ENERGY Modified UbD Unit Design

Title of Unit	Integrating Solar Tracking into an Aquaponics System	**Grade Level**	6-8
Curriculum Area	Science, math, engineering	**Time Frame**	5-10 days
Developed By	Katrina Vaughn		

Identify Desired Results (Stage 1)

Goals (Content Standards)

- Students will design, build, and test a solar tracking system that will power an aquaponics system which the students will also design, build, and test.

Understandings	Essential Questions
Students will understand that...	**Questions that provoke, address conceptual foundation**
• The student • understands that light energy from the sun can be turned into electricity with a photovoltaic (solar) cell. • knows variables such as clouds, shading and direction of panel tilt, that can affect the amount of power that the photovoltaic cell produces. • understands the factors that can increase the amperage output of their photovoltaic system including cell area, collection devices and intensifying devices. • will be able to explain the economic problems and solutions their team encountered in powering a specific load with their available monetary resources. • will understand that our current energy problems require cooperation and a new economic model.	• Can light energy from the sun be turned into electricity? If so, how? • Can clouds and the tilt of a solar panel affect the amount of power it produces? • How can the amperage output of a solar panel be increased? • How can solar panels provide economic solutions for an area? • How can cooperating with others help produce energy crisis solutions?
Knowledge Students will know...	**Skills** Students will be able to...
• • What happens when the panel is turned over away from the light? • What happens when part of the panel is shaded with your hand? How much of the panel can you shade before the motor stops? • Observe the rotation of the propeller blades, which way are they turning? What happens when the wires are attached the opposite way (red to black)? • Does the angle of the cell in relation to the sun	• Apply scientific principles to design, construct, and test a device that either minimizes or maximizes thermal energy transfer. • Evaluate competing design solutions for maintaining biodiversity and ecosystem services • Construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resourcesimpact Earth's systems.

make a difference in how fast the propeller turns? • What happens when the two alligator clips touch? ● Discuss variables that can affect the output of the photovoltaic cell such as: • time of day • weather conditions • time of year • location (latitude) on earth 16. Questions for further discussion: • How could you use a solar powered system for a flashlight which you want to use at night when the sun isn't shining where you are? Hint: You need a device to store the electricity. (A battery) • What could we do to produce more electricity on a cloudy day? (Use more cells in the system)	● Obtain, evaluate, and communicate information about the uses and conservation of various natural resources and how they impact the Earth. ● Obtain, evaluate, and communicate information to examine the interdependence of organisms with one another and their environments. ● Obtain, evaluate, and communicate information about the law of conservation of energy to develop arguments that energy can transform from one form to another within a system

Assessment Evidence (Stage 2)

Performance Task	Other Evidence (quizzes, tests, observations…..)
● Students will design, build, and test a solar tracking system that will power an aquaponics system which the students will also design, build, and test. ● Students will compose a paragraph/lab report with evidence justifying where they would utilize solar panels. The proficiency scale will include components for collaboration, data, and safety points.	● Students will complete a STEM Interest Inventory Post-Survey. ● Students will complete a Solar/Aquaponics Posttest.

STEM Criteria

Science	Technology
● Apply scientific ideas or principles to design, construct, and test a design of an object, tool, process or system. ● Energy is spontaneously transferred out of hotter regions or objects and into colder ones. ● A solution needs to be tested, and then modified on the basis of the test results in order to improve it. ● Biodiversity describes the variety of species found in Earth's terrestrial and oceanic ecosystems. The completeness or integrity of an ecosystem's biodiversity is often used as a measure of its health. ● Changes in biodiversity can influence humans' resources, such as food, energy, and medicines, as well as ecosystem services that humans rely on—for example, water purification and recycling.	● Typically as human populations and per-capita consumption of natural resources increase, so do the negative impacts on Earth unless the activities and technologies involved are engineered otherwise. ● The use of technologies and any limitations on their use are driven by individual or societal needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions. Thus technology use varies from region to region and over time.

Engineering	Mathematics
● Evaluate competing design solutions based on jointly developed and agreed-upon design criteria.	● Temperature is a measure of the average kinetic energy of particles of matter. The relationship between the temperature and the total energy of a system depends on the types, states, and amounts of matter present. ● There are systematic processes for evaluating solutions with respect to how well they meet criteria and constraints of a problem.

Complex System

- The transfer of energy can be tracked as energy flows through a designed or natural system.
- Small changes in one part of a system might cause large changes in another part.
- Cause and effect relationships may be used to predict phenomena in natural or designed systems.
- All human activity draws on natural resources and has both short and long-term consequences, positive as well as negative, for the health of people and the natural environment.

