Nano: the Greatest Power by the smallest scale

By Rima J Solh, 2016 CTI Fellow
Southwest Middle School

This curriculum unit is recommended for Eighth grade Mathematics, all levels

Keywords: nanotechnology, scale, Nano scale, measurement, metric system, Nano time, Nano ruler, surface area, volume, ratio of surface area to volume, metric system, scientific notation numbers, Nano consumers, careers with nanotechnology,

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

Synopsis: 8th grade students will learn about nanotechnology, its daily impact factors, and its multidisciplinary application. Because of the tremendous impact of this discipline, I have planned to use Nanotechnology education to teach two math skills. Students will apply Nano education on solving problems scientific notation numbers, using the measures of nanoparticles and Nano time. We will also apply it on another math content: volume and surface area. In both cases, Students should be able to apply the literacy impact on mathematics when they gather evidence to support a claim and defend that claim in an argumentative essay. Because it is a new subject to them, they will be reading articles about it. As the reading progresses, students will be formulating their opinions on its impact and the products evolving out of it, and the measurement scale used. Our principal is a big advocate of literacy and his main focus this year in the school's improvement plan is to incorporate a literacy skill in each lesson, project, and unit planning. As a result, I have planned the assessments of this unit as an argumentative essay, reflections questions on videos and articles, scientific inquiry activity, and a project with a choice of two options.

I plan to teach this unit during the coming year to 95 students in eighth grade honors math.

Nano: the Greatest Power by the smallest scale

Rima J. Solh

Rationale

Students learn how to write scientific notation numbers in 7th grade if they were enrolled in honors math class. In 8th grade all level students should learn how to write scientific notation numbers and how to perform all operations with this form. However, math teachers and I usually struggle to find examples and applications for this standard. And we usually find examples of huge numbers to write with the positive exponent of base 10. This unit is a perfect application for using scientific notation numbers with the negative exponent of base 10, since the Nano scale is very tiny. Students will write negative power numbers for measuring ingredients for products they use every day. Therefore, this unit's rationale is justifiable, exciting, and interesting. I am expecting lots of "aha" moments; the students' motivation would be indefinite as a result of the scientific inquiry and investigations used from modern products using the most recent technology. Needless to say this subject is brand new to me too and all the readings I have been doing so far has amazed me and attracted me to investigate and read more and more. I am hoping my students will acquire the same feelings so that the learning process would flow smoothly, and I am looking forward to encountering whatever inspiration will hit. We will learn math while investigating modern products which has been affected by Nanotechnology during manufacturing. Some examples are incredibly surprising. I have never expected to see my face moisturizer by L'Oreal among the list of products affected by nanotechnology. The classroom activities and lessons which will focus on examples from nanotechnology are so huge that I am forcing myself to limit the number of examples because scientific notation unit should be covered only in 1-2 days. Additionally, I am going to use all the investigations from this unit also when I teach volume (1-2 days). Proving that surface area matters even when volume is very small within the activity planned "ratio of surface area to volume" will be a great asset to the students' experiences and knowledge. Throughout the unit, students will be creating and adding to a graphic organizer to help them gather the evidence they need to help support their claim advertisement.

Another motivation to adopt Nanotechnology on teaching volume and surface area is these CTI seminars in which I learnt so much about chemical reactions and how Nano particles affect the production, process, and changes in materials and its reactions

Background

I teach eighth grade Mathematics at Southwest Middle School in Charlotte, NC. Southwest Middle School is a public middle school in the suburbs of Charlotte which serves 1,419 students in grades 6 - 8. Minority enrollment is 74% of the student body (majority Black), which is more than the state average of 49%, non-Hispanic 40%; white, non-Hispanic 26%; Hispanic 25%; Asian/Pacific Islander 4%; and Multiracial. 58% of the 1,423 students here are paying reduced lunch prices. The student: teacher ratio of 19:1 is higher than the NC average of 16:1. Math classes are sectioned according to EOG scores. I will plan to teach this unit across the board to all my three honors classes with the appropriate differentiation. The challenge lies more about applying literacy in math class where we face the reality of teaching English Learners (ELL) students within honors curriculum.

This year I have the privilege of teaching three Honors Math classes. My challenge lies in the fact that all my 85 students scored in the 7^{th} grade End of Grade test in the levels of 1 and 2. But they were enrolled in Honors math classes for different reasons. My first block contains the majority of "ELL" students who are newcomers to USA and their English Proficiency is level 1. My third block contains 31 students, and my fourth block has three "special Needs" students with 504 plans. Therefore, planning with differentiation is my biggest challenge and time-consuming. I will adapt it with this unit as well.

