natural hazards, and changes in climate and their influence on human activity.
- Choose a level of accuracy appropriate to limitations on measurement when reporting quantities showing relationships among availability of natural resources, occurrence of natural hazards, and changes in climate and their influence on human activity.

Samples of Open Education Resources for this unit: *These are student sense-making experiences that can be used after being modified to be three dimensional.*

Arduino.cc is the Arduino website. There you can find free software and a host of information for all levels of user.

NSTA has numerous resources across all types of science that are NGSS-aligned.

Appendix

Differentiation

Enrichment	• Utilize collaborative media tools • Provide differentiated feedback • Opportunities for reflection • Encourage student voice and input • Model close reading • Distinguish long term and short term goals
Intervention & Modification	• Utilize “skeleton notes” where some required information is already filled in for the student • Provide access to a variety of tools for responses • Provide opportunities to build familiarity and to practice with multiple media tools • Leveled text and activities that adapt as students build skills • Provide multiple means of action and expression • Consider learning styles and interests • Provide differentiated mentors • Graphic organizers
ELLs	• Pre-teach new vocabulary and meaning of symbols • Embed glossaries or definitions • Provide translations • Connect new vocabulary to background knowledge • Provide flash cards • Incorporate as many learning senses as possible • Portray structure, relationships, and associations through concept webs • Graphic organizers

21st Century Skills

- Creativity
- Innovation

- Critical Thinking
- Problem Solving
- Communication
- Collaboration

Integrating Technology

- Chromebooks
- Internet research
- Online programs
- Virtual collaboration and projects
- Presentations using presentation hardware and software