Learning Plan (Stage 3)

Detailed Lesson Plan:

Grade/ Grade Band: 6-8 STEAM
Topic: Aquaponics & Solar Tracking
Lesson Time Frame: 5-10 days min.
Brief Lesson Description: Students will explore the current design of an aquaponics system and its power needs and build a classroom model. The students will design a solar tracking system to power the aquaponics system.
Performance Expectation(s): Students will design, build, and test a solar tracking system that will power an aquaponics system which the students will also design, build, and test.
Specific Learning Outcomes: The student • understands that light energy from the sun can be turned into electricity with a photovoltaic (solar) cell. • knows variables such as clouds, shading and direction of panel tilt, that can affect the amount of power that the photovoltaic cell produces. • understands the factors that can increase the amperage output of their photovoltaic system including cell area, collection devices and intensifying devices. • will be able to explain the economic problems and solutions their team encountered in powering a specific load with their available monetary resources. • will understand that our current energy problems require cooperation and a new economic model.
Prior Student Knowledge:

Solar Energy for Kids article: https://www.renewableenergyworld.com/ugc/articles/2016/06/solar-energy-for-kids.html

Department of Energy photovoltaics for kids https://www.eia.gov/kids/energy.php?page=solar_home-basics

Solar Photovoltaic Technology Basics https://www.energy.gov/eere/solar/articles/solar-photovoltaic-technology-basics

Home Hydroponics KLUKO, D. (2017). Home Hydroponics. *Popular Mechanics*, 85. Retrieved from https://search.ebscohost.com/login.aspx?direct=true&db=tth&AN=120293252&site=ehost-live

Solar cells that store energy for several weeks article: https://www.forbes.com/sites/williampentland/2015/06/23/biomimicry-could-lead-to-solar-cells-that-store-energy-for-several-weeks-new-study-says/#de1e13e3e1d8

What is aquaponics and how does it work? https://aquaponics.com/aquaponics-information/

The Raynor Company (producers of hydroponics system in Fitzgerald, GA) https://www.theraynorcompany.com/team

Introduction to solar photovoltaics https://www.youtube.com/watch?v=2mCTSV2f36A&feature=youtu.beHow

Solar Works https://www.youtube.com/watch?v=dkO7ioNUXnw&feature=youtu.be

How does sunlight turn into electricity? https://www.youtube.com/watch?v=DFDn6eTV0jQ&feature=youtu.be

What is light made of?https://www.youtube.com/watch?v=AZ8WkY_9kro&feature=youtu.be

Possible Preconceptions/Misconceptions: Energy doesn't come from the Sun. Solar power can't be used in our area. A solar panel can use up all the Sun's energy. Solar panels can cause cancer.

Related Research 1. How are photovoltaics used in the space program? In telecommunications? Use the internet to collect data and pictures of these applications. Are the photovoltaic cells different or the same as those used in terrestrial applications? 2. How are photovoltaic cells made? Research the difference between single crystal, poly crystal and thin film cells. Which is the cheapest to produce? Which has the highest efficiency? 3. At the present time there are more photovoltaics in use on the continent of Africa than the North American continent. Why is this so? (Hint: It has nothing to do with climate, weather or latitude)
Points to cover could include: • What happens when the panel is turned over away from the light? • What happens when part of the panel is shaded with your hand? How much of the panel can you shade before the motor stops? • Observe the rotation of the propeller blades, which way are they turning? What happens when the wires are attached the opposite way (red to black)? • Does the angle of the cell in relation to the sun make a difference in how fast the propeller turns? • What happens when the two alligator clips touch?
Students will examine the data they have gathered during this study and come up with improvements and/or adaptations to improve their solar panel trackers.

Performance Expectations: Apply scientific principles to design, construct, and test a device that either minimizes or maximizes thermal energy transfer.* [Clarification Statement: Examples of devices could include an insulated box, a solar cooker, and a Styrofoam cup.] [*Assessment Boundary: Assessment does not include calculating the total amount of thermal energy transferred.*]

Constructing explanations and designing solutions in 6–8 builds on K–5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific ideas, principles, and theories.

Temperature is a measure of the average kinetic energy of particles of matter. The relationship between the temperature and the total energy of a system depends on the types, states, and amounts of matter present.

The transfer of energy can be tracked as energy flows through a designed or natural system.

While watching these video clips, students will realize how powerful solar energy can be. Some questions to consider: How does solar energy work? How can you store energy? What do you do if it's a cloudy day?

Students will use the Internet and google Earth to formulate a hypothesis about where on each of the continents would it be the most efficient to utilize solar panels. They will specifically focus on our home state of Georgia. Students will record their findings on a chart.

Background Information Photovoltaic cells (called PV or solar cells) are made of silicon (sand). The silicon is heated to extreme temperatures. It is doped (coated/mixed) with chemicals, usually boron and phosphorous. This sets up an unstable environment within the photovoltaic cell. When light strikes the cell, electrons are dislodged and travel along wires placed within the cell. The electrons follow the wire and power whatever load is attached, in this case a motor. This flow of electrons is called electricity. PV cells use sunlight to produce electricity. Photovoltaic systems are quiet, clean, and non-polluting.

MS-LS2-5.

Apply scientific ideas or principles to design, construct, and test a design of an object, tool, process or system.

PS3.B: Conservation of Energy and Energy Transfer

Evaluate competing design solutions for maintaining biodiversity and ecosystem services.* [Clarification Statement: Examples of ecosystem services could include water purification, nutrient recycling, and prevention of soil erosion. Examples of design solution constraints could include scientific, economic, and social considerations.]

