A Multifaceted Unit on Cells, Scale, and Nanotechnology

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Overview

This unit is intended for students in Grade 7 and will be scheduled to occur over a three to four month period. The unit is designed using several activities that can stand-alone, but are intended to build, reinforce, and enrich student learning. In this curriculum unit a selection of objectives and activities are combined to provide students with multiple opportunities to acquire relevant information and synthesize learned content using strategies similar to the problem-based approach. Students in grade seven (7^{th} graders) will be introduced to what a cell is, some of the first leading contributors to theories about cells, and the components that comprise a cell. Here the concept of surface area-to-volume ratio is introduced. Students will learn and make a model of cell organelles and how animals take in nutrients and expel waste products, along with the accompanying terminologies. The metric system will be covered providing a framework of size of ordinary objects and extremely small-sized material. Students will then integrate and apply learned content to nanotechnology and the real world. Finally, through the production of a culminating project, students will visually demonstrate why surface area to volume is related.

Rationale

As a teacher, it is important to reach all learners. Because they are diverse learners, it is important to note the set of skills and previous knowledge urban students bring to a class Consequently, instruction should be provided with as much practical application as possible. Hopefully, in this manner students will have a better appreciation for the instructional material. As a result, teachers may find students have more academic gains than if they just taught the subject through rote and memorization.

Student Performance

This curriculum is being developed because students performed below average during coverage of cell theory within the first report period of the school year. Specifically, a class within the School District of Philadelphia that was taught life and physical science had their data compared to similar students within their school and school district. Looking at *Figure 1(in the* appendix at the end of this document) this class performed below their peers in the school and district.

However, the up and down trends are similar for all 7th grade students in both the school and district, that completed the benchmark mark test during the 2008-2009 academic year. Looking at the data a few notes come to mind. First, students completing the benchmark in the School District of Philadelphia performed, on average, at or below fifty percent. Second, students seemed to have similar increases/decreases in comprehension and/or comfort level with the content across the District. This is particularly interesting because it discounts differences between teachers and school/classroom resources.

Figure 1 (in appendix) data points correlate to the following Core Curriculum topics: The month of October focused on descriptions of the six kingdoms and classification; November covered cell theory and parts of the cell; the content of January highlighted Earth's atmosphere; the focus of March was weather; and May covered descriptions of waves and their properties. The trend patterns for all students suggest there are multiple variables that influence learning. Qualitatively, teachers know some factors include students perception of the subject and/or the teacher, whether the subject is at the beginning, middle or end of the school day, whether it is warm or rainy and even school vacations. Given the multitude of varied factors, teachers must focus on one or two factors that relate to learning and channel their energies appropriately.

Teacher Observations

As a novice classroom teacher, it became obvious that at least one of the factors in student success was the language of the subject. Inner-city students in general do not have exposure to the vocabulary and the contexts that words have as they relate to science. As an example, the word 'volume' has multiple definitions as listed by merrianm-webster.com:

1. a series of printed sheets bound typically in book form; book; a series of issues of a periodical;
2. the amount of space occupied by a three-dimensional object as measured in cubic units (as quarts or liters)
3. the degree of loudness or the intensity of a sound

In science, the context of the word 'volume' relates to the amount of space occupied by matter as measured in cubic units. Yet students' background knowledge of the word 'volume' relates most often to the loudness of sound when using technology, such as a radio or television. Most students have no formal training on the word-definition for 'volume'. Most individuals come to know the meaning through everyday occurrences, such as being asked to turn down the volume which is immediately followed by someone manipulating a control that reduces the degree of loudness from a radio or television.

Students' ability to comprehend content and achieve targeted learning goals can be hampered by their associative word patterns they bring into the classroom. Bolger, et al. note in their article Context Variation and Definitions in Learning the Meanings of Words: An Instance-Based Learning Approach that "*deriving meaning involves the explicit goal of attempting to learn the meaning of target words from context whereas incidental learning assumes the absence of any explicit learning goal*" (124). In short, Bolger, et al are stating one must consciously know they are learning a new word-meaning and also be actively engaged in the process of learning the new word-meaning. This is exactly what individuals do when they open a dictionary to get the meaning of an unfamiliar word that was encountered while reading a book.

