Nano Who, Nano What? Nano Particles!

by Ashley Renzo, 2016 CTI Fellow
Northwest School of the Arts

This curriculum unit is recommended for: 8th Grade

Keywords: Nanomaterial, carbon, graphene, nanotubule, quantum dot, solar cell, physical property, chemical property

Teaching Standards: See Appendix 1 for teaching standards addressed in this unit.

Synopsis: Nano technology is an emerging field of fast scientific research and growth. From the latest advances in consumer electronics, to cutting edge research in renewable energy, the advancements in nano materials impacts our lives in many ways. The following unit is designed to introduce middle school students to fundamental concepts of nano technology, materials, and ways in which emerging nano technology has shaped the fields of science. Many technologies are utilizing the element of carbon, which is a perfect way to tie nanotechnology into lessons about the periodic table. This curriculum unit attempts to connect the diverse concepts of physical, and chemical properties of nanomaterials and their corresponding macromaterials. The students will explore how graphene and carbon nanotubules work together, while they work together to come up with new ideas to propel the field of nanotechnology further into the 21st century. Students will also get hands-on experience with various everyday materials that express several different physical and chemical properties. They will also be introduced to nonfiction text pieces from educational resources, and the kid-friendly nano-magazine, Nanooze.

I plan to teach this unit in the fall of 2017, in the 8th grade classroom.

Nano- What? Nano-Who? Nano PARTICLES!

Ashley J. Renzo

Introduction

Rationale

The field of nanotechnology is constantly growing and evolving to meet the ever changing challenges and needs of a society with an increasing reliance on technology. It is important that our culture is both informed and involved with identifying these needs. To teach this unit will involve connecting concepts related to chemistry on the nanoscale, applying these to life on the macroscale, and increasing the use and efficiency of renewable energy in everyday life.

Students in the 8th grade have studied the basic ideas of matter and energy throughout the elementary and middle school years. Students have learned in previous years that matter makes up everything, and that energy can be utilized from both renewable and nonrenewable sources. During the 8th grade year, the curriculum expands to include content that focuses on the periodic table and how atoms interact with one another. The energy unit in 8th grade focuses on how renewable energy works, and why it is important to preserve and conserve resources for future generations.

This unit for “It’s a Small World” is relevant both to the North Carolina Standard Course of Study’s Essential Standards, and anyone that is interested in increasing the use of renewable energy for home and business use. The course of study for CMS science units is broken down further into fifteen teaching modules.

While teaching the module that relates to the periodic table and atoms, students are introduced to the concept that atoms are too small to see with the naked eye. The subatomic particles of proton, neutron, and electron are also introduced, as well as the fact that they hold positive, neutral, and negative charges, respectively. The students will be introduced to these concepts theoretically, while also being taught the real-life implications of these ideas.

It is imperative that they students have a thorough understanding of the properties of electrons, especially valence electrons, before beginning this nanoscience unit. Electrons are negative subatomic particles that reside in orbits surrounding the nucleus. Valence electrons are the electrons that reside in the outermost orbit of an atom. Due to the affinity of an atom to lose or gain an electron, chemical properties are determined. These chemical properties relate to how an element will react in a chemical reaction, which is known as reactivity. Reactivity is a concept that is reinforced through hands-on student led experiments involving common substances such as calcium carbonate and spinach.

While teaching about the tiny scale that atoms are measured on, it would be fitting to then include the scope and scale of nanoscale science. Students may be familiar with the terms "microscopic" or "nanosecond", but may need description and comparison to show the size of atoms in a way that makes sense to them. The atom is usually described in AMU, or atomic mass units. Atomic mass units are helpful in describing how heavy the atoms are, but does not describe the width or height of the atom. However, nanoparticles have different sizes that can be measured in nanometers, and picometers at even smaller scales. Since nanometers are a derivative of meters which measure length, it would make sense to correlate an atom to a measure of length that students are familiar with.

There are many visual aids that will assist in describing the meter and millimeter as a unit of length (meter sticks and rulers). YouTube video clips can describe further the scale of how small the nanometer is. To describe the size of nanoparticles will be the first concept that the students will grasp, before they are introduced to the properties and abilities of nanoparticle research that is applied to the renewable research field. This approach helps the students to understand the overall concept, as well as how it is applied practically in real life situations they are familiar with.

In addition to learning about size and scale of nanoparticles, physical and chemical properties will also be addressed. Physical properties are the properties that can be observed and measured without making a new substance. By teaching the students about the physical, as well as chemical properties, the students will be able to have a much better understanding as to how the overall electro-mechanical structures work which drive a lot of modern technologies.