Department of Energy photovoltaics for kids https://www.eia.gov/kids/energy.php?page=solar_home-basics

Energy is spontaneously transferred out of hotter regions or objects and into colder ones.

Stability and Change

Students will complete a STEM Interest Inventory Pre-Survey. See **Appendix D** for STEM Interest Survey.

load - a device to which power is delivered, such as a motor, a light, or a household appliance

MS-ESS3-4.

Engaging in Argument from Evidence

ETS1.A: Defining and Delimiting an Engineering Problem

Small changes in one part of a system might cause large changes in another part.

Students will complete a Solar/Aquaponics Pretest. See **Appendix E** for Pretest.

Construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resourcesimpact Earth's systems. [Clarification Statement: Examples of evidence include grade-appropriate databases on human populations and the rates of consumption of food and natural resources (such as freshwater, mineral, and energy). Examples of impacts can include changes to the appearance, composition, and structure of Earth's systems as well as the rates at which they change. The consequences of increases in human populations and consumption of natural resources are described by science, but science does not make the decisions for the actions society takes.]

Solar Photovoltaic Technology Basics https://www.energy.gov/eere/solar/articles/solar-photovoltaic-technology-basics
Engaging in argument from evidence in 6–8 builds on K–5 experiences and progresses to constructing a convincing argument that supports or refutes claims for either explanations or solutions about the natural and designed world(s).
The more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be successful. Specification of constraints includes consideration of scientific principles and other relevant knowledge that is likely to limit possible solutions. *(secondary)*

S6E6. Obtain, evaluate, and communicate information about the uses and conservation of various natural resources and how they impact the Earth. a. Ask questions to determine the differences between renewable/sustainable energy resources (examples: hydro, solar, wind, geothermal, tidal, biomass) and nonrenewable energy resources (examples: nuclear: uranium, fossil fuels: oil, coal, and natural gas), and how they are used in our everyday lives. b. Design and evaluate solutions for sustaining the quality and supply of natural resources such as water, soil, and air. c. Construct an argument
Evaluate competing design solutions based on jointly developed and agreed-upon design criteria.

ETS1.B: Developing Possible Solutions

Cause and Effect

S7L4. Obtain, evaluate, and communicate information to examine the interdependence of organisms with one another and their environments. d. Ask questions to gather and synthesize information from multiple sources to differentiate between Earth's major terrestrial biomes (i.e., tropical rain forest, savanna, temperate forest, desert, grassland, taiga, and tundra) and aquatic ecosystems (i.e., freshwater, estuaries, and marine). (Clarification statement: Emphasis is on the factors that influence patterns across biomes such as the climate, availability of food and water, and location.) *Law of conservation of matter – biogeochemical cycle*
Home Hydroponics KLUKO, D. (2017). Home Hydroponics. *Popular Mechanics*, 85. Retrieved from https://search.ebscohost.com/login.aspx?direct=true&db=tth&AN=120293252&site=ehost-live
A solution needs to be tested, and then modified on the basis of the test results in order to improve it. There are systematic processes for evaluating solutions with respect to how well they meet criteria and constraints of a problem. *(secondary)*
Cause and effect relationships may be used to predict phenomena in natural or designed systems.
S8P2. Obtain, evaluate, and communicate information about the law of conservation of energy to develop arguments that energy can transform from one form to another within a system. c. Construct an argument to support a claim about the type of energy transformations within a system [e.g., lighting a match (light to heat), turning on a light (electrical to light)]. d. Plan and carry out investigations on the effects of heat transfer on molecular motion as it relates to the collision of atoms (conduction), through space (radiation), or in currents in a liquid or a gas (convection).
Construct an oral and written argument supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem.

LESSON PLAN – 5-E Model
Students will view videos that demonstrate unique ways people have utilized solar power. (insert video links)
See **Appendix A** and **Appendix B** for Materials list
Review lab safety rules for students before beginning any lab work:
http://www.uft.org/chapters/lab-specialists/lab-safety-rules-for-students. See **Appendix C** for safety rules.
ENGAGE: Opening Activity – Access Prior Learning / Stimulate Interest / Generate Questions:
Students will view videos that demonstrate unique ways people have utilized solar power. (insert video links)
While watching these video clips, students will realize how powerful solar energy can be. Some questions to consider: How does solar energy work? How can you store energy? What do you do if it's a cloudy day?

Students may not understand that solar energy can be stored and used for power.
Students will complete a STEM Interest Inventory Pre-Survey. See **Appendix D** for STEM Interest Survey.
Students will complete a Solar/Aquaponics Pretest. See **Appendix E** for Pretest.

EXPLORE: Lesson Description – Materials Needed / Probing or Clarifying Questions:

- ☐ See **Appendix A** and **Appendix B** for Materials list
- ☐ Students will use the Internet and google Earth to formulate a hypothesis about where on each of the continents would it be the most efficient to utilize solar panels. They will specifically focus on our home state of Georgia. Students will record their findings on a chart.
- ☐ Some questions to consider: What do the different colors on the map legend represent? Can you place solar panels anywhere? If the amount of sunlight different at different times of the day/year? Where is the best location for a solar panel? Can this renewable energy be stored?