Content Background

My 8^{th} grade cohort uses lessons from the Discovery Education curriculum using common core standards. We began using this curriculum last year and had some major successes as well as major fails. Lots of teachers received their training in the summer and some of us were getting the training while teaching it. The standards and outline used from the "Unpacked Document" of Public Schools of North Carolina. The standard 8.EE.3 mandates that students "use scientific notation to express very large or very small numbers. Students compare and interpret scientific notation quantities in the context of the situation, recognizing that nanometer is 1×10^{-9}. And the second standard Grade 8 » Geometry » Solve real-world and mathematical problems involving volume of cylinders, cones, and spheres. »

Students entered the 8^{th} grade having minimal writing skills in terms of scientific notation and changing it back into standard form. It is not only the Nano technology application part is the challenge; the literacy part of this unit is the bigger challenge. This year, we are using Canvas to house our lessons, documents, and assignments to begin integrating technology into every classroom. Students were introduced to creating a graphic organizer to contain the skill in writing the scientific notation method. In addition, they will be reading articles about Nano technology and watching videos,

writing their reflection, and answering some questions before their final project submission.

The concluding formal assessment is a product of the student's choice showing the students' success in comprehending the Nano technology general education and applying it to show their skills in advertising a career path connected to nanotechnology. The other informal assessments will include an argumentative essay where they have to support their knowledge on Nano technology and its impact on our modern society by claiming a product made with Nano science based on evidence they found during their research on Nano technology. This assignment will be supported with an outline or graphic organizer taught by the Language Arts teacher. The essay will be broken down so that students basically will be researching, reflecting, and writing drafts before they finalize the essay. A rubric will be provided to get them accustomed to checking their final draft to make sure all requirements were met.

Most of my resources are from the lesson plans website which is part of the National Nanotechnology Infrastructure Network (NNIN). This website consists of specialized nanotechnology laboratories at 13 universities across the nation was funded in 2004 by the National Science Foundation as part of the NNI program. The NNIN provides researchers from across the nation with economical access to state-of-the art nanotechnology facilities.

Strategies and lessons

Our principal and our school leadership team has been eagerly promoting growth in literacy this year; and they are requesting for literacy proof in every lesson plan. My intentions are to help students understand the size of Nano scale while learning about nanotechnology and its impact on their future. I will open the unit with questions, like: How many of you have heard the word Nano? In, what ways have you heard the term Nano used? What do you think Nano means? The purpose of this lesson is to help students learn "*what is Nanotechnology*?" to understand the size of the Nano scale, and to relate the size of a nanometer to everyday objects while learning the math skills. Therefore, the first introductory hands-on activity is reading the article from the National Nanotechnology Infrastructure Network's education portal. It can be accessed from http://www.nnin.org/nnin_what.html.

Next, Students will view the panel discussion video *Introduction to Nanotechnology* (26 minutes) prepared by the Penn State University's center for Nanotechnology Education and Utilization. Students will learn the benefit of nanotechnology on society.

Nanotechnology is changing the world and the way we live, creating scientific advances and new products that are smaller, faster, stronger, safer, and more reliable. After about 20 years of steady progress in nanotechnology research and development,

scientists in the United States and around the world have a much clearer picture of how to create Nano scale materials with properties never before envisioned. Scientists and engineers are exploring exciting new discoveries at the Nano scale every day. Nanotechnology is helping to considerably improve, even revolutionize, many technology and industry sectors: information technology, energy, environmental science, medicine, homeland security, food safety, and transportation, among many others.

Students will have the chance to discuss their feelings and findings on the size and its impact on human function by answering the following questions below. The answers provided in italics should be suggested or concluded through the discussions and videos.