Many technologies which leverage nanoparticles include: televisions with quantum dots, pregnancy tests, and tonic water. Tonic water contains quinine, which is a molecule that can fluoresce under blacklight, making it a perfect substance to use to demonstrate the property of fluorescence to any age of student. Although, quinine itself is not a nanoparticle, it can be used to demonstrate the fluorescent property in an easy to observe manner, Sometimes, large proteins, like C60 and carbon nanotubes can be considered nanoparticles, and their properties can be observed. Many of these technologies the students may already be familiar with, enabling the students to have a deeper and more personal connection with the material.

School/Student Demographics

Each block of eighth grade science meets every other day for 90 minutes per class. There is a total of 156 students in the eighth grade class, broken up into six blocks. The physical science unit introduces a variety of new concepts, so blending the nanoscale science unit with the periodic table and renewable resource unit will tie concepts together with ease.

Northwest School of the Arts (NWSA) has a diverse student body, grades 6-12. Presently, we have 1020 students enrolled (451 middle school/ 569 high school) that are 27% male and 73% female; 49% African-American students, 38% White students, 7% Hispanic, 1% Asian and about 5% of our students come from other races and ethnicities; 47% are identified as economically disadvantaged. Our staff consists of 36 core subject, including 2.5 positions in foreign language, 17.5 art teachers, and 3 CTE teachers. Our 81 EC students are served by an EC staff of 3 and one assistant. Our ACT data indicated that our composite ACT score was 20.1 and our percentage pass rate was 70.6 percent. Our graduation rate in 2014 was 96.9%, the second year in a row it was over 95%, and it was 97.4% for 2014-2015

Unit Goals

In this unit, students will be able to identify nanoscale materials as materials that have dimensions of 1 to 100 nanometers. They will be able to describe the pros and cons of current solar cells, and describe how nanoparticles may solve some efficiency problems that are currently observed in solar technology today such as loss of energy during conversion. Energy is lost when solar energy enters the photovoltaic cell and is converted to electrical energy. Students will be able to identify the difference between physical and chemical properties (as required by the North Carolina standard course of study). This unit will diversify the presentation of information on physical and chemical properties to include how nanoscale particles, quantum dots, and macroscale materials differ due to their size, but are still made of the same type of atoms. Teaching the students about these deep concepts is critical to their understanding of how nano systems operate at the quantum level.

Students will have previous knowledge of physical and chemical properties. This unit will add additional information about how nanoparticles have different properties than the macro particles that come to mind when certain materials are mentioned. For example, nanoparticles of silver have completely different properties than the silver that is in a ring or necklace made of silver. For example, silver nanoparticles have antibacterial properties, which would not be said about silver that the general population is used to seeing. A common property that would be used to describe silver on the macroscale would be that it is shiny, a solid at room temperature, and that it is an excellent conductor of heat and electricity.

As far as chemical properties, rate of reactivity can also be explained and demonstrated using particles of different size and shape. When a substance has more surface area, a chemical reaction will happen at a faster rate. Nanoparticles also display this property, as there can be many receptor sites on a nanoparticle surface. Even though the particle is very small, there can be many receptor and reaction sites on a surface of a nanoparticle or a quantum dot.

Physical properties are those that can be measured or seen without any changes made to the chemical formula of the substance. One that can be focused on for this unit plan is fluorescence. Nanoparticles will both absorb and emit different color light than its macroscale counterpart.

Content Research

Every substance in the known universe is made of atoms. Atoms are the most fundamental unit of matter, giving objects their mass and density.   Every atom his unique chemical and physical properties. The properties of a single atom of any given element can be vastly different than those of the same element in mass quantities. Nanotechnology studies are currently exploring how cutting-edge advancements are leading the way in the fields of energy, health, and technology.

The field of nanotechnology is not only broad, but growing constantly as new discoveries are being made in a variety of fields. Nanotechnology is a subset of scientific knowledge that reaches to chemistry, biological sciences, and physics. Nanotechnology is defined as “the branch of technology that deals with dimensions and tolerances of less than 100 nanometers, especially the manipulation of individual atoms and molecules.” This means that the field of nanotechnology studies particles as small as a molecule of water, a single virus particle, or as large as a bacterium. For this curriculum unit, the focus will be on first describing what exactly qualifies as a nanoscale structure, and then the vast differences between nanoscale particles how nanoscale technology relates to the field of renewable energy, specifically solar energy.