As stated by Bolger, et al., the more exposure an individual has to a word, the more associative connections they may develop. This would occur as the individual had repeated encounters with a word as used in varied contexts and also as the individual was exposed to the explicit definitions of the word. "*In word learning, a resonance mechanism would cause words in the reader's knowledge base that are related to the context to be activated; and these words, along with the words in the context, would become associated with the new word. What is learned then would be a weak pattern of association that would become part of the word's associative meaning*" (124).

Learning occurs most effectively when students have multiple venues in which to acquire and reinforce knowledge. Therefore, teaching students with hands-on activities will increase their contextual understanding of concepts taught. Further, the use of scaffolding has been shown to provide a richer learning environment. Through the use of process science teaching, students have used observing and recording to apply concepts and terms to learn and reinforce the content. Instruction has also occurred through the use of literature to provide students with varied material that informs the reader about the content and real-world applications. Through the use of manipulative activities, students have observed demonstrations from the teacher and their peers.

In the short term, student willingness to learn will increase as the teacher incorporated different models of science teaching – process science teaching, reading about science, and direct instruction. In the long-term, it is the goal of this teacher to incorporate project-based science to give students an opportunity to collaborate through inquiry and design in which they can take more ownership in and of their learning.

Real-World Application

Nanotechnology and its applications abound. Whether reading a leisure book or a scientific journal, one comes across biological and technological trends in current or future applications of nanotechnology. Biologically, nanotechnology is being developed among other things, for pharmacological uses. The Journal of Nanobiotechnology describes research that is being conducted to use bacteria as a delivery system for vaccines and drugs. The journal articulates some of the possible uses as "*numerous biological applications of nanotechnology, including self-assembly of supramolecular structures, slow release and delivery of enzymes and drugs, biocoatings and molecular switches actuated by chemicals, electrons or light. Many of these applications involve the development of sophisticated self-assembled surface substrates, particularly those with defined spaci*ng" (volume 1, issue 6). In short, drugs are being developed that can be 'programmed' for the specific patient condition to be treated. These pharmaceuticals are designed to be attached to the surface of a delivery system and ejected or combined with the bacteria, virus, or cellular material responsible for the ailment.

The delivery of pharmaceuticals via bacteria occurs at the surface. All chemical reactions take place at the surface where outer electrons can interact with other electrons. It is the property of adsorption of matter that allows particles to bind relatively weakly on the surface and not the inner spaces. This is different than the property of absorption where particles are immersed into the inner cavities of matter whereby the entire volume and surface can become saturated.

Application

If you asked your students "how many have taken medicine in the past", almost all would raise their hand. As individuals, teachers and students alike, people take medicines for a host of reasons. In a broad perspective, these reasons include management of biological, physiological, and psychological functions. Learning how the body processes and could process medicines seems no different than learning how the body digests food. It is simply an opportunity to better understand ourselves and the natural and man-made environment.

In this unit students will explore the surface area-to-volume ratio. The topic will be taught using process science teaching, reading about science, direct instruction, model-building, and incorporation of project-based science. This will give students an opportunity to collaborate through inquiry, design, and will include artifacts to explore surface area-to-volume ratio. For example, students will use an egg and discuss how the growing chicken gets its nutrients, read literature about cells and eggs, use math manipulatives to reinforce the mathematical content, and use various materials to model surface area-to-volume ratio and endocytosis and exocytosis.

The curriculum unit will be implemented during the first report period when students learn about cells and cell theory as prescribed by the School District of Philadelphia's Scheduling Timeline. Cell theory begins approximately late October.

Objectives

This unit is intended for students in Grade 7 and will be scheduled to occur over a three to four month period. The unit is designed using several activities that can stand-alone, but are intended to build, reinforce, and enrich student learning.

Building Model of Cell Instructional Objective

As an introduction, students will participate in an activity designed by Kathryn Hopkins, Cells on Ceiling. In teams students will be assigned an animal cell organelle to research. Also, all student teams will cooperate to create a large scale-sized model of an animal cell and its organelles. As an assessment tool, student teams will use a photocopy of an animal cell and its parts and cross-reference with the model to verify that all cell organelles are incorporated.