1. Define Nanotechnology. *Nanotechnology is the science and technology of small things – in particular things are less than 100nm in size.*

2. What is the diameter of human hair? *60 – 80,000nm*

3. One nanometer is equal to *10-9 meters*

4. List the three important factors included in nanotechnology.

    a. *Small size, measured in 100s of nanometers or less*
    b. *Unique properties because of the small size*
    c. *Control the structure and composition on the nm scale in order to control the properties.*

5. What is new about nanotechnology? *Scientists and engineers can understand and control atoms and molecules and their properties to make new functional materials and devices.*

6. What is meant by to-down nanotechnology? Give an example. *It is when small features are made by starting with larger materials and patterning and "carving down" to make Nano scale structure in precise patterns. Example – microprocessor.*

7. What are the branches of science involved in the study of nanotechnology? *Physics, chemistry, electrical engineering, chemical engineering, biochemistry and biophysics, and materials science.*

8. In reading the article, the term "highly interdisciplinary area" was used, explain what is meant by highly interdisciplinary. *It involves ideas integrated from many traditional disciplines.*

First Math Skill

Changing the pace of the lesson to cover the math skill will be done by completing the chart below. It presents a valuable lesson and examples to review some metric system examples from daily life. I will use these as examples when I model the lesson and solve examples on writing numbers in scientific notation from daily life application. We will complete this chart as a class. All these lesson materials: The posters, Nanometer, The scale of Things, the article, the worksheet, and the video will all be uploaded to the class canvas for the students' convenience.

Prefix	What power of 10 does this prefix represent	What object exist at this distance from the earth or at this scale?
Peta-	$1x10^{15}$	Entire solar system
Giga-	$1,000,000,000 = 1x10^{9}$	Distance of the earth and moon
Kilo	$1,000 = 1 \times 10^{3}$	Distance between two towns
Deci-	$0.1 = 1 \times 10^{-1}$	A lily flower with a bee on it
Centi-	0.01 or 1×10^{-2}	Approximate width of a pinky fingernail
Milli-	$.001 = 1 \times 10^{-3}$	A bee's eye
Micro-	$.000001 = 1 \times 10^{-6}$	Virus on a bacterium
Nano-	$0.000000001 = 1 \times 10^{-9}$	Structure of DNA

Teaching how to write very small scientific numbers with Nano scale is the first math goal of this unit. The hands-on activity is completing a data table where students will record estimated diameter, diameter in centimeters, diameter in millimeters, and diameter in nanometers for 10 objects. (See appendix 2). But first, I will ask the students to jot down their estimates in the first column, then I will provide a metric ruler and a Nano Ruler (available at nanozone.org). Have students identify the metric markings, such as

millimeters (mm) centimeters (cm) decimeters (dm). They should also examine the Nano Ruler to see the units of measurement. Then, students will complete the table by measuring and entering their results in the table. Afterwards, they need to be converting the measurements into the other metric units. For example, if the length is 1.9 meters, then you would convert the 1.9 meters to 190 centimeters, 1900 millimeters. Micrometers and nanometers can be written using scientific notation. After measuring and recording the data, the whole class will be drawing conclusions to analyze the data. I will lead a class discussion about their estimates and actual sizes. We will compare the measurements in the data table across each row. How are they similar? How are they different? Students should conclude that the measurements numbers are the same except for the location of the decimal point. We will also discuss how we determine which metric unit is best for which object. Students should conclude that using the metric unit is easy to read and say for our regular objects; whereas Nano scale is used to measure the very tiny, almost invisible materials. Then I will talk about the metric system and the English system and compare them. Students should conclude that the metric system makes it easy to convert one unit to the other. For instance to change meters to centimeters, we only have to move the decimal point two places to the right. On the other hand, changing inches to yards requires multiplication by 36, and changing inches to feet requires multiplication by 12.

To write scientific notation numbers in Nano scale should also include an important dimension, the time. Students will be exposed to the nanotechnology timeline, National Nanotechnology Initiative explains in details the history of nanotechnology. Moreover, students will be learning about the very speedy movement of nanoparticles. We use Nano scale for measuring the very fast motions of materials, molecules, and events inside man-made or natural process. For example, the motion of medicine inside the body, the solar light, and the exchange in stock market.

In nature around us there are various physical events that occur on time scales from the yoctosecond (10^{-24} second) to the exasecond (10^{18}second). In the time it just took your heart to beat once, the computer on the desk next to you completed about one billion clock cycles, whereas the electron of a hydrogen atom could have circled its proton about 1 quadrillion (10^{15}) times. On the other hand, that very slow heart beat is actually quite fast and fleeting if one considers it relative to the 500 quadrillion (500 x 10^{15}) second lifetime of our universe. Within this tremendous range of time scales, science and technology, which are constantly improving, determine how accurately different events can be measured or inferred.