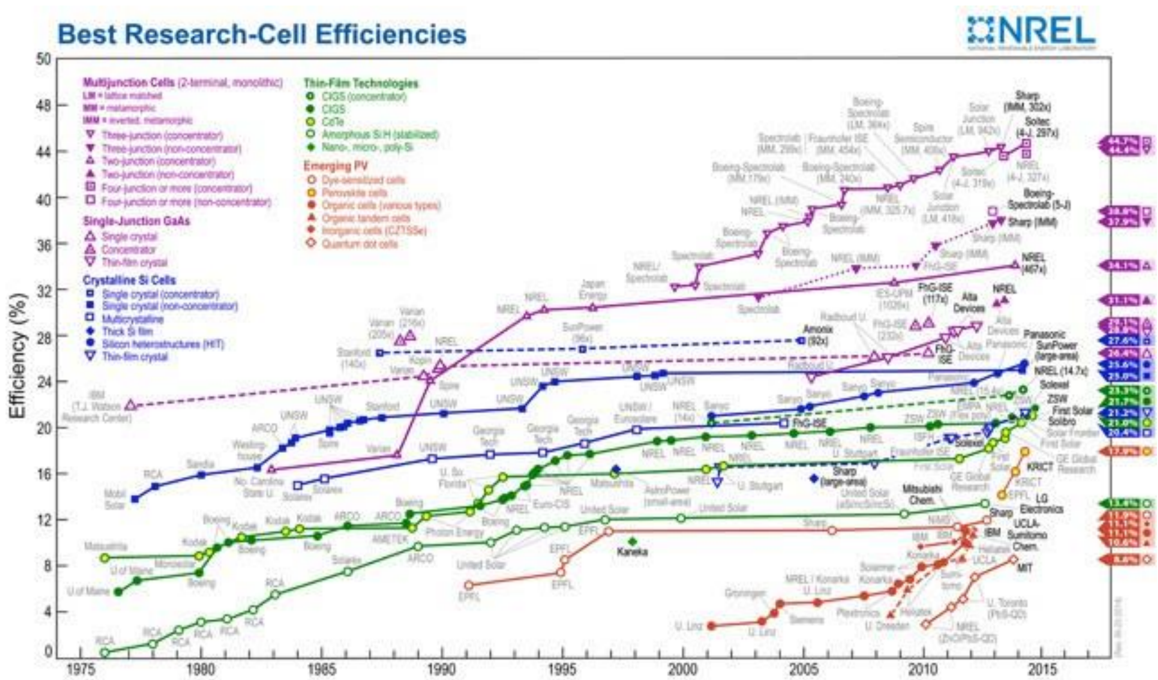
The most common method of collecting solar energy is to use a silicon- based structure to capture energy from the sun. However, silicon- based structures on average do not produce more than 20% output of energy. Nanoparticles are currently being tested to increase the efficiency of solar cells by both absorbing more light, and emitting more energy to be collected and used. The practical implication of the use of nano particles in photovoltaic cells can increase yield by approximately 10%. However, these numbers can vary as the technology is continually being improved upon.

The need for renewable energy sources has greatly increased in the past few decades. Nonrenewable resources have been the primary source of energy in the last century. These nonrenewable fossil fuels include natural gas, coal, and oil. The higher the demand placed on nonrenewable energy sources, the more quickly they will be depleted. Seeking alternative sources of energy will help to lessen the overall ecological impact that humanity is placing on the environment. (Bauer, Chapter 2.1) Theoretically, solar energy could be the main source of the Earth’s energy needs. The input of solar energy in the outer atmosphere is greater than the current energy needs of the citizens of Earth. The amount of solar radiation that reaches the outer atmosphere also is larger than the amount of any other light source, such as that from other stars, or reflected light from the moon. Comparing renewable energy source, solar radiation has a potential of use far greater than that of wind energy and biomass energy. Wind and biomass energy are also driven by solar energy. (Bauer) By using nanotechnology-based solar energy, we can harness the most efficient renewable resource, while decreasing the need for fossil fuels, and less efficient renewable resources.

Due to the fact that modern society is increasingly dependent on technology, there is a definite need to begin exploring solar energy as an efficient and viable source of energy. To put this need to scale, the sun provides enough energy over 1.5 hours to fulfill the world's energy needs for an entire year (Nanoscale design to enable the revolution in renewable energy). Currently, crystalline silicon photovoltaic cells are the most universally used tools to harness solar energy. Various types of organic and inorganic materials are being studied to determine both cost and energy efficiency. Notably, vacuum deposited thin film technologies, and inexpensive organic materials have had energy efficiencies ranging from a few percent (organic materials) to 15% (thin film technologies). Photovoltaic cells use the absorption of photons by a semiconductor to generate electricity. Efficiency of the crystalline silicon single absorber cells has a maximum efficiency of 32% (Nanoscale design to enable the revolution in renewable energy). Two major aspects of solar energy that nanoscale technology hopes to improve is the cost of manufacturing solar cells, and improving solar cell efficiency.