Reading Instructional Objective

After the model is complete, students will listen to a recording and follow in the assigned textbook, Cells, Heredity, and Classification, to read the section *The Diversity of Cells*. Periodically, students will stop and identify terms that are unfamiliar. Students will again and independently re-read the section and will quickly write images and associations of words that came to mind as they read. Then, in teams, students will tally and organize the vocabulary selected as a class to create a frequency chart. Using the frequency chart, student teams will create a collage that pictorially illustrates six science terms identified.

Students will then create a timeline, dating the discovery of cells and key events between 1492 and 1879. For recent and current events, students will use websites for appropriate research.

Direct Instruction Instructional Objective

After students have been introduced to the basics of the cell, they will observe a demonstration by the teacher of endocytosis and exocytosis. Through use of a strainer, the teacher will provide an opportunity for students to understand how cell and organelle membranes act to let some materials in/out and not other materials. Students will then discuss and puzzle through, as a group, what other materials could have been selected and how different sized materials affect the ability and rate of substances to pass through a barrier. Students, working in groups, will perform the demonstration, independently as a lab, by selecting materials and analyzing results in oral and written form.

Similarly, students will learn or review the metric units of measurement. Students will cover the formal definitions of the units of mass, distance, and the metric prefixes. Using Holt, Rinehart and Winston's Mathematics in Context: Made to Measure, students will compare units of measurements from a historic and practical perspective. Next, students will use the textbook published by Holt, Rinehart and Winston Introduction to Matter to cover what mass measures (matter) and how matter can be described.

Finally, students will make comparisons of objects from ordinary sizes down to the nano-sized through use of a lesson, Size and Scale-Learning about Measurement, developed by the Georgia Institute of Technology. Using common objects, students will scale down objects using the metric system. At the conclusion, students should have an understanding of and be able to visualize the nano-scale as compared to ordinary-sized objects.

Project –Based Instructional Objective

Students will synthesize prior learning of the cell as they investigate nanotechnology and its application through problem-based learning. Using readings from on-line journals, students will learn about emerging techniques of nanotechnology in the pharmaceutical industry. Following, students will work on a surface area-to-volume ratio lab, using curriculum materials provided by the National Nanotechnology Infrastructure Network. The surface area-to-volume ratio activity will guide student's inquiry and at this point students will realize there are accompanying mathematical skills they will have to incorporate. Through collaborative work, students will enrich their understanding and skills as applied to science, literacy, history, and math. The project will culminate with students presenting concrete artifacts, such as posters or models. Students will use a checklist, of which a sample is included at end of this document, to provide a framework for cooperative and collegial participation of learning.

Correlation To School District of Philadelphia

The curriculum unit aligns with the objectives of the Scheduling and Timeline of the Core Curriculum. These objectives pertain to 7th grade science, during the 1st quarter of the school year (2nd Six Week Cycle) and include the following:

- State the parts of the cell theory
- Explain why cells are so small
- Describe the parts of the cell

- Describe how eubacteria are different from archaebacteria
- Explain the difference between Prokaryotic cells and Eukaryotic cells
- Identify the parts of a eukaryotic cell
- Explain the function of each part of a eukaryotic cell

In addition, the curriculum unit directly coordinates with the Pennsylvania Academic Standards for Science as outlined in 3.3.7.B. These standards are listed in the Appendix at the end of the document. Through use of the textbook, discussion, manipulatives, and research, students will describe the cell as the basic structural and functional unit of living things, identify the levels of organization from cell to organism, compare life processes at the organism level with life processes at the cell level, and explain that cells and organisms have particular structures that underlie their functions. Students will apply cell theory and cellular function and structure applications to nanotechnology.

Strategies

The following strategies will guide the performance of the teacher in assisting students in learning and synthesizing information on cells and nanotechnology.

Model Building Strategies

In the Journal of Research in Science Teaching, authors Barab et al. of the article Virtual Solar System Project: Building Understanding through Model Building, state that artifacts support students learning and understanding (722). Using model-building as a strategy, it is the responsibility of the teacher to facilitate cooperative learning within the classroom environment.