EXPLAIN: Concepts Explained and Vocabulary Defined:

- Review lab safety rules for students before beginning any lab work: http://www.uft.org/chapters/lab-specialists/lab-safety-rules-for-students. See **Appendix C** for safety rules.
- Background Information Photovoltaic cells (called PV or solar cells) are made of silicon (sand). The silicon is heated to extreme temperatures. It is doped (coated/mixed) with chemicals, usually boron and phosphorous. This sets up an unstable environment within the photovoltaic cell. When light strikes the cell, electrons are dislodged and travel along wires placed within the cell. The electrons follow the wire and power whatever load is attached, in this case a motor. This flow of electrons is called electricity. PV cells use sunlight to produce electricity. Photovoltaic systems are quiet, clean, and non-polluting.
- **Vocabulary:** Key Words & Definitions
- load - a device to which power is delivered, such as a motor, a light, or a household appliance
- orientation - set in a definite position with reference to the points of the compass
- photovoltaic (PV) - the effect of producing electric current using light 'photo': light 'voltaic': relating to electricity (volt)
- system- a group or combination of things or parts forming a complex or unified whole
- Solar panels - a panel designed to absorb rays from the sun and convert to electricity
- Solar energy - radiant energy from the sun
- Temperature sensors - a device that measures temperature through an electrical signal
- Renewable energy - energy from a source that is quickly replaced by natural processes
- dual-axis solar tracker - solar tracker device that follows the sun's energy across two axes
- automated position - position measurement that responds to infrared technology
- sensorless solar tracker - system which calculates the maximum power point for tracking sunlight

ELABORATE: Applications and Extensions:

Related Research 1. How are photovoltaics used in the space program? In telecommunications? Use the internet to collect data and pictures of these applications. Are the photovoltaic cells different or the same as those used in terrestrial applications? 2. How are photovoltaic cells

made? Research the difference between single crystal, poly crystal and thin film cells. Which is the cheapest to produce? Which has the highest efficiency? 3. At the present time there are more photovoltaics in use on the continent of Africa than the North American continent. Why is this so? (Hint: It has nothing to do with climate, weather or latitude)

EVALUATE:
Points to cover could include: • What happens when the panel is turned over away from the light? • What happens when part of the panel is shaded with your hand? How much of the panel can you shade before the motor stops? • Observe the rotation of the propeller blades, which way are they turning? What happens when the wires are attached the opposite way (red to black)? • Does the angle of the cell in relation to the sun make a difference in how fast the propeller turns? • What happens when the two alligator clips touch?

Discuss variables that can affect the output of the photovoltaic cell such as: • time of day • weather conditions • time of year • location (latitude) on earth 16. Questions for further discussion: • How could you use a solar powered system for a flashlight which you want to use at night when the sun isn't shining where you are? Hint: You need a device to store the electricity. (A battery) • What could we do to produce more electricity on a cloudy day? (Use more cells in the system)

Formative Monitoring (Questioning / Discussion): Students will compose a paragraph/lab report with evidence justifying where they would utilize solar panels.

Summative Assessment (Quiz / Project / Report):
Students will complete a STEM Interest Inventory Post-Survey. See **Appendix D** for STEM Interest Survey.
Students will complete a Solar/Aquaponics Posttest. See **Appendix E** for Posttest.
Students will compose a paragraph/lab report with evidence justifying where they would utilize solar panels. The proficiency scale will include components for collaboration, data, and safety points. See **Appendix F** for Proficiency scale.

Elaborate Further / Reflect: Enrichment:
Students will examine the data they have gathered during this study and come up with improvements and/or adaptations to improve their solar panel trackers.

Resources:

Next Generation Science Standards Solar Energy. Retrieved on July 3, 2018 from https://www.nextgenscience.org/search-standards?keys=solar+energy&tid%5B%5D=106.

Georgia Standards of Excellence – Science grades 6-8. Retrieved on July 3, 2018 from https://www.georgiastandards.org/Georgia-Standards/Pages/Science.aspx .

Lab Safety Rules for students from United Federation of Teachers. Retrieved on July 8, 2018 from http://www.uft.org/chapters/lab-specialists/lab-safety-rules-for-students.

A Sensorless MPPT-based Solar Tracking Control Approach for Mobile Autonomous Systems. Retrieved on July 7, 2019 from https://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=7793551.

The Raynor Company. Retrieved on July 2, 2019 from https://www.theraynorcompany.com/team.

What is aquaponics and how does it work? Retrieved on July 2, 2019 from https://aquaponics.com/aquaponics-information/.

Home Hydroponics KLUKO, D. (2017). Home Hydroponics. *Popular Mechanics*, 85. Retrieved from https://search.ebscohost.com/login.aspx?direct=true&db=tth&AN=120293252&site=ehost-live

Resources:

Next Generation Science Standards Solar Energy. Retrieved on July 3, 2018 from https://www.nextgenscience.org/search-standards?keys=solar+energy&tid%5B%5D=106.