A nanosecond (ns) is a SI unit of time equal to one billionth of a second (10^{-9} or $^{1}/_{1,000,000,000}$ s). One nanosecond is to one second as one second is to 31.69 years. The word nanosecond is formed by the prefix Nano and the unit second. Its symbol is ns. So a time measurement is a direct or indirect comparison to this defined standard. I will

share with the class few examples of very speedy natural and chemical processes which are measured in Nano scale. Some examples like,

Humans can correctly identify images seen for as little as 100 milliseconds. A whole class discussion on the biology of human eye sight and the mathematics of lenses.

An electromagnetic wave transports its energy through a vacuum at a speed of 3.00 x 108 m/s (a speed value commonly represented by the symbol c). The actual speed of an electromagnetic wave through a material medium is dependent upon the optical density of that medium. Different materials cause a different amount of delay due to the absorption and reemission process. Furthermore, different materials have their atoms more closely packed and thus the amount of distance between atoms is less. These two factors are dependent upon the nature of the material through which the electromagnetic wave is traveling. As a result, the speed of an electromagnetic wave is dependent upon the material through which it is traveling. For more information on physical descriptions of waves, visit The Physics Classroom Tutorial.

The technology of quantum dots is applicable here. I, personally, enjoyed this knowledge with our professor during the seminars. Quantum dots are very cool to discover how tiny they are, how they move, and how they change color. The most notable usage of this technology is the TV screens. As Dr. Raymond M. Soneira, President of Display Mate, explains: "Instead of using existing White LEDs (which have yellow phosphors) that produce a broad light spectrum that makes it hard to efficiently produce saturated colors, Quantum Dots directly convert the light from Blue LEDs into highly saturated narrow band primary colors for LCDs."

As a whole class we will read the article in the Washington Post which was published in 2011 by Charles Krauthammer about the implications of the discovery of a particle that can travel faster than light. This will open up a discussion and I will allow opinions to be exchanged so that the students get involved and get fascinated in the research of this field.

The second math skill

I will teach with a hands-on activity will be applied when students learn volume in 8^{th} grade. By the way, they should have mastered surface area skill in 7^{th} grade; so this activity is an extension on prior knowledge. It is designed to help students understand how nanoparticles may be more effective catalysts by investigating how the surface area-to-volume ratio of a substance is affected as its shape changes. This activity is meant to complement a chemistry unit on catalysts. Nano-sized materials have a significant portion of their atoms on the surface. Understanding how catalysts work involves studying chemical reactions at the molecular and atomic scale. For this reason, catalysis can be considered one of the earliest forms of Nano scale science. Students will experience the

impact of surface area of the particles by their chemical reactions. I will model the experiment shown in this video.

After we finish the experiment, this classroom activity should be another valuable learning goal. Students will make shapes from clay and record their findings when they change the surface area. This activity works well individually. But first I will review with my students how to calculate surface area. Then I have to teach volume of rectangular prism (box), cylinder, cone, pyramid, and sphere, according to 8^{th} grade standard. Provided that the students have grasped the skill of calculating volume, handouts of the worksheet and formulas will be provided. Students will be given waxed paper, modeling clay, metric ruler, calipers, pencil, and a calculator. First, the students have to make a prediction of what shape we should use to make it more explosive. I will lead them to the conclusion that a ball is the most appropriate shape. Students will follow the instructions to make the biggest shape they can make out of the piece of clay they have. They will be guided on how to measure the diameter so that they will be able to calculate the volume and surface area of the shape. Next, students are asked to split the clay and make two shapes; then they measure the diameter to get the radius and record the volume of each smaller ball and the surface area of each. Step three is to divide each ball into two smaller shapes and to measure and record the surface area of each. Bearing in mind and keep reminding the students that the volume of the original shape is the volume of all the smaller shapes which were originated from the original one. The teachers' background section, resources, and preparation are provided in the references. The main goal behind this activity is that students should be guided to the comprehension of how effective is the surface area-to-volume ratio in chemical reactions. They should find out that as the surface to volume ratio increases a greater amount of substance comes in contact with surrounding material. This result in a greater proportion of the material being exposed for potential reaction. Therefore, industries determine how quickly the chemicals will react by calculating the surface area-to-volume ratio (A/V) of the reactants; and thus they try to use reactants and catalysts that will react very quickly to form the products they will sell, in order to make profit. I will remind students that catalysts accelerate a chemical reaction without interfering with the finished product by helping the reactants to meet much more quickly. Then we will begin the lab.