The role of the teacher will be that of coach to allow students the freedom of range in decision-making. Primarily, the teacher will provide a framework in which students work together. One strategy the teacher can use is to give students an assigned role or component for building the model. This will give students a start point from which to begin working in their group. It should be noted that roles of students' might change within their individual group.

At the conclusion of model-building, students will complete a survey evaluating their role and that of their partners. This activity within the curriculum will become the reference point for students for how groups work and can be improved to work for their project-based activity.

Reading Instruction Strategies

During reading instruction the teacher will use the guiding framework of why prior knowledge is necessary in preparing students to become more confident and competent readers of the various types of texts they will be assigned. To accomplish this, the teacher will have students read and dialogue with other students. The teacher will use strategies such as paired summarizing where students work in pairs reading and summarizing; reciprocal teaching, where students read and write questions they have about text to discuss in small groups; and metacognition, where the teacher will model how an individual develops internal conversations with the text as they read.

Direct Instruction Strategies

Direct instruction has multiple components. As outlined in Introducing Academic Strategies to Students: A Direct-Instruction Approach by Jim Wright, these steps will be broken down as follows: (1) the teacher will explicitly show and explain the information and how to use it, (2) the teacher will allow the students time to reinforce and practice using the information under supervision with frequent feedback and praise, (3) the teacher will allow students time to use the skill independently , and (4) the teacher will provide the students with multiple settings or situations in which the information is used.

The teacher will use direct instruction to cover the topics of metric units of measurements using material published by Holt, Rinehart and Winston's Mathematics in Context: Made to Measure. The topics of mass and matter will be covered using the textbook also published by Holt, Rinehart and Winston, Introduction to Matter. The teacher will provide opportunities of learning related to measuring objects at the nano-scale. The teacher will use instructional material, Size and Scale-Learning about Measurement, developed by the Georgia Institute of Technology and available at the Education Portal website of the National Nanotechnology Infrastructure Network.

Project –Based Strategies

The strategy used by the teacher will be that of facilitator or tutor. Problem-based projects are inherently designed to be controlled and directed by way of student inquiry. The teacher will assist students' independent endeavors of completing the assigned activity, where they must use prior knowledge and synthesize content learned. The teacher will be available to guide students, but not provide them with specific answers. Here the teacher will have to resist re-teaching. Floundering students will be encouraged with techniques such as reduction of proximity. For instance, initially, the teacher will sit next to students needing assistance as they work through a solution, providing verbal and non-verbal affirmation. Upon the next occurrence, the teacher will provide encouragement from a slight distance. The overarching strategy is to create a nurturing and non-threatening environment so that students progress through their learning independently.

Classroom Activities

The following lesson plans are examples for the instructional objectives of model building, reading, direct instruction, and the culminating project. Some of the lesson plans are created by the teacher while others are borrowed. If the lesson plan is borrowed it will appear similar to how the author published it, with a notation of the identity of the publisher. Typically, a frame of time is not given in acknowledgement that each group of students is inherently unique potentially requiring more time to prepare and complete activities and lessons. However, the entire curriculum unit is covered by design, over a three to four month period.

Building Model of Cell Instructional Objective

Cells on Ceiling lesson as borrowed from Kathryn S. Hopkins, a teacher from Robinson High School in Waco, TX as it was posted on web page of The National Health Museum. The Museum has a dedicated site where teachers of health and bioscience can exchange lessons and activities at http://www.accessexcellence.org/AE/.

- *Strategy*: group, cooperative learning, model building
- *Materials*: large clear plastic drop cloth (Can be purchased at a building supply company in various sizes), string or wire to attach "cell" to the ceiling, student-created organelles
- *Assessment*: the teacher can evaluate the students on the oral and written presentation of the cell structure: what were the criteria for choosing the particular media for the cell structure, and did students communicate its function and importance? The three components that need to be considered in the evaluation are the individual report, team work and collaboration, the individual organelle in relationship to the whole cell product. The criterion by which the completed cell is evaluated includes originality (media used and presentation), flexibility (media used), fluency of description, and elaboration (attention to detail in making the structure). Students rate each other verbally and on a 1 to 10 scale. Also, each student does a self-evaluation of his/her contribution to the group.
- The warm-up for this activity is a forced-relationship (synectics) exercise whereby students justify an unusual comparison. For example, a nucleus is like a computer because...it organizes information. This format leaves the portion of the sentence after "because..." incomplete for the students to fill in. Additional examples are: a chloroplast is like a microwave because.... Or, the cell membrane is like a Ziploc™ bag because.... Each student generates his/her own "reasons" and sentence completions. Comparisons are shared and discussed.