One of the current drawbacks of using photovoltaic cells is the fact that even though they are a renewable way to convert energy, they can be quite costly to implement. In addition to being expensive, solar cells need to be produced very carefully, using pure and high quality materials. This ensures that the quality and consistency of the produced solar cells will be extremely high, maximizing the expected energy yield. When nanoparticles are used in solar cells, a layer of the particles on the top of the slide will absorb the light that it is exposed to. Polymer layers are used in the current solar cells that were examined in our summer experience. The polymer layer(s) helped not only with binding the nanoparticles to the slide, but ensuring maximum absorbency by the nanoparticle layers.[1]

One of the many technological hurdles facing solar cell technology is maximizing the efficiency of solar energy absorbency. By adding nanoparticles to the surface of solar cells, it can be demonstrated that efficiency can be improved greatly. The chart below shows many different means by which photovoltaic cells absorb energy, and measuring their subsequent efficiency:



This chart shows the nanoparticle technology in red as the "emerging PV" or emerging photovoltaic technology. [2] As far as efficiency of the emerging technology, the efficiency of nanoparticles has been steadily increasing through their development between the years 2001 through 2014. All fields have shown improvement in efficiency, however nanotechnology is the new technology on the scene, and it will be interesting to see their growth in efficiency in the near future. As the field of nanotechnology becomes more mainstream, there is the possibility that these technologies can improve the pollution problem from overuse of fossil fuels.

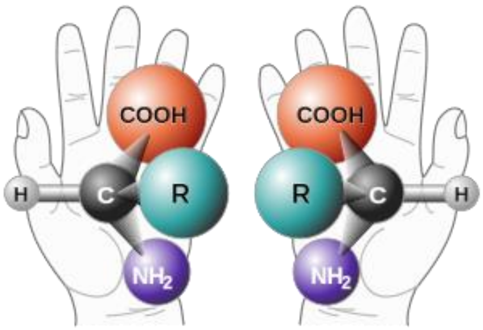
In addition to adding to the renewable resource field of study, nanotechnology is also used to make a material called graphene. Graphene is a fullerene consisting of carbon atoms that is one atom thick. To describe graphene, a fullerene is a form of carbon that has the shape of a hollow cage of atoms. Carbon is a crucial element in many concentrations of chemistry, including organic chemistry and organic concentrations of nanoscience. This is due to the arrangement of valence electrons in the carbon atom. Graphene is just one on the many forms of carbon that can be used to enhance technology. Display screens can be enhanced with graphene to become more durable, yet still retain the thinness that consumers look for when purchasing technology.

The prevailing thought of many scientists in the field is that carbon nanotubes are in competition with graphene to be used in such was in state of the art technology. However, research is being done to determine if graphene can be used in conjunction with carbon nanotubules to enhance color on screens, and also increase durability. A scientist named James Tour, and his team at Rice University have been working to develop carbon nanotubes in a way that they have not been used before. A common technique to grow large sheets of graphene is to use a mechanical process known as Chemical Vapor Deposition, or CVD. In CVD, a gas is used in a heated chamber, along with a substrate to produce a material film on the substrate. In the case of graphene, a copper substrate and a furnace can be used to produce large amounts of graphene. However, one downside to that method was that the graphene was damaged when it was pulled off of the copper substrate. A polymer layer could be used to help prevent breakage, however that layer could introduce impurities to the graphene.

A new method is introduced by Rice and his team that will have the possibility of reducing the damage done during the manufacturing process. First, they coat the copper with both single and multi-walled nanotubes. Next, they heat and cool the material. When heated, the nanotubes decompose into graphene, and also form a covalent layer which is attached to the graphene layer. This new product is described as "rebar graphene" to denote that it is exceedingly strong.[4]

Another prominent property of graphene is that it can be boosted to thicken and reinforce carbon nanotubes. [4] A carbon nanotube consists of carbon in a honeycomb lattice rolled into a cylindrical shape. Although the diameter of a carbon nanotubule is of nanoscale size, the length can be more than one micrometer. The unit micrometer is commonly known as a micron. A micrometer is measured as 10^{-6} meters, therefore it is actually larger than the nanometer. So, a carbon nanotubule can be nanoscale in width, but not necessarily nanoscale in length. Carbon nanotubes are also used in the technology industry due to their small size, as well as their ability to conduct electricity. A unique physical property of carbon nanotubes is that their electronic structure is dependent on their geometry, and more specifically their geometry related to their chirality. [5]

Chirality is an essential topic in the field of organic chemistry. Organic chemistry studies the chemical makeup of living or once-living organisms, all of which contain carbon. Molecules of many carbon-containing substances can have the geometric property of chirality. However, a molecule does not need to be organic to be considered chiral or achiral. If a molecule is chiral it will have a mirror image of itself that can be superimposed on it. The property of chirality can be explained as the left hand of a person, mirroring the right hand when they are placed palm sides together. The image below shows the chirality of both a generic molecule, and the hands of a person. This would be an example of a chiral molecule, since is it a mirror reflection of itself. [5]



Whether or not a nanotubule is chiral or not will determine how effective the nanotubule is when it is conducting electricity. Both the geometric shape, and the ability to conduct electricity are considered physical properties of the nanotubes. A nanotube can have very good conductivity, which is also a metallic property. However, if the chirality is different, it may be a semiconductor, similar to a metalloid. It is likely that the smallest semiconductor devices would be based on carbon nanotubes.[4] Silicon is a very common and important element that displays the properties of semiconductors. As different elements and compounds are found to have semiconducting properties, it is important to stress to students that the field of science is always changing, due to new research and discoveries.