Procedure for surface area-to-volume ratio activity

1. Place the wax paper atop your desk. For each of the steps below, be sure to use all of the clay. Do not remove any clay between measurements.
2. Press the clay into a ball shape.
   - Use the caliper to measure the diameter of the ball. Divide it to find the radius. Use the volume formula, calculate the volume of the ball. Volume of a ball (sphere): 4/3 pi x $(\text{radius})^3$
3. Use the surface area formula given, Surface Area of a Sphere = 4 pi r^2, calculate the surface area of the shape.

4. Use the table provided below to record your findings, then calculate the ratio of surface area/to volume
5. Divide the ball into two smaller balls, using all the clay. Here students should be reminded that the volume remains the same but we have to calculate the surface area of each of the smaller balls.
6. Use the calipers to measure the ball's diameter. Write your measurement in the table, calculate using the formula and record.
7. Roll the clay and split each ball into two smaller balls; then repeat the measuring, calculating, and recording the surface area of each ball.

	Surface area of each (cm^2)	Total surface area of all objects (cm^2)	Volume (cm^3)	Ratio: $\frac{\text{surface area}}{\text{volume}}$
One ball				
Split into 2 balls			same	
Split each into 2 more balls			same	
Split the smaller into more smaller balls			same	

Draw Conclusions

1. Which shape had the smallest surface area-to-volume ratio?
2. Which shape had the largest surface area-to-volume ratio?
3. Of the shapes you tested, which shape would you recommend as the most reactive catalyst? Explain.
4. Why are manufacturers interested in using nanoparticles for catalysts? *Manufacturers want to make their products cheaply. They can do this by using inexpensive materials that can be quickly made. Nanoparticles have a high surface area-to-volume ratio and would react very quickly.*

After analyzing the surface area to volume ratio, I will show the students another video where a teacher demonstrates the same experiment we did with alka seltzer, proving that the smaller surface area produces higher reaction. I will start a conversation on careers and educational opportunities in nanotechnology. By now, students should have learnt what nanotechnology from the opening activity and they learnt its scale and its effect on chemical reaction.

Moreover, for integrating literacy in my lesson plans, as required, I will read to the students the introduction to this activity, which states their mission and goal and what the expectation when they complete it.

"*Plants can now be turned into a car fuel based on alcohol, but the exhaust has pollutants, like carbon dioxide. We need your help to make a clean burning fuel cell that combines hydrogen and oxygen to make energy, steam, and nothing else. The fuel cell itself has already been invented, but we still haven't been able to cheaply make a hydrogen source. Many oil refineries use a platinum catalyst to make a fuel, but platinum is so rare that it's worth more than gold. We must find a cheaper alternative! Nickel is for more abundant than platinum, and much cheaper. If we can find a way to use nickel instead of platinum, we might make hydrogen fuel cells affordable for the masses! Nickel if it is made small enough, can react with air like dynamite. Help us make a device that will make hydrogen using only air, water vapor, and sunflower oil using two nanoparticle catalysts – one based on carbon, and the other based on nickel. What shape should we use for the nickel nanoparticles to make them more explosive?"*

The Project

The final part of the unit is a formal assessment with a project. Students will have the option of choosing a career or a consumer Nano-product. A rubrics will be handed out and the concluding artifact presented by the students is a poster.

Option 1: Career project.

This aligns with the career week which the 8th grade counselor promotes each year. Therefore, this project not only impacts the students' college-readiness; it will also provide positive impression to my leadership proficiency for my evaluation. The students should be able to gather information on what are the career opportunities in a particular field or what are the career paths to enter nanotechnology. Using the internet, students should determine what area of nanotechnology interest them. These can include:

- Electronics/semiconductors Industry
- Biotechnology and medical fields
- Pharmaceutical Industry
- Optoelectronics
- Environment and water purification
- Food and agricultural industry
- University research and teaching
- Health and safety

The research should be presented on a poster and questions they might want to explore include: what type of job? What types of degrees are available? How does this job incorporate nanotechnology or education background of nanotechnology? What is the typical pay level? What type of place would you work in? What type of training do you need? Would you like to do this job, why and why not? I created my own rubrics (appendix 3) but some of the titles from this rubrics.

Option 2: Product commercial.

