Internet of Things (IoT) at UCF

UNIVERSITY OF CENTRAL FLORIDA

UCF RET Site: Collaborative Multidisciplinary Engineering Design Experiences for Teachers

UCF RET Program

YOUR NAME

Course Number and Name

[Date]

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- Remember to do your 3R reflection include an updated copy of your lesson plan, developed assessment tools, presentation materials, to the evaluator. See implementation plan instructions developed by the evaluator. Send within a week after completing the lesson to bonnie.swan@ucf.edu

RET Site: The Power of "Why?": Using Engineering to Demonstrate and Clarify Knowledge of Energy, Thermodynamics, and Electromagnetic Wave Concepts by Constructing a Rube Goldberg Machine

Lesson/ Energy Unit Plan

Subject Area(s): Science
Course(s): Comprehensive Regular and Advanced
Grade Level: 7th
Suggested Length of Lesson: Multiple Days over several units of curriculum

Lesson Summary: Students need to be offered the opportunities to question the reasons for why different situations occur. Higher order thinking is necessary to be preplanned by the teacher with the expectation that the teacher must be flexible in case the lesson and/or discussion takes longer or goes into a different direction than expected. During the 9 weeks of material, small scale engineering design projects will be conducted to practice the procedures of engineering design. Introductory Coding is also expected within the 7th grade curriculum and will have begun prior to this lesson.

Prerequisite Knowledge: Kinetic and Potential Energy, Basic Knowledge of Forces, Basic Concepts of Circuits, Scratch or equivalent Coding software, Classroom Procedures Well Established for Labs, Group Projects, and Group Communication, beneficial prior experience with Engineering Design Process

Materials/Technology Needed

- **Laptop/iPad/Chromebook with WiFi**
- **A collection of recycled materials to use for construction such as cardboard, soda bottles, craft sticks & paper towel tubes**
- **Tape/Glue/Scissors/String/Paper**
- **Marbles/Spherical Object to represent Radiopharmaceutical in protective case**
- **Piezo sensors and/or buzzers**
- **Peltier Thermoelectric Cooler (optional as a demonstration during the Energy Unit)**
- **Robotic device that moves by Coding (optional if Coding practice had occurred prior to this lesson)**

Lesson Objective(s)/Learning Goal(s) (2-4)	**Standard(s)/Benchmark(s) Addressed (2-4)**
▪ To demonstrate an understanding of Energy transformations to effectively design a Rube Goldberg machine ▪ To demonstrate how adding or removing heat will increase or decrease energy and effectively design that component in the Rube Goldberg machine ▪ To demonstrate how EM waves illustrate amount of energy and effectively design that component in the Rube Goldberg machine	- SC.7.P.11.2 - Investigate and describe the transformation of energy from one form to another. - SC.7.P.11.3 - Cite evidence to explain that energy cannot be created nor destroyed, only changed from one form to another. - SC.7.P.11.1 - Recognize that adding heat to or removing heat from a system should result in a temperature change and possibly a change of state - SC.7.P.10.2 - Observe and explain that light can be reflected, refracted and or absorbed. -SC.7.P.10.1- Illustrate that the sun's energy arrives as radiation with a wide range of wavelengths, including infrared, visible, and ultraviolet, and that white light is made up of a spectrum of many different colors.

Standards for Mathematical Practice
Not Required within the scope of this Project

Evidence of Learning (Assessment Plan)

- **A Pre and Post-test will be given and compared. (Not included)**

Recommended Assessment(s) and Steps
-The Rube Goldberg machine development (group) and Individual Reflection Assignment are summative assessments
-The Post-test will be a Formative.

Instructional Strategies

- Cooperative Learning
- Inquiry-Based Learning
- Effective Questioning
- Generating and Testing Hypotheses
- Graphic Organizers
- Project-Based Learning
- Graphic Organizers

Description of Lesson Activity/Experiences
Students will design, create, evaluate and modify a Rube Goldberg machine.