Georgia Standards of Excellence – Science grades 6-8. Retrieved on July 3, 2018 from https://www.georgiastandards.org/Georgia-Standards/Pages/Science.aspx .

Lab Safety Rules for students from United Federation of Teachers. Retrieved on July 8, 2018 from http://www.uft.org/chapters/lab-specialists/lab-safety-rules-for-students.

A Sensorless MPPT-based Solar Tracking Control Approach for Mobile Autonomous Systems. Retrieved on July 7, 2019 from https://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=7793551.

The Raynor Company. Retrieved on July 2, 2019 from https://www.theraynorcompany.com/team.

What is aquaponics and how does it work? Retrieved on July 2, 2019 from https://aquaponics.com/aquaponics-information/.

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Appendix A

Item	Quantity	Cost per item	Total cost	ASIN
20 plus gallon sturdy plastic bin with lid (dark color or keep covered) 23 x 16.25 x 12.38	4	**$9.98**	**$39.92**	Lowe's
Concrete mixing tray 26'x20"x6"	4	**$7.00**	**$28.00**	B001AQ0CDI
Ebb-and-flow kit	4	**$6.95**	**$27.80**	B00P218CAM
Oil-free pond pump (150-400 GPH)	4	**$21.99**	**$87.96**	B07FVPLD99

2 feet ½ " black vinyl tubing	1 (20 feet)	**$8.97**	**$8.97**	B004DL0Y9O
1 ¼ " spade bit or holesaw	1			
Ph/EC meter	1	**$16.99**	**$16.99**	B07NM669CF
Programmable electrical power strip - 125V	1 (8 outlets)	$20.99	 $20.99	B00U0MJLLW
LED grow light	1 (4 pack)	$20.99	 $20.99	B01L74WDPW
Grow light strips LED (4pc)-28W Purchase OPTION	2	**$29.74**	**$59.48**	B07JN2KD32
Plant nutrient-16oz organic	4	$9.49	$37.96	B00XV19RKO
Arugula seeds –organic pack	4	$2.79	$11.16	B000VDDNKU
Rock-wool starters with cubes -30	1	$8.29	$8.29	B07RW6YMX9
Initial Total Expense for four hydroponic systems			$326.53	
Cost to replenish items each year			$57.41	
Cost of Reusable items (Items in bold are reusable)			**$269.12**	

Appendix B

Order Items	Description	Specs	Quantity	ASIN
Solar Charge Controller	Load, battery, solar	3A	1	B072MMDY4F
Arduino Uno	open-source microcontroller board	based on the Microchip ATmega328P	1	B008GRTSV6
Servo motor with servo arms	With 3 ribbon wires and female port	Metal Gear 2843 (A046100)	2	B07C5PGD3Q
Screws	Round slotted solid brass	#2 x 3/8"	12	B07D1R8TM1

Ribbon & patch wires	5 wires ribboned 5 individual 5cm - 20cm	1 male port and 1 female port 2 male ports	1	B078ZWZYYX
Protoboard	construction base for prototyping of electronics	6 cm x 4 cm	1	B01N78ETXO
Protoboard	construction base for prototyping of electronics	2 cm x 1.5 cm	1	B07FK3GFHS
Male pin header connector	strip that can be cut or broken into smaller strips (break away)	straight male header	15	B076DTWB92
Resistors	1/4 Watt, +/- 5% tolerance PTH resistors	10K Ohm (brown, black, orange)	4	B01GQFVSXK
9V Battery connector	Battery Strap; Snap-On	Vinyl; 4 Leads; 26 AWG; Red/ Black; 1 Cell; 9 Volt	1	B0779ZSNS3
Photo light sensitive resistor	Resin sealed; Max Voltage: 150 Volt DC ; Max Wattage: 100mW	Light Resistance (10 Lux): 50-100 Kohm; MΩ:5		B01JAGW8PO
Solar Panel 18V	Polysilicon solar panel for outdoor use; black	11.1 x 5.6 x 0.7 “ Polycrystalline silicon	1	B01FUQF7P6

Wood cut pieces	**Description**	**Specs**	**Quantity**
base	Mounting piece for solar tracker	22cm x 24 cm x 3.5cm(thick)	1
Wall unit	Mounting piece for solar charge controller	8cm x 10.5cm x 3.5cm (thick)	1
Mounting legs	Mounting legs for 3D printed base of solar tracker	15cm x 1.5 cm x 3.5cm (thick)	2

3D printed pieces	**Description**	**Specs**	**Quantity**
Base Gear and Panel Mount.stl	Included in online file	Included in online file	1
Base Gear Shaft.stl	Included in online file	Included in online file	1
Horiz Servo Gear.stl	Included in online file	Included in online file	1

LDR Divider.stl	Included in online file	Included in online file	1
Panel Bracket.stl	Included in online file	Included in online file	1
Tracker Base.stl	Included in online file	Included in online file	1
Vertical Servo Gear.stl	Included in online file	Included in online file	1
Online access to stl files available at: https://www.thingiverse.com/thing:53321			

Appendix C

United Federation of Teachers
A Union of Professionals

From UFT.org (http://www.uft.org)