Students should select a consumer product with nanotechnology used in manufacturing it to advertise. They will investigate the material and manufacturing label to present the nanotechnology used. They will include a picture of the product and download a copy of the product description information sheet. The goal is to advertise the product by including such information as what is Nano about the product and why it is better than its non-Nano counterpart. The rubrics for this option mandates that the poster should include description of the product, how is it used, what is "Nano" about it, how does it work, how is it different from its "non-Nano counterpart, and what do you think of the product? Although this is an informational type of research, students are asked to think critically about the product. Is it really good? Does it have any potential harm? Is it better than non-Nano product? Certainly, I will provide my students with a list of websites for potential sources for their research and a Nano products resource list from National Nanotechnology Infrastructure Network. Additional information on consumer products utilizing nanotechnology is available at http://www.nanotechproject.org (A nanotechnology Consumer Products Inventory). At this site you will find a list of over 200 products with a description of the product and a link to the manufacturer's web site. Rubrics for this project is presented. The advertisement should include at least the required information below:

	Major components of the advertisement
Title: The product	
What is it used for? Or How does it work?	
What's Nano about it?	
What is the advantage of using Nano in this product?	
Does it have other applications	

Average Price	
Is there a non-Nano product alternative?	
The information was obtained from: **List "bibliography" of your research**	

Closure

As a conclusion to the unit, I have to mention the one difficulty I had to deal with during this preparation of this unit. I was so overwhelmed with the immense information, research, and resources for nanotechnology. I was stunned with all the information about its impact on our society and our future. This huge power of nanotechnology on our civilization has challenged me with lots of thinking and planning on how to limit my questions and inquiries to this unit's plan. It has been so hard to adhere to the outline and to the appropriate content as much as the students' minds, feelings, and reactions will spread out with this subject; I am sure it will be a valuable, fascinating turning point for them and their future. As you read above, I have used it to teach two math skills while I had to "back off" a lot before I dig deeply into more scientific statistics; I kept reminding myself, it is for 8^{th} graders. I am sure my students will enjoy this unit while learning, investigating, and reflecting on the future with nanotechnology as much as I enjoyed the research, the readings, and all the seminar meetings in the Chemistry lab at UNCC.

Appendix 1: Implementing Teaching Standards

The common core standards for the math skills:

CCSS.MATH.CONTENT.8.EE.A.3
Use numbers expressed in the form of a single digit times an integer power of 10 to estimate very large or very small quantities, and to express how many times as much one is than the other. For example, estimate the population of the United States as 3 times 108 and the population of the world as 7 times 109, and determine that the world population is more than 20 times larger.

CCSS.MATH.CONTENT.8.G.C.9
Solve real-world and mathematical problems involving volume of cylinders, cones, and spheres.
Know the formulas for the volumes of cones, cylinders, and spheres and use them to solve real-world and mathematical problems.

The Common Core Standards in reading informational text, writing, and language are as follows:

- RL.8.1. Cite the textual evidence that most strongly supports an analysis of what the text says explicitly as well as inferences drawn from the text.
- RL.8.4. Determine the meaning of words and phrases as they are used in a text, including figurative and connotative meanings; analyze the impact of specific word choices on meaning and tone, including analogies or allusions to other texts.
- RL.8.5. Compare and contrast the structure of two or more texts and analyze how the differing structure of each text contributes to its meaning and style.

W.8.9. Draw evidence from literary or informational texts to support analysis, reflection, and research.

a. Apply grade 8 Reading standards to literature (e.g., "Analyze how a modern work of fiction draws on themes, patterns of events, or character types from myths, traditional stories, or religious works such as the Bible, including describing how the material is rendered new").

b. Apply grade 8 Reading standards to literary nonfiction (e.g., "Delineate and evaluate the argument and specific claims in a text, assessing whether the reasoning is sound and the evidence is relevant and sufficient; recognize when irrelevant evidence is introduced").

- W.8.11b. Create poetry, stories, plays, and other literary forms (e.g. videos, art work).