Prior to Day 1

-Students will have practiced with piezoelectric buzzers & sensors, with coding a robot, with The Golden Circle Method, and with the Energy, Thermodynamics, and Waves Units.
-Students must follow practiced Expectations & Procedures for Group Projects.
-Pre-Assessment will have already been completed.

Day 1

-Project is Introduced with Expectations
-The Scenario is discussed as a class
-Students will complete the graphic organizer
-Research will be divided equally as a group

Day 2

-Students will complete the Research and share brainstorming and drawing an idea will be completed individually
-Group members will discuss the parts of each design that should be on the group design
-An agreed on design will be completed along with a list of needed supplies
- Supplies will be collected and prepared

Day 3

-The building responsibilities will be divided and the group begins to build
-Testing while building is recommended

Day 4

-Group members will complete the build
-Testing & Analyzing will occur if time permits

Day 5

-Groups will do a short walk through of all the other projects and offer constructive feedback
-Groups will complete Testing & Analyzing
-Groups will discuss the Testing results and an feedback offered
-The group members will agree on modifications and draw or list the changes needed

Day 6

- Groups will make modifications and Test & Analyze
-Decide how the group will present and what will be explained
-Project should be finished by the end of class!

Day 7

- Set up machine for Presentations
- Each Group will Present their machine and explain their thoughts on their design
- Class members are to be supportive of other groups

After the Completed Project

Each student will complete an Individual Reflection Assignment with a list of choices
Option 1: Video the machine in process and add your voice explaining the science concepts
Option 2: Write an Essay describing the Science behind the Machine
Option 3: Draw a Rube Goldberg machine and write detailed information of the science

The Post-test is the Formative Assessment & the Project and Assignment is the Summative.

Engineering Connection (60-100 words/3 sentences)

This overarching project should effectively assess effective application of energy transformations, heat transfers, and wave concepts used on the designed Rube Goldberg machine. The Individual Reflection Assignment will assess effective characterizations (with explanation) of each energy transition, heat transfer, and wave concept used within the machine. Lastly, the machine will be evaluated for effective design and construction as a cooperative group.

Engineering Category (choose one)

x	relating science and/or math concepts to engineering (primarily science & math with some engineering)
	engineering analysis or partial design (primarily engineering with some science/math)
	engineering design process (full engineering design)

Key Words			
	chemical energy **electrical energy** **energy** **electromagnetic energy** **kinetic energy** **Law Conservation of Energy** **mechanical energy** **potential energy** **radiant energy** **sound energy** **thermal energy** **transformation**	**conduction** **conductor** **convection** **heat** **insulator** **Kinetic Theory of Matter** **radiation** **states of matter** **temperature** **thermal energy**	**absorption** **amplitude** **crest** **frequency** **medium** **period** **reflection** **refraction** **scattering** **translucent** **transparent** **transverse wave** **trough** **vacuum** **wavelength**

Introduction/Motivation (written as if talking to students)

Today each group will be presented a problem and need to design and build a working solution. In your Engineering Design Packet, you were given a scenario of a young girl with cancer named Jenny that is wanting to rest at home instead of in the hospital. The family has been able to set up all necessary supports, but there is one concern. The family lives near a body of water that overflows its banks when it rains more than 1 inch within a day. When the water overflows, the home is inaccessible except when for a ferry that is a walk of 2 or more miles through challenging terrain. They have a boat that can be used in emergencies, but otherwise it is not practical. Even though this situation, does not occur often it is an issue that the family wants to have a plan in place just in case. Jenny receives chemotherapy pills throughout the week. These pills are a radiopharmaceutical that is only effective for a short period of time. A radiopharmaceutical is a medicine that is radioactive which means it gives off a small amount of radiation. In case the water overflows, there is not a way to get the medicine to Jenny within the timeframe required.

The project is to design a Rube Goldberg machine to transport the medicine in its protective container from where the water starts to where the water end near the home. Jenny's mom explained that Jenny has always been fascinated by Rube Goldberg machines and that is why she is requesting it so that Jenny can watch it from her window.