Quantum Dots are a perfect example of how new discoveries are being used to express properties of elements on a small scale. Quantum dots are tiny particles or nanocrystals that have diameters in the range of two to ten nanometers. Since they are so small, their properties vary from those of larger particles. Quantum dots are very strong for their size. They are very powerful devices with the ability to convert light to any color on the visible spectrum with very high efficiency.[7]

This property of fluorescence in different color is a great way to express the physical property of fluorescence based in particle size. Quantum dots are used to boost the color spectrum displayed in LCD television screens. Since the dots can be fine tuned to express a specific color based on size, they are a great fit to be used in LCD screens. Also, since only the needed colors are expressed, the television will use less energy than a television without quantum dots. The quantum dot range starts at 500 nanomater wavelength (expressed as blue light) and a quantum dot size of 2 nanometers and increases to a 650 nanometer wavelength (expressed as red light) and a quantum dot size of 6 nanometers. [7]

Instructional Implementation

Teaching Strategies

Students will be given a scaffolded approach to the field of nanoscience. The lesson will be opened with a brainstorming session about what the word “nano” brings to mind. The ideas brought up by the students will be recorded on the classroom board, giving the teacher time to discuss how these ideas apply to “nano” and “nanoscience”. Once the brainstorming session has been completed, the students will read articles that pertain to the field of nanoscience. Honors and high level classes will research a particular product or field of nanoscience that is of interest to them.

All classes will have the chance to experience two hands-on activities. One activity would be the reaction-rate activity that shows the chemical property of the reaction rate of different sizes and shapes of calcium carbonate in the form of marble. The second activity will utilize molecules extracted from spinach to illustrate florescence. This activity will prove to the students that chorophyl extracted from a spinach leaf will fluoresce under a black light, whereas the full spinach leaf will not have the property of fluorescence. After all lessons have been taught, students will be given an assessment that will review vocabulary necessary to the unit, as well as important concepts that tie together nanoscale science, physical and chemical properties, and also solar energy.

Classroom Lessons and Activities

Day 1 Lesson

As a warm up activity, students will be grouped at tables of 3 to 4 students, and asked the following questions for small group discussion, and then reviewed with large group discussion.

- Who has heard of the metric system of measurement? (Answers will vary)
- What is the metric system? (The metric system is a decimalised system of measurement based on ten)
- How does it differ from our system of measurement (inch, foot, yard, mile, are used in United States measurement systems. The United States system which is not base ten)
- How many inches are there in one meter? (39.37 inches)
- What is the smallest thing you can think of? (atoms, electrons, protons, germs, molecules). Most students say a grain of sand, dust, a flea etc.
- What is a nanometer? (Answers will vary)
- How many nanometers are in one meter? (1,000,000,000nm)

The following images will be shown and discussed. Students will discuss when to use what units, and come up with any examples they might know about each type of unit of measure, and possibly the scientific notation used for each unit.

International Systems of Units (S.I Unit):

The International system of Units (SI) is a system of measurement that has been agreed internationally. The SI is founded on seven SI base units for seven base quantities assumed to be mutually independent, as given in Table below.

Base quantity		Base Unit	
Name	Symbol	Name	Symbol
Time	t	second	s
Length	l	meter	m
Mass	m	kilogram	kg
Temperature	T, θ	Kelvin	K
amount of substance		mole	mol
luminous intensity		candela	cd
Electric current	I	ampere	A

Prefiks	Symbol	Multiplying factor
yotta	Y	1 000 000 000 000 000 000 000 000 = 10^{24}
zetta	Z	1 000 000 000 000 000 000 000 = 10^{21}
exa	E	1 000 000 000 000 000 000 = 10^{18}
peta	P	1 000 000 000 000 000 = 10^{15}
tera	T	1 000 000 000 000 = 10^{12}
giga	G	1 000 000 000 = 10^{9}
mega	M	1 000 000 = 10^{6}
kilo	k	1 000 = 10^{3}
hecto	h	100 = 10^{2}
deka	da	10 = 10^{1}
deci	d	0,1 = 10^{-1}
centi	c	0,01 = 10^{-2}
milli	m	0,001 = 10^{-3}
mikro	μ	0,000 001 = 10^{-6}
nano	n	0,000 000 001 = 10^{-9}
piko	p	0,000 000 000 001 = 10^{-12}
femto	f	0,000 000 000 000 001 = 10^{-15}
atto	a	0,000 000 000 000 000 001 = 10^{-18}
zepto	z	0,000 000 000 000 000 000 001 = 10^{-21}
yocto	y	0,000 000 000 000 000 000 000 001 = 10^{-24}

Day 2 Lesson

Students will continue to engage in discussion and digging in to the basics of what nanoparticles are and the technology that they are used in. Students will read, "Nanooze Issue 14:Energy", to gain a deeper understanding of the practical applications of nano science and nano technology. Depending on the reading levels, and needs of a particular class, this can be accomplished by popcorn reading, small group reading, or the teacher can read as the students follow along.