Lab safety rules for students

- Report all accidents, injuries, and breakage of glass or equipment to instructor immediately.
- Keep pathways clear by placing extra items (books, bags, etc.) on the shelves or under the work tables. If under the tables, make sure that these items can not be stepped on.
- Long hair (chin-length or longer) must be tied back to avoid catching fire.
- Wear sensible clothing including footwear. Loose clothing should be secured so they do not get caught in a flame or chemicals.
- Work quietly — know what you are doing by **reading** the assigned experiment **before** you start to work. Pay close attention to any **cautions** described in the laboratory exercises
- Do not taste or smell chemicals.
- Wear **safety goggles** to protect your eyes when heating substances, dissecting, etc.
- Do not attempt to change the position of glass tubing in a stopper.
- **Never** point a test tube being heated at another student or yourself. Never look into a test tube while you are heating it.
- Unauthorized experiments or procedures **must not** be attempted.
- Keep solids out of the sink.
- Leave your work station clean and in good order before leaving the laboratory.
- Do not lean, hang over or sit on the laboratory tables.
- Do not leave your assigned laboratory station without permission of the teacher.
- Learn the location of the fire extinguisher, eye wash station, first aid kit and safety shower.
- Fooling around or "horse play" in the laboratory is absolutely forbidden. Students found in violation of this safety rule will be barred from participating in future labs and could result in suspension.
- Anyone wearing acrylic nails will not be allowed to work with matches, lighted splints, bunsen burners, etc.
- Do not lift any solutions, glassware or other types of apparatus above eye level.
- Follow all instructions given by your teacher.
- Learn how to transport all materials and equipment safely.
- **No eating or drinking in the lab at any time!**

Source URL: http://www.uft.org/chapters/lab-specialists/lab-safety-rules-for-students

Appendix D

National Science Foundation Grant

STEM PRE-POST Survey

Name _____ Date _____ Grade _____

Please read each question carefully and select the answer that BEST reflects your opinion.

Question Number	Question	Strongly Agree	Agree	No Opinion	Disagree	Strongly Agree
1.	I enjoy learning about science, technology, engineering, and math (STEM).					
2.	Learning STEM is important for my future success.					
3.	We do a lot of interesting activities in science class.					
4.	I will study STEM if I go to college after high school.					
5.	I am sure I can do well on science tests.					
6.	I usually give up when I do not understand a STEM concept.					
7.	Science is one of the most interesting school subjects.					
8.	Science is easy for me.					
9.	I will NOT pursue a STEM-related career in the future.					
10.	I like to watch TV and online programs about STEM.					
11.	I cannot understand STEM even if I do my very best.					
12.	STEM is useful in solving everyday life problems.					
13.	I am motivated to pursue a career in STEM.					
14.	I really enjoy STEM lessons.					
15.	I will continue studying STEM after I leave high school.					
16.	I am confident that I can be successful in STEM.					
17.	We live in a better world because of STEM.					

18.	I would enjoy working in a STEM-related career.					
19.	Knowing STEM can help me make better choices about my health.					
20.	I will take additional STEM classes in the future.					

Table 1 Items measuring students' interest in STEM

1.	I enjoy learning about science, technology, engineering, and math (STEM).
3.	We do a lot of interesting activities in science class.
7.	Science is one of the most interesting school subjects.
10.	I like to watch TV and online programs about STEM.
14.	I really enjoy STEM lessons.

Table 2 Items measuring students' perceptions about STEM.

2.	Learning STEM is important for my future success
4.	I will study STEM if I go to college after high school.
9.	I will NOT pursue a STEM-related career in the future.
15.	I will continue studying STEM after I leave high school.
18.	I would enjoy working in a STEM-related career.

Table 3 Items measuring students' STEM self-efficacy

5.	I am sure I can do well on science tests.
6.	I usually give up when I do not understand a STEM concept.
8.	Science is easy for me.
11.	I cannot understand STEM even if I do my very best.
16.	I am confident that I can be successful in STEM.

Table 4 Items measuring students' desire continue applying STEM to their lives

12.	STEM is useful in solving everyday life problems.
13.	I am motivated to pursue a career in STEM.
17.	We live in a better world because of STEM.
19.	Knowing STEM can help me make better choices about my health.
20.	I will take additional STEM classes in the future.

Adapted from Brown, P. L., Concannon, J. P., Marx, D., Donaldson, C. W., & Black, A. (2016). An Examination of Middle School Students' STEM Self-Efficacy with Relation to Interest and Perceptions of STEM. *Journal of STEM Education: Innovations and Research*, *17*(3), 27–38. Retrieved from https://search.ebscohost.com/login.aspx?direct=true&db=eric&AN=EJ1115641&site=eds-live&scope=site.