Each group has been tasked with designing and building a 3 foot section of the overall machine. There are certain constraints that have been listed in your packet.

Remember we have discussed how energy is conserved but can transform from one form to another form. Remember the concept of thermodynamics and how heat is transferred from the object with the higher temperature to the object with the lower temperature. Lastly, you studied how the Electromagnetic Spectrum transfers energy through waves. All of this topics and the knowledge you have will help you with your design.

Lesson Closure (written as if talking to students)

Based on your engineering experience along with the Individual Reflection Assignment, you can now see how Energy causes or is affected by other topics within science. This will not be the last time that we will explore energy along with other topics and find that they are interrelated. All matter has energy. Living organisms seek out or produce energy to survive. Within the earth there is energy including in the rocks, dirt and water bodies. Atoms storage and/or release energy when a chemical reaction occurs. Everything you learned in these units will be practiced again from a different perspective.

Background

Lesson plan designs oftentimes focus on *what* topics are to be taught and *how* it will be accomplished. This uninspiring methodology generally leads to focusing on a check off list of topics taught in isolation and without real world connections. In turn students mature out of the willingness to follow an adult's instructions and into thinking individuals capable of determining that this lack of inspiration is not worth their time or effort. Ultimately this methodology leads to the majority of students becoming "passive students, who wait like empty vessels to be filled"

with knowledge. (Jennings, Surgenor, & McMahon, 2013) As has been well documented through research, students that are activity participating with constructing their own new knowledge are more successful. For instance research conducted in 2006 found that when classes were divided into lecture-only and cooperative learning only, then:

> "[s]tudents in the cooperative learning classes not only performed at a level above their peers in standardized testing of content knowledge and in critical thinking and problem-solving tasks ($p < 0.05$), but they also were more positive about their learning experience." (Anderson, Mitchell, Osgood, 2005)

Clearly the goal of our education system is to produce high performing students, but unfortunately there is not one method that has been discovered through convincing experimental data to be implemented in all classrooms throughout the country. Even the research and comparisons of multiple types of educational methodologies have conflicting experimental results. One study compared experimental data from 29 papers with both randomized and non-randomized groups of primarily medical students to determine the effectiveness of Problem-Based Student Centered Learning on achievement.(Matthews, 2003) It was determined that "[t]he randomized studies show no effect of [Problem Based Learning], maybe even a negative effect, on performances on the NBME licensure examinations." (Matthews, 2003) But, the same study did conclude the following:

> "The [Problem Based Learning] students received significantly higher ratings from house staff and faculty on four clinical rating scales: amount of factual knowledge (means: 3.11 versus 2.90; d = +.50; p = .0001); take history and perform physical (3.22 versus 3.05; d

= +.42; *p* = .002); derive differential diagnosis (3.04 versus 2.86; d = +.46; *p* = .005); and organize and express information (3.49 versus 3.33; d = +.39; *p* = .004)." (Matthews, 2003)

Based on this data of medical students, which achievement measurement is more valuable to consider? It can be argued that educating future doctors makes the clinical rating scores a more valuable indicator of future success in the career in which the education is preparing the student. Therefore, how achievement data predicts the future success of the student for which the education is training that student should be valued more than the achievement data of a random survey of factoids and basic applications of material taught within a course. Data focusing on the human behavior and implementation of the knowledge is imperative when accessing successful educational methodologies.