- Each student is assigned a cell part to research, create, and place inside of a clear plastic drop cloth (the cell) the size of one-half of the classroom ceiling. Students must use critical thinking skills and problem solving to find the appropriate media for their cell structures. The structures must be scaled to the size of one-half of the ceiling.
- Each class plans and makes its own cell. One is a plant cell, and the other is an animal. (If more classes are involved and classes are large, sizes can be scaled down to produce more cells.)
- The challenge is finding something (a media) of a size proportional to a "ceiling cell." A cytoskeleton of straws, an endoplasmic reticulum of toilet paper or crepe paper, lysosomes of blue ping pong balls, or chloroplasts of green tennis balls are a few ideas for structures.
- The individual report is flexible in terms of format. The presentation could be a scientific paper and informative speech, newscast, HyperCard stack, slide show, dramatization, or story book. Reports must include the following: title, comparison of individual structure to a modern day (common) object, function of structure, appearance of structure, drawing of total cell with all parts labeled, and rationale for choosing the specific media used for the ceiling model.

Reading Instructional Objective

- *Strategy*: paired summarizing, reciprocal teaching, metacognition
- *Materials:* text, journal relevant to unit
- *Assessment:* pose a question and have each student write a response. After, ask a few volunteers to share their response. A question may be "What did you learn from this exercise as it relates to preparing yourself to become a more confident and competent reader of the various types of texts you will be assigned in different classes?'
- *Essential Question*: Why is prior knowledge necessary in preparing students to become more confident and competent readers of the various types of texts they would be assigned in different disciplines?
- *Before*: The teacher will distribute to students a reading passage of one paragraph from relevant journal (relating to content) and have them write one to two sentences summarizing the paragraph and the perceived purpose of the article the paragraph was taken from. Then students will re-read it and this time take note of the images/associations made as they read the paragraph. Next, the teacher will go around the room and have each briefly read their summary and include one association. This should be limited to the 1-2 written sentences. As students share the teacher or designated student will record responses on the board highlighting differences.
- *During*: The discussion will be driven toward knowledge-building dimensions. The teacher will ask whether there were any words or a phrase that were

unfamiliar, or was the word order and sentence structures uncomfortable as a 'readable fit'. Again, responses will be recorded on the board. The teacher will inform students that many people tend to read easiest genre or text that has an appeal. The teacher will continue to tell students that often just one or two unfamiliar words can hinder understanding of a sentence and consequently the passage. Common words that students are uncomfortable with will be highlighted and then students will be asked what made the other phrases less uncomfortable. This should ultimately lead to a conservation relating to prior knowledge and how it influences comprehension. Finally, the teacher will lead students into a discussion of associations students made with other prior information that did facilitate understanding.

- *After*: The class will take a slight detour away from science content to reinforce to concept of knowledge building and visualization as it relates to literacy skills. With students working in groups of no more than three, they will read and discuss the *Star Spangled Banner* and identify the larger ideas/images associated with the text of the song. Each group will report out to class what prior knowledge, if any, is necessary to fully comprehend the meaning /message of the song. (This should relate to American History). Though this does not relate to the content of the curriculum, the lyrics offer visual imagery to drive home the bigger idea of prior knowledge and visualization of text.

Direct Instruction Instructional Objective

There are several lessons that will be covered using direct instruction. These include endocytosis and exocytosis, the metric system, and size comparisons.

<u>Endocytosis and Exocytosis Lesson</u>

Students will observe as teacher uses a strainer using listed materials to separate substances.

- *Strategy*: demonstration
- *Materials*: wire mesh, gravel, marble, pan, sand, water, bucket, balloons
- *Assessment*: on-going, informal
- Students observe a strainer to understand how cell and organelle membranes act to let some materials in/out and not others.