Nanooze articles are geared towards students, and each issue is full of nanoscience articles that cover a variety of scientific nano-based topics. This particular issue includes articles that examine how watts are used to measure energy, various types of batteries, the substance graphene, the efficiency of a solar panel, and a question and answer page from a chemical engineer. All of these concepts are very important when discussing the use of nanotechnology in real world scenarios. Also, the substance graphene is noted as one of the first nanotechnologies used. Graphene was discovered by two people that pulled a single layer of carbon off onto tape. This can be demonstrated by the teacher or students, using pencils and tape also, as a quick hands-on activity. Students can draw a thick layer onto their papers with pencils, then try and pull off only a single layer with tape. You can extend this past a demonstration by asking students to identify criteria, constraints, and have them come up with a hypothesis about how easily they can complete this task. Students can even expand further by coming up with their own experiment for how they can create graphene, using easy to find materials (tape, pencil, glue, gum, clay, etc.)

Students will be given the chance to read through the articles as a small group. They will use annotating techniques to review words that are new and unfamiliar to them. This nanooze issue has a very thorough article about solar energy and how nanotechnology can increase efficiency in the renewable energy field of study. To review the solar material, students will make a square foldable with three flaps. The outside top flap will have the words " Effieincy, Quantum Dots, and Solar Panel". The inside of the top flap will describe the term that is covering the top side. Underneath the term, on the inside of the foldable, the students will put a fact or example. On the entire back of the foldable, the students will draw a picture that includes a representation of the solar panel, how quantum dots are used, and an example of efficiency.

For an exit ticket activity, students will write a paragraph that includes three of the following key vocabulary words: graphene, efficiency, quantum dot, battery, carbon, watt, nanoscale and nanotechnology. This day's lesson activities fit well with the focus on co-curricular activities, as well as the North Star reading initiative across Charlotte-Mecklenburg School District.

Day 3 Lesson

As a warm up activity, students will brainstorm famous scientists that they know off hand, and describe the contributions they have made in science. Some expected answers would include Albert Einstein, Galileo, Dmitri Mendeleev, and possibly Neil DeGrasse Tyson or Bill Nye. After discussing what the students have come up with, the teacher will talk about James Rice as a very important scientist that is conducting research in the nanotech field, using both graphene and nanotubes together to make technological advances in the screens of everyday devices, such as televisions, hand held tablets and cell phones.

The students will then read the article "Graphene and Nanotubes:Two Great Materials Even Better Together", by Dexter Johnson. They will then use a graphic organizer of their choice, such as venn diagram, T-chart, or flow chart to describe the three different ways to manufacture nanoparticles. After the graphic organizers are complete and discussed in small groups, the students will identify the pros and cons of using graphene and nanotubules in everyday technology. For advanced classes, the students can begin to explore quantum dots, and they ways that they are used in augment technology as well.

Day 4 Lesson

Warm up activity- Review day two's activity with the article "Graphene:The Material of the 21at Century". Students will read the article, then watch the clip that is embedded at http://learningenglish.voanews.com/a/graphene-the-material-of-the-21st-century/2681970.html.[3] The clip is two minutes long, and covers many interesting facts about the nanomatierial graphene.

After students have read and discussed the article, and watched the short clip, they will take this online quiz to review what they have learned from the article. Link to the quiz- http://learningenglish.voanews.com/a/2685415.html. [4] This quiz will review the important vocabulary from the article, as well as how graphene products are produced and used.

After reviewing the quiz, a brief review of surface area reactivity as a chemical property will be discussed. Reactivity then refers to the rate at which a chemical substance tends to undergo a chemical reaction in time. If a substance is broken into smaller pieces, then it will react faster, due to higher surface area, and the ability to react with more of the solvent it is placed into. This illustration is significant in demonstrating how variables such as mass, surface area, and geometric proportions can impact how chemical reactions can occur.

One of the main chemical properties that can be easily expressed through nanoparticles is the effect of surface area on the rate of a chemical reaction. To express this through a hands-on activity can be shown as a demonstration by the teacher, or a small group activity in groups of 3 to 4 students.

Materials Needed

- 3 samples of calcium carbonate in the form of marble- 1 piece of marble in a cube, 1 piece broken into a few smaller samples, 1 piece broken into very small, fine pieces
- 20 cm^3 of 1M Hydrochloric acid
- 3 100 ml beakers

Students can observe the reaction and write down how fast the reaction occurs, and also sketch what each beaker looks like initially, after 30 seconds, after one minute, and after two minutes. The students will be able to observe that the higher the surface area, the faster and more vigorous the rate of reaction will be. This can also be expressed using alka-seltzer tablets and vinegar, with whole tablets, broken tablets, and tablets that have been crushed.