To become an effective and well-informed educator that makes lesson decisions that are the most effective in educating towards the future of each student within the class, it is necessary to determine the goals in which the educator is working towards. These goals should not solely include state and/or achievement test scores, but also what other skills and abilities should each student develop while participating within the class. When determining those life and educational goals for a lesson, unit, semester, and when the overall year, it is necessary to have a structure in which to determine which goals should be included. Much like as in the educational

sector, businesses struggle to determine what goals to strive towards, what actions are necessary to increase the business' likelihood of success, and how those goals are to be implemented. Simon Sinek, an author and motivational speaker, gave a TED talk in 2009 in which he describe the concept of "The Golden Circle" (*Figure 1*). (Nelson Holmes, 2012) He explained that most businesses focus solely on the "what" and "how" of their products and business goals, and oftentimes struggle as a company to succeed. On the other hand, the companies that identify the "why" of their company and products are much more likely be succeed. The "why" includes "why does your organization exist?" That does not include "to make a profit… that is the result."

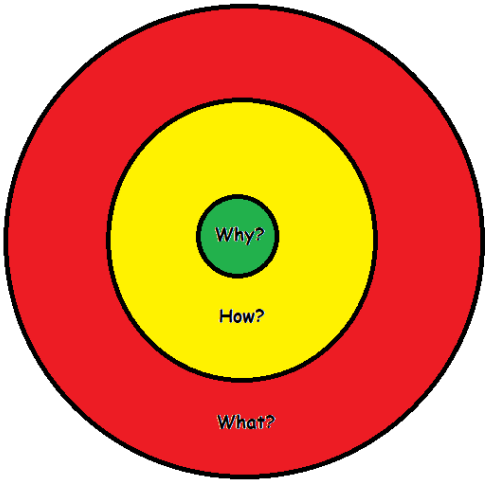

Figure 1: The Golden Circle described by Simon Sinek.

After the why is completely determined the "how" and "what" determinations can be made. The reason the companies that define the "why" first are more successful is because it is rooted in the human psychology of wanting "to do business with people who believe what you believe." There are similarities between the educational system and a large business; for that reason the concept of "The Golden Circle" can be applied to education as well.

When executing The Golden Circle concept for seventh grade Science classes, a list of questions was created to better determine the "why" for the overall school year, projects, units and motivations as the teacher. These are a few questions: "Why do students need to be educated?", "How can education impact the future success of the student as an individual in the

society?", and "What are the instructional, behavioral, and social concepts that must be taught for each student to be a *productive* member of society?" After much reflection and analysis, it was determined that this course will focus on a Constructivism methodology as the primary framework with various other educational methodologies used as determined for individual lessons. Constructivism is the "theory that equates learning with creating meaning from experiences." (Ertmer & Newby, 2008) To accomplish this methodology, Engineering Design Processes will be practiced throughout the school year so that the students will construct meaningful projects related to the topics.

The Overarching Unit Lesson that will be described focuses on the concepts of Energy, Thermodynamics, and the Electromagnetic Spectrum wave concepts. An introduction to coding will have also occurred during this Unit, but prior to the lesson presented. As discussed in the article, "Assessing Learning Progression of Energy Concepts Across Middle School Grades: The Knowledge Integration Perspective," energy is a difficult concept for students to effectively demonstrate their understanding. (Lee & Liu, 2010) The authors ultimately concluded that "pursuing single correct ideas for each science problem may play a detrimental role in promoting understanding of highly integrated concepts such as energy conservation." (Lee & Liu, 2010) Based on this conclusion, it is important that the unit is integrated as a whole and addresses how each concept effects another concept.

Projects also offer an opportunity to introduce students to a real world application. The article "Incorporating Nanoscale Science and Engineering Concepts into Middle and High School Curricula" states the following:

> "Research has suggested that students are more motivated to learn and their achievement levels increase when teachers use practices and topics that stimulate student interest. Student interest is often sparked from topics that are relevant to their lives, such as pharmacology topics." (Daly & Hutchinson, 2007)