Students will then proceed with an inquiry activity understand how cell and organelle membranes act to let some materials in/out and not others using <u>The Jelly Bean Problem</u> lesson as borrowed from Glenn Westover, a teacher from Louis & Sarah Block Yeshiva High School in St. Louis, MO as it was posted on web page of The National Health Museum. The Museum has a dedicated site where teachers of health and bioscience can exchange lessons and activities at http://www.accessexcellence.org/AE/. This activity focuses on endocytosis so students will be asked to reverse the solved process to demonstrate exocytosis.

- *Strategy*: group, cooperative learning
- *Materials*: (per group of two students) 1 plastic shopping bag, 1 pair of scissors, 15 cm of string, 4 pieces of wrapped candy
- *Assessment*: have students do a drawing (like the solution above) to describe the process of endocytosis.
- *Note*: preparation for this activity students are asked, "How can large particles get into cells?" If students understand the cell to be a fluid-filled membrane (like a water balloon) then the problem of maintaining its integrity with a hole in its side presents a problem as a mechanism for taking in food particles. Prepare students by first letting them play with bubbles to experience fluid-like membranes.
- Before starting the exploration activity, have the students consider the following (kinds of) questions:
  - How do large particles, those too large to diffuse, get into cells?
  - Do cells have mouths?
  - Does swallowed food mingle or mix with the organelles?
  - Which cell organelle could function as a mouth?
- The Problem: With the materials in hand, the students are challenged to get the candy into their bag according to the following rules:
  - The candy must enter through a solid part of the bag.
  - The inside of the bag may not be directly open to the external environment.
  - The candies entering the bag must remain clustered together.
  - Students may work with their hands in the bag to act as the inside of a cell.
  - The candy may be eaten only if it enters the bag "cell" under the specified conditions. Students must show the teacher their solution before they may eat any candy.

Metric System Lesson

Instructional materials as provided by the School District of Philadelphia will be Math in Context: Made to Measure, Geometry and Measurement.

- *Strategy*: group, cooperative learning
- *Materials*: (per group of two students) 1-meter piece of rope, centimeter or inch rulers, inch or centimeter tape measure, meter stick, paper clips, yardstick
- *Assessment*: the Metric Measurement Hunt from the Free Library by Farlex, which can be accessed at http://www.thefreelibrary.com/. Students will work with a partner to find items in the classroom with specific metric lengths, such as 45 cm,

1.5 m, and 6 mm. They will record the object, the actual length, and the difference between the estimated and actual length. Discuss the objects found and the accuracy of students' guesses. Choose an appropriate non-standard measurement unit to measure length.

- *Students will*
  - Investigate historical measurement units by averaging the length of body parts.
  - Compare the customary and metric measurement systems.
  - Investigate the relationship between customary and metric measurement units and find conversion rules.

Introduction to Matter Lesson

- *Strategy*: individual, group, cooperative learning
- *Materials*: various materials, including, solids, liquids, and gas
- *Assessment*: students complete a 15 item quiz
- Students will explore the difference between mass and weight and how both are measured by observing a demonstration on volume.
- After students will label sheets of paper with section heading from Properties of Matter to learn about matter and how volumes of solids, liquids and gases are measured.
- As students read the section they will write what they learned about each main idea under the appropriate label heading

Size and Scale Lesson

Size and Scale-Learning about Measurement has been developed by the Georgia Institute of Technology and is available at the Education Portal website of the National Nanotechnology Infrastructure Network. The teacher should refer directly to the website for additional information and materials that may be useful for this activity at http://www.nnin.org/doc/sizeandscalerevised.pdf.