Appendix E

National Science Foundation Grant

Solar/Aquaponics PRE-Test

Name _____ Date _____ Grade _____

1. **Solar (or PV) cells are made of many individual cells stacked together, and these are made of materials called _____.**
   a. diodes
   b. electrometals
   c. semiconductors
   d. I don't know

2. **In order to create higher current, solar cells are connected in _____.**
   a. inverters
   b. series
   c. parallel
   d. I don't know

3. **In order to increase voltage, several solar cells are connected in _____.**
   a. I don't know
   b. wires
   c. parallel
   d. Series

4. **The electricity generated from a solar panel is fed into the electricity grid using _____.**

a. I don't know
b. inverters
c. semiconductors
d. Panels

5. **What is the photovoltaic effect?**

a. Process of creating photons from voltage
b. Process of converting kinetic energy into electricity
c. I don't know
d. Process of converting sunlight into electricity

6. **What is the unit for power?**

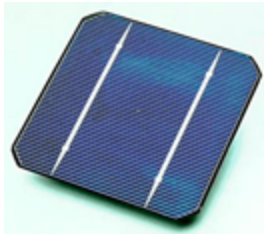
a. amps
b. watts
c. I don't know
d. Newtons

7. **The electromagnetic spectrum describes the entire range of light radiation from _____ to _____.**

a. I don't know
b. x-rays, radio waves
c. gamma rays, radio waves
d. gamma rays, microwaves

8. **Which device converts direct current (DC) from a PV system to alternating current (AC) used by appliances in a house?**

a. inverter
b. I don't know
c. alternator
d. Battery

9.  **What is another name for a solar panel?**

a. photon
b. I don't know
c. photovoltaic panel
d. photon panel

10.  **Tiny packets of energy that come from the sun are called:**

a. rays
b. photons
c. I don't know
d. Electrons

11. The sun is best suited for solar use in what part of the United States?

a. I don't know
b. north
c. northeast
d. Southwest

12.  **A solar panel is made up of what type of material?**

a. I don't know

b. plastic
c. gold
d. silicon

13. Electricity is the movement of:

a. atoms
b. I don't know
c. electrons
d. Protons

14. Is solar energy a renewable or a non-renewable source of power?

a. Renewable
b. Non-renewable
c. Half/Half of both
d. I don't know

15. Why is solar energy considered a renewable energy source?

a. You can get money back from the government if you put solar panels on your house
b. I don't know
c. The sun's energy will not run out for billions of years
d. Solar energy can be used to recharge batteries

16. Aquaponics is the combination of _____ and _____.

a. plants and water
b. I don't know
c. hydroponics and aquaculture
d. hydroponics and plants

17. How does aquaponics help the environment?

a. Less water is needed.
b. Food can be grown locally and not shipped in from far away.
c. I don't know
d. Choice "a" and "b"

18. The nitrogen cycle has three living organisms:

a. fish, plants, and people
b. I don't know

c. fish, bugs, and algae
d. fish, plants, and bacteria

19. Hydroponics is producing....

a. plants without soil.
b. plants in soil.
c. plants & aquatic animals together.
d. I don't know

20. The acidity of water is known as _____?

a. water hardness
b. pH
c. I don't know
d. chlorine level

21. During photosynthesis, a plant takes in carbon dioxide, and releases oxygen through the _____.

a. chlorophyll
b. leaf
c. I don't know
d. Stomata

22. The process by which organic substances are broken down into a simpler organic matter is called _____.

a. I don't know
b. photosynthesis
c. decomposition
d. Aquaponics

23. The quality of not being harmful to the environment or depleting natural resources, and thereby supporting long-term ecological balance is called _____,

a. sustainability
b. I don't know
c. unsustainable
d. Pollution

24. A system where living things depend on one another and their environment to grow is called a(n) _____.

a. Home
b. I don't know

c. Ecosystem
d. Community

.....

National Science Foundation Grant

Solar/Aquaponics POST-Test

Name _____ Date _____ Grade _____

1. **Solar (or PV) cells are made of many individual cells stacked together, and these are made of materials called _____.**
   a. diodes
   b. electrometals
   c. semiconductors
   d. Solarductors

2. **In order to create higher current, solar cells are connected in _____.**
   a. inverters
   b. series
   c. parallel
   d. Wires

3. **In order to increase voltage, several solar cells are connected in _____.**
   a. inverters
   b. wires
   c. parallel
   d. Series

4. **The electricity generated from a solar panel is fed into the electricity grid using _____.**
   a. wires
   b. inverters
   c. semiconductors
   d. Panels

5. **What is the photovoltaic effect?**
   a. Process of creating photons from voltage
   b. Process of converting kinetic energy into electricity
   c. Process of creating light from electricity

d. Process of converting sunlight into electricity

6. What is the unit for power?

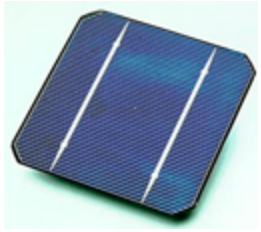
a. amps
b. watts
c. joules
d. Newtons

7. The electromagnetic spectrum describe the entire range of light radiation from _____ to _____.

a. ultraviolet, infrared
b. x-rays, radio waves
c. gamma rays, radio waves
d. gamma rays, microwaves

8. Which device converts direct current (DC) from a PV system to alternating current (AC) used by appliances in a house?

a. inverter
b. diode
c. alternator
d. Battery

9.  **What is another name for a solar panel?**

a. photon
b. heliostat
c. photovoltaic panel
d. photon panel

10.  **Tiny packets of energy that come from the sun are called:**
    a. rays
    b. photons
    c. protons
    d. Electrons