Day 5 Lesson

To connect the concepts of nanoparticles and solar energy a "Juice from Juice" experiment can be demonstrated by the teacher or completed by the students in small groups of 3 to 4 students. The Juice from Juice experiment will show how blackberry juice can be used to conduct an electrical current.

As a warm up/review activity the teacher will discuss the use of photovoltaic cells, and how they are produced and where they are currently used. Students can compare the pros and cons of the current silicon-based cells. Some responses may include that the cells are expensive, manufacturing plants are not common, people may not want solar cells on neighborhood buildings, etc.

Before beginning the experiment the teacher will need to introduce the dye-sensitized solar cell (known as a DSSC for short), and how is it related to the task of building a blackberry juice solar cell. The DSSC is made of four parts, a semiconductor, dye, conductive glass electrodes, a redox electrolyte, and a light source.[8] A link to the Juice For Juice site is included in "Teacher Resources" section. The kits will also have to be purchased separately from Arbor Scientific.

Day 6 Assessment

Students will be assessed on their ability to express and define the following vocabulary terms that are crucial to the unit- graphene, carbon nanotubule, quantum dot, dye-sensitized solar cell, photovoltaic, reaction rate, physical property, chemical property, fluorescence, nanometer, micron.

Students will use the vocabulary tic-tac-toe format to show what they know in a unique way, while the teacher is able to assess their strengths and weaknesses during the completion of the project. Below, is the format of how to deliver the tic-tac-toe assessment or project:

Vocabulary Tic-Tac-Toe

Name:____ Block:____

1. Develop a word search with the vocabulary words. Provide an answer key.	2. Create a crossword puzzle that has each of your vocabulary words in it. Be sure to put the answers on one side and the blank crossword on the other, so it can be used.	3. Design a fill-in the blank test for your vocabulary words. You may use definitions and/or context clues to help with this task. Provide an answer key.
4. For each of your vocabulary words, create an example of one of the following: a synonym, antonym, simile, metaphor, or an analogy	5. Write the definitions for your vocabulary words. **MUST be hand-written!**	6. Write a sentence with each of your vocabulary words. Be sure to use proper punctuation and grammar. (Cannot be the **definition**!!)
7. Make a comic that uses each of the vocabulary words. Must include pictures, color, and text!	8. Draw a picture to represent each vocabulary word. Put them together into a picture book format. Be sure to identify each vocabulary word with the picture.	9. Write a story that makes sense using all of your vocabulary words in their context. Be sure to use correct grammar and punctuation.

Choose three of the activities in any winning Tic-Tac-Toe pattern. Complete 3 activities (# 5is always REQUIRED) for each vocabulary list. This is to be completed in class as well as at home.

This is due on _____________

I have chosen to do activity # 5, #________ and # _________.

The teacher can use this also as a differentiation piece, as the students will choose activities in a pattern that will include the basic needs, as well as options that suit their learning style.

Appendix 1- Teaching Standards

8.P.1.1 Classify matter as elements, compounds, or mixtures based on how the atoms are packed together in arrangements.

8.P.1.2 Explain how the physical properties of elements and their reactivity have been used to produce the current model of the Periodic Table of elements. This will be expressed with the hands-on marble rate of reaction experiment. Also, students will need to be familiar with the periodic table to identify the elements needed for the experiment, and the carbon-based graphene.

8.P.1.3 Compare physical changes such as size, shape and state to chemical changes that are the result of a chemical reaction to include changes in temperature, color, formation of a gas or precipitate. Rate of chemical reactions will be expressed in the marble experiment, as well as touched on during the Juice from Juice blackberry experiment.

8.P.2.1 Explain the environmental consequences of the various methods of obtaining, transforming, and distributing energy. The Juice from Juice experiment will demonstrate a method of how an electrical current is produced.

8.P.2.2 Explain the implications of the depletion of renewable and nonrenewable energy resources and the importance of conservation. Quantum dots are used in television screens to produce brighter and crisper colors, as well as conserving energy by only making colors needed for the screen.

Student Resources

Articles by Nanooze are all great resources. The one that I reference is "Solar Cells and Quantum Dots", by Lynn Charles Rathbun.