- *Strategy*: group, cooperative learning
- *Materials*: images of objects and the units of measurement (available for download), string, rope, or clothesline to create the "scale", clothespins or clips to secure images to the "scale"
- *Assessment*: on-going, informal
- *Other useful materials*:
  - "*Powers of Ten*" explores the relative size of things from the microscopic to the cosmic -- http://powersof10.com
  - Teaching resources on the metric system can be found at the U.S. Metric Association -- http://lamar.colostate.edy/~hillger/

    - "*Scale of Objects*" by Nanosense offers a series of units designed for high school students: http://www.nanosense.org
    - "*How Small is Nanotechnology*?" offers activities to explore the size of the nanoscale including the nanometer ruler. http://nanozone.org/How.htm
    - "*Zoom" and "Re-Zoom*" by Istvan Banya are interesting picture books related to size and scale. Although designed for younger children, even adults enjoy the books' images.
    - NNIN Nanotechnology Poster is a simple poster about nanotechnology with a graphic on relative size of objects at http://www.mirc.gatech.edu/education.php/teacher.resources.php
    - *The Scale of Things* poster from the Office of Basic Energy Sciences is available at http://www.er.doe.gov/bes/scale_of_things.html
    - "How big is a…?" is a interactive size comparison found at
    - http://www.cellsalive.com/howbig.htm
- *Note to Teacher*: in advance of the lesson, download pictures of items of various sizes. Also included are images for different units of measurement such as one meter, one millimeter, etc. Laminating the images will allow them to be used multiple times. Place size markers (1 meter, etc.) along the "scale" by using a logarithmic scale where each equidistant point equals a base ten. You will mark out from 10-9 to 103 for a total of 13 points along the "scale." For elementary students the 1 Meter image may be placed on the line as the first example.
- Prior to beginning the activity, the teacher should introduce or review the metric system. Questions to prompt the discussions:
    - Who has heard of the metric system of measurement?
    - What is the metric system? (The metric system is a decimalized system of measurement based on ten)
    - How does it differ from our system of measurement (inch, foot, yard, mile, 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? (atom, electron, molecule). Most students say a grain of sand, dust, a flea etc.
    - What is a nanometer?
    - How many nanometers are in one meter? (1,000,000,000nm)
    - Can you tell which objects are manmade and which ones made by nature?
    - Explain to students that there is enormous scale in our world and in our universe – from tall mountains to red blood cells; from the solar system to the bacterium that causes disease and illness.
- Hand out an equal number of pictures to each student along with the clothespins. Have them interact with each other to determine how to arrange the pictures on the clothesline in order from smallest to largest. Once completed, have the students present their results to the class and have a class discussion about the order. Correct any misplaced items and explain to the students why the item(s) is

out of order. For example, a common misconception is that a virus is larger than a bacterium.

Project –Based Instructional Objective

The Surface Area-to-Volume Ratio of Nanoparticles was developed by the University of California Santa Barbara and is available at the Education Portal website of the National Nanotechnology Infrastructure Network. The teacher should refer directly to the website for additional information and materials that may be useful for this activity at http://www.nnin.org/nnin_k12surfacevolume.html.

- *Strategy*: group, cooperative learning
- *Materials*: 8.5 inch × 11 inch sheet of waxed paper, modeling clay, the size of a walnut (3 per student), metric ruler, calipers, with metric markings, pencil, calculator, small rectangular box. Prior to beginning the activity, purchase modeling clay at a crafts store. Waxed paper can be purchased at a grocery store. The wax paper is not necessary, but will assist with cleanup. You may wish to purchase calipers at a science supply house or a hardware or hobby store to increase the accuracy of measuring the ball and cylinder. Inexpensive ($5 each) calipers can be purchased online at Widget Supply http://www.widgetsupply.com/page/WS/PROD/measure/BKH29.
- *Assessment*: on-going, informal
- *Note to Teacher*: follow the link below for an easy-to-read article about how surface-to-volume ratio and nanoparticle catalysts may help fuel automobiles. http://www.memagazine.org/nanoapr05/balls/balls.html. This link is a short, sweet article explaining the introduction in the student worksheet: http://www.guardian.co.uk/uk_news/story/0,3604,1291039,00.html
- Before beginning the activity, review with students how to calculate surface area and volume of a cube, box, ball, and cylinder (in student worksheet).
- Guided Dialog Before beginning the lab, review the meaning of these terms:
    - Reactant A substance that is part of the initial materials needed for a chemical reaction.
    - Product A substance that is produced by the chemical reaction.
    - Catalyst A substance that is used to increase the reaction rate of a chemical reaction but does not become part of the end products—it remains unaltered during the reaction.
- Ask students: What happens during a chemical reaction? Chemical reactions occur when the reactants (particles) come into contact with each other and form new products.
- What factors affect what products are formed? Whether or not the reactant atoms are compatible (it depends on the number of valence electrons in the atoms); whether the atoms will meet fast enough to make a new product