11. The sun is best suited for solar use in what part of the United States?
    a. It is the same throughout
    b. north
    c. northeast
    d. Southwest

12.  **A solar panel is made up of what type of material?**
    a. copper
    b. plastic
    c. gold
    d. Silicon

13. Electricity is the movement of:
    a. atoms
    b. photons
    c. electrons
    d. Protons

14. Is solar energy a renewable or a non-renewable source of power?
    a. Renewable
    b. Non-renewable
    c. Half/Half of both

d. Neither

15. Why is solar energy considered a renewable energy source?

a. You can get money back from the government if you put solar panels on your house
b. Solar energy is cheaper than fossil fuels
c. The sun's energy will not run out for billions of years
d. Solar energy can be used to recharge batteries

16. Aquaponics is the combination of _____ and _____.

a. plants and water
b. aquaculture and water
c. hydroponics and aquaculture
d. hydroponics and plants

17. How does aquaponics help the environment?

a. Less water is needed.
b. Food can be grown locally and not shipped in from far away.
c. Chemical fertilizers do not need to be sprayed on plants for nutrients.
d. All of the above

18. The nitrogen cycle has three living organisms:

a. fish, plants, and people
b. plants, bacteria, and algae
c. fish, bugs, and algae
d. fish, plants, and bacteria

19. Hydroponics is producing....

a. plants without soil.
b. plants in soil.
c. plants & aquatic animals together.

d. None of these

20. The acidity of water is known as?

a. water hardness
b. pH
c. nitrate
d. chlorine level

21. During photosynthesis, a plant takes in carbon dioxide, and releases oxygen through the _____.

a. chlorophyll
b. leaf
c. lungs
d. Stomata

22. The process by which organic substances are broken down into a simpler organic matter is called _____.

a. rock cycle
b. photosynthesis
c. decomposition
d. Aquaponics

23. The quality of not being harmful to the environment or depleting natural resources, and thereby supporting long-term ecological balance is called _____,

a. sustainability
b. climate change
c. unsustainable
d. Pollution

24. A system where living things depend on one another and their environment to grow is called a(n) _____.

a. Home
b. School
c. Ecosystem
d. Community

Appendix F

NSF – RET Energy Proficiency Scale on Hydroponics and Solar Tracking		Grades 6-8
Score 100	**In addition to score 90 performance, the student demonstrates in-depth inferences and applications that go beyond what was taught.**	
	Score 95	*In addition to score 90 performance, partial success at score 100 content*
Score 90	The student will: • Work collaboratively in a group to design, build, and collect data. • Create a lab report to examine their data and demonstrate their understanding of the safety points. • Apply scientific ideas or principles to design, construct, and test a design of an object, tool, process or system. • Apply scientific principles to design, construct, and test a device that either minimizes or maximizes solar energy. • Evaluate competing design solutions for maintaining biodiversity and hydroponic ecosystems. • Construct an argument supported by evidence for how increases in human population and consumption of natural resources impact Earth's systems	
	Score 85	*No major errors or omissions regarding score 80 content, and partial success at score 90 content*
Score 80	**(6th) Obtain, evaluate, and communicate information about the uses renewable energies and how they impact the Earth**—The student will: • Ask questions to determine the differences between renewable/sustainable energy resources (examples: hydro, solar, wind, geothermal, tidal, biomass) and nonrenewable energy resources (examples: nuclear: uranium, fossil fuels: oil, coal, and natural gas), and how they are used in our everyday lives. • Design and evaluate solutions for sustaining the quality and supply of natural resources such as water, soil, and air. • Construct an argument **(7th) Obtain, evaluate, and communicate information to examine the interdependence of plants with one another and their environments**—The student will: • Ask questions to gather and synthesize information from multiple sources to differentiate between Earth's major terrestrial biomes (i.e., tropical rain forest, savanna, temperate forest, desert, grassland, taiga, and tundra) and aquatic ecosystems (i.e., freshwater, estuaries, and marine • Emphasis the factors that influence patterns across biomes such as the climate, availability of food and water, and location **(8th) Obtain, evaluate, and communicate information about the law of conservation of energy to develop arguments that energy can transform from one form to another within a system**.—The student will: • Construct an argument to support a claim about the type of energy transformations within a system [e.g., lighting a match (light to heat), turning on a light (electrical to light) • Plan and carry out investigations on the effects of heat transfer on molecular motion as it relates to the collision of atoms (conduction), through space (radiation), or in currents in a liquid or a gas (convection).	
	Score 75	*Partial success at score 70 content, and major errors or omissions regarding score 80 content*
Score 70	**With help, partial success at score 70 content and score 80 content**	
	Score 65	*With help, partial success at score 70 content but not at score 80 content*
Score 60	**Even with help, no success**	

Adapted from Proficiency scales for New Science Standard by Marazano. Retrieved on July 8, 2019 from https://www.marzanoresources.com/proficiency-scales-new-science-standards-workshop.