Appendix 2

Data table for measurements

Object	Estimated diameter	Diameter in centimeters (cm)	Diameter in Millimeters (mm)	Diameter in Nanometers (nm)
Penny				
Quarter				
Marker				
Small can				
Pencil				
M&M				
Mint				
Large Can				

Appendix 3

Rubrics for Career Project

	Advanced 90-100	Proficient 80 - 89	Basic 70 - 79	Below Basic 60 - 69
Description of the career	Detailed description of the job is required. Information on job responsibilities is given along with the condition and frequency in which they are done.	There is a description of the job requirements. Information on some job responsibilities is given.	There is little description of the job requirements	No description of the job is included
Education and Training	There is a detailed description of the educational, training requirements. It provides information on any degrees, certificates, licenses, or other special requirements. It also provides the estimated time required to complete requirements.	There is a description of the educational/training requirements. It provides information on any degrees, certificates, licenses, or other special requirements.	There is little description of the educational/training requirements.	There is NO description of the educational/training requirements.
Salary and benefits	There is a detailed description of the salary and possible benefits for this career. It includes the average and highest level salary levels and gives the yearly, monthly, and hourly rate, if applicable.	There is a description of the salary for this career. It gives the yearly, monthly, and hourly rate, if applicable.	There is little description of the benefits and salary levels for this career.	There is NO description of the salary for this career.
Personal Reflection	Developed a detailed justification of personal characteristics and	Developed a list of personal characteristics that are beneficial to	Developed a list of personal characteristics, but does not	Did NOT develop a list of personal characteristics.

And opinion to pursue the career	natural abilities that are beneficial to professionals in this career.	professionals in this career.	state why they are beneficial to the career.	
Total points				

Bibliography

http://www.nnin.org/sites/default/files/files/edu poster11x172 QR code.pdf.

Poster for classroom

Digital image. National Nanotechnology Infrastructure Network. Accessed October 30, 2016. http://www.nnin.org/sites/default/files/files/scale_of_things_26may06.pdf.

Poster will be displayed in the classroom and uploaded in class canvas for students information

Degrees That Work: Nanotechnology. January 11, 2010. Accessed September 09, 2016. https://www.youtube.com/watch?v=Joa7OyzEFGs.

This is the introductory video that students will watch and reflect on

"8th Grade Mathematics Unpacked Content." Public Schools of North Carolina. Accessed June 06, 2016.

http://www.ncpublicschools.org/docs/curriculum/mathematics/scos/8.pdf.

This document is designed to help North Carolina educators teach the Common Core (Standard Course of Study). NCDPI staff are continually updating and improving these tools to better serve teachers.

Bonsor, Kevin, and Jonathan Strickland. "The World of Nanotechnology." HowStuffWorks. Accessed October 30, 2016. http://science.howstuffworks.com/nanotechnology.htm.

The article on this website is interactive and provides lots of images for the

students while reading. I did not print it. I uploaded the URL link on the class canvas.

"Everyday Applications of Nanotechnology." Science in Community Colleges. October 3, 2011. Accessed November 20, 2016. http://ccweek.com/article-2630-everyday-applications-of-nanotechnology.html.

This report lists examples of daily life applications of nanotechnology.

By Submitting This Form, You Accept the Mollom Privacy Policy. "National Nanotechnology Infrastructure Network." Exploring Nanotechnology through Consumer Products. Accessed October 30, 2016. http://www.nnin.org/education-training/k-12-teachers/nanotechnology-curriculum-materials/exploring-nanotechnology.

This is a great resource for the consumer product project for teachers to share with students

By Submitting This Form, You Accept the Mollom Privacy Policy. "National Nanotechnology Infrastructure Network." How Big Is a Nanometer? Accessed October 30, 2016. http://www.nnin.org/education-training/k-12-teachers/nanotechnology-curriculum-materials/how-big-nanometer.

This is a detailed lesson plan giving us the right to use, copy, and print. I used it and it is effective for the students to comprehend the size of a nanometer

Diddams, Scott, and Tom O'Brian. "What Is the Fastest Event (shortest Time Duration) That Can Be Measured with Today's Technology, and How Is This Done?" *Scientific American*. doi:10.1075/ps.5.3.02chi.audio.2f.

Most current theories of the universe hold that time, space, and energy all become intertwined at very short time intervals and over very short distances, for which energy becomes very great

There's Plenty of Room at the Bottom. By Richard Feynman. December 29, 1959.

Krauthammer, Charles. "Gone in 60 Nanoseconds." *The Washington Post*, October 7, 2011. Accessed 2016. http://www.highbeam.com/doc/1P2-29817214.html?refid=easy_hf.

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A good resource for math formulas

"Time Conversion Tables from Nanoseconds, and Quicker, to Light Years." Time Conversion Tables from Nanoseconds, and Quicker, to Light Years. Accessed November 20, 2016. http://www.simetric.co.uk/si_time.htm.

This website is a great resource to teach time measurement in regular and Nano

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Notes from Dr. Marcus Jones while attending the seminars.