This lesson presents a scenario that expands on the nuclear energy topic already introduced within this unit: the use of radiopharmaceuticals in Nuclear Medicine. Nuclear Medicine includes diagnostic imaging scanners such as PET (positron emission tomography) and CT (computer tomography) that require a radiopharmaceutical to be used for the device to detect. Radiopharmaceuticals are usually either a pill or IV made up of "isotopes incorporated into substances such as sugars, proteins, water and other biologically active compounds that have specific localization patterns in the body." (Duncan, 1998) For instance, when a patient is needing a PET/CT scan to diagnose brain cancer, the radiopharmaceutical given is generally a radiotracer (the isotope) attached to a sugar molecule. Because of 'the increased metabolism of glucose in brain tumors", the sugar molecule is metabolized at a higher rate than in healthy cells. (Duncan, 1998) The PET/CT can detect the differing rates of metabolism of the radiotracer and produces an imagine outlining the location(s) of the highest metabolism (the tumor) and the lowest metabolism (the heathy cells). In addition to cancer detection, radiopharmaceuticals with

PET/CT scanners can be diagnostically used for Parkinson's, Schizophrenia, strokes, and heart disease to only name a few.

Radiopharmaceuticals can also be used without imaging devices for other purposes including chemotherapy. Radiopharmaceuticals cannot be mass produced due to the half-life of the radiotracer which is generally between a few hours to several days. Therefore, there is a limited amount of time flexibility between the production of the radiopharmaceutical and when it should be administered. One large factor that must be considered as part of the timeframe the radiopharmaceutical must be utilized by the patent is the delivery time from the lab to the patient. As of 2012 there were only 151 cyclotrons, the machine that the radiopharmaceuticals are produced in, throughout the United States with only 101 of those being used solely for commercial use. (Ikotun, Clarke, & Sunderland, 2012)

Prior to the unit lesson piezoelectric sensors and buzzers were introduced. Piezoelectricity occurs when certain crystals are physically stressed causing the chemical bonds in the crystal to break. (Ikeda, 1990) The energy from those bonds is released from the crystals in the form of electricity. When a piezo buzzer is connected in an electrical circuit, the piezo buzzer produces a sound when a force is applied. The applications of the Piezo Effect are increasing including research with piezo sensors being added to highways as a method to produce electricity. (Guo & Lu 2017) In addition, the Peltier Effect is excellent for demonstrations only as the temperature extremes pose a safety risk for students. The Peltier Effect occurs when a current passes across a metal junction between two materials causing one side to increase in

temperature (release heat) and the other side decrease in temperature (absorb heat). Current research using the Peltier Effect include adding the devices within proximity of photovoltaic cells to help increase the efficiency of collecting solar energy. (Najafi & Woodbury, 2013)

Important Vocabulary

Term	Definition
Energy	The ability to do work or cause change.
electromagnetic energy	A form of energy that travels through space and gas as waves.
Law Conservation of Energy	The law that states that energy cannot be created or destroyed but can be changed from one form to another.
conduction	Energy is passed from atom to atom through direct contact.
convection	The transfer of thermal energy by the circulation or movement of a liquid or gas
heat	The energy transferred between objects that are at different temperatures.
Kinetic Theory of Matter	The theory that all matter is made up of tiny particles in constant motion.
radiation	Energy that is radiated or transmitted in the form of rays or waves or particles.
temperature	A measure of the average energy of motion of the particles of a substance.
frequency	The number of complete wavelengths that pass a point in a given time.
vacuum	An empty space with no particles of matter.
wavelength	The distance between two corresponding parts of a wave.

Troubleshooting Tips

Other Helpful Information

YouTube Video Clips
Peltier Effect: https://youtube/rT9-HUzUqhQ

Nuclear Medicine: https://www.youtube.com/watch?v=oWVsnFz-KqA

Radiopharmaceuticals: https://www.youtube.com/watch?v=8YlABLzefKg

Piezoelectricity: https://www.youtube.com/watch?v=YEJ2qryXcIQ

Quizlet
Vocabulary: https://quizlet.com/_6v5503

Attachments

List here any lesson or activity attachments not included within this document, such as the following:

- **Engineering Design Packet**
- **Rube Goldberg Machine Rubric (not included due to being in Canvas)**

Remember to send these as separate files along with your unit/lesson plan.

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