Teacher Resources

The website by the Solar Army is a great reference for how to present the "Juice from Juice" experiment, as well as the materials needed. The Dye Sensitized Solar Cell kit mentioned in Juice for Juice experiment (Day 5) can be purchased from Arbor Scientific at the following location: http://www.arborsci.com/dye-sensitized-solar-cell-kit-16

Notes

1. https://eng.ucmerced.edu/sett/presentations-1/7-Nanotechnology.pdf
2. http://i2.wp.com/understandsolar.com/wp-content/uploads/2014/11/best-solar-cell-efficiency-nrel_c.jpg

3. http://learningenglish.voanews.com/a/graphene-the-material-of-the-21st-century/2681970.html
4. http://spectrum.ieee.org/nanoclast/semiconductors/materials/graphene-and-carbon-nanotubes-two-great-materials-even-better-together
5. Physical Properties of Carbon Nanotubes R. Saito, G. Dresselhaus, M.S. Dresselhaus
6. https://en.wikipedia.org/wiki/Chirality_(chemistry)
7. http://www.nanosysinc.com/what-we-do/quantum-dots/
8. http://thesolararmy.org/jfromj/

Bibliography

"Best Research-Cell Efficiencies." Digital image. http://i2.wp.com/understandsolar.com/wp-content/uploads/2014/11/best-solar-cell-efficiency-nrel_c.jpg.

The "Solar Cell Efficiencies" chart by NREL (Nation Renewable Energy Laboratory) is an excellent resource for assisting with understanding efficiency improvements made in various types of solar cells from 1975 until 2015. This chart can be simplified and presented to science students to provide a graphic illustration of how advancements in technology lead to lower cost, higher yielding solar cells.

"Chirality (chemistry)." Wikipedia. Accessed December 02, 2016. https://en.wikipedia.org/wiki/Chirality_(chemistry) .

The Wikipedia article on chirality is an excellent resource for introducing the concept of chirality to middle and high school students. Since most biochemicals are chiral, providing students with an introduction to the concepts of "handedness" as it relates to chirality, is advantageous to helping them understand the more advanced concepts related to renewable energy. The Wikipedia article provides a great overview of the history of chirality, as well as how it is applied in biochemistry as well as inorganic chemistry.

"Graphene: The Material of the 21st Century." VOA. Accessed November 23, 2016. http://learningenglish.voanews.com/a/graphene-the-material-of-the-21st-century/2681970.html.

The Voice Of America News (VOA) provides great articles on recent scientific, economic, and political issues in a simplified format for students. The article published by VOA on graphene is great for equipping students with background knowledge of what graphene is, as well as how it is produced by Vorbek Materials. Since Vorbek Materials produces graphene for consumer electronic devices as well as industrial purposes, students can leverage this resource for practical applications of how graphene is used in everyday life.

"Juice from Juice | The Solar Army." The Solar Army. Accessed December 04, 2016. http://thesolararmy.org/jfromj/.

The “Juice From Juice” program from CalTech seeks to provide students with resources for taking concepts related to renewable energy production and applying them to a classroom setting. CalTech provides a vast amount of workshops and other resources to educators who are seeking to provide interactive learning experiences for multiple grade levels.

“Dye Sensitized Solar Cell Kit.” Arbor Scientific. Accessed December 04, 2016. http://www.arborsci.com/dye-sensitized-solar-cell-kit-16

The “Juice from Juice” Dye Sensitized Solar Cell experiment kit provides all of the supplies necessary to demonstrate how blackberry juice can be used to conduct an electrical charge. The demonstration of how natural and organic materials can be used to solve real-world problems is a powerful testimony to the work scientists are conducting in labs all around the globe.

"Quantum Dots." Quantum Dot Pioneers. Accessed December 02, 2016. http://www.nanosysinc.com/what-we-do/quantum-dots/ .

Johnson, Dexter. "Graphene and Carbon Nanotubes: Two Great Materials Even Better Together." IEEE Spectrum: Technology, Engineering, and Science News. 2014. Accessed November 23, 2016.

Many of the deeply technical scientific concepts introduced in this curriculum unit pertaining to quantum physics could prove to be difficult for students to grasp in the middle to high school age range. However, the application of quantum dots to LED display technology is an excellent resource to connect students to the real world applications that quantum dots provide. NanoSys is an electronics firm who specializes in manufacturing display technology built from quantum dots efficiently and cost effectively. This article provides detailed insight into how NanoSys uses the abstract scientific concepts to produce tangible technology that most students interface with on a daily basis.

http://spectrum.ieee.org/nanoclast/semiconductors/materials/graphene-and-carbon-nanotubes-two-great-materials-even-better-together .

Kelley, David F. *Nanotechnology in Solar Energy Conversion*. Pdf.

Saitō, Riichirō, G. Dresselhaus, and M. S. Dresselhaus. *Physical Properties of Carbon Nanotubes*. London: Imperial College Press, 2005.

While graphene is a great material for providing the foundations to enhance many new and existing technologies in a profound way, it is quite difficult to produce due to its delicate nature. The article, “Graphene and Carbon Nanotubes: Two Great Materials Even Better Together” provides an overview of how researchers at Rice University are leveraging carbon nanotubes in an “unzipping” process in order to more reliably produce graphene at a greater scale. Since graphene and carbon nanotubes are two components introduced in this curriculum unit,

providing students with an understanding of how the carbon nanotubes reinforce graphene is foundational to the application of these concepts.