- How would an increase in surface area-to-volume ratio for a catalyst increase its effectiveness?
- As the surface to volume ratio increases a greater amount of a substance comes in contact with surrounding material. This results in a greater proportion of the material being exposed for potential reaction.
- What factors affect whether an industry can inexpensively make a product or whether the product would cost more to make? The chemical reaction rate—in order to make a profit, industries try to use reactants and catalysts that will react very quickly to form the products they will sell.
- How can industries determine how quickly the chemicals will react? by calculating the surface area-to-volume ratio (A/V) of the reactants
- Remind students that catalysts accelerate a chemical reaction without interfering with the finished product by helping the reactants to meet much more quickly. Now, begin the lab using Student Worksheet or Guide The Surface Area-to-Volume Ratio of Nanoparticles: Part I as found at National Nanotechnology Infrastructure Network, http://www.nnin.org/nnin_k12surfacevolume.html.

Annotated Bibliography/Resources

Reading List

Berg, Linda Ruth, Barbara Christopher, and Mark Taylor F. Cells, Heredity, and Classification. Austin, TX: Holt, Rinehart and Winston, 2005. Instructional text to be used in the classroom.

Cuevas, Mapi, and Sally A. Vonderbrink. Introduction to Matter. Austin, TX: Holt, Rinehart and Winston, 2005. Instructional text to be used in the classroom.

Math In Context. Mathematics in Context: Made to Measure. Holt, Rinehart and Winston Instructional text to be used in the classroom.

Teachers Resources

Barab, Sasha, A., et al. " Virtual Solar System Project: Building Understanding through Model Building." JOURNAL OF RESEARCH IN SCIENCE TEACHING 37.7 (2000): 719. A research based article that articulates how model-build promotes student understanding of scientific content.

Bolger, Donald J., et al. "Context Variation and Definitions in Learning the Meanings of Words: An Instance-Based Learning Approach." Discourse Processes 45.2 (2008)

Franklin Catalog. Penn Libraries. May 20, 2009
An article that discusses students' ability to comprehend content and achieve targeted learning goals as a factor of their word-associations.

"Celebrate metric week: metric week is October 9 to 13. Middle school math teacher Diane McKeen shares five favorite ideas." The Free Online Library by Farlex. <http://www.thefreelibrary.com/Celebrate+metric+week:+metric+week+is+October+9+to+13.+Middle+school...-a0153293022>
The teacher can find activities to provide students with opportunities to apply and investigate the relationship between customary and metric measurement units. On the noted web page are activities that relate to the metric system.

Freitas, Robert A., Jr. "Pharmacytes: An Ideal Vehicle for Targeted Drug Delivery." JOURNAL OF NANOSCIENCE AND NANOTECHNOLOGY 6.9-10 (Sep-Oct 2006): 2769.
Article describes research that is being conducted to use bacteria as a delivery system for vaccines and drugs.

Hopkins, Kathryn, S. "Cells on Ceiling." The National Health Museum. School District of Philadelphia. <http://www.accessexcellence.org/AE/AEC/AEF/1994/hopkins_cells.php>
This activity will guide student in creating a model of a cell to learn the parts of the cell and its structure.

Krajcik, J., C. Czerniak, and C. Berger. Teaching Science in Elementary and Middle Schools: A Project-Based Approach. 2nd ed. New York: McGraw Hill, 2003.
This book discusses and outlines the guiding principles of problem-based learning and student-centered lessons that are relevant to real-world issues.

"NNIN - Education Portal." National Nanotechnology Infrastructure Network. <http://www.nnin.org/nnin_edu.html>
National Nanotechnology Infrastructure Network (NNIN) consists of 14 sites located at major universities across the country. At this portal teachers and students can learn all about the world of very small structures.

"Problem Based Learning Initiative." Southern Illinois University School of Medicine. Monday, April 03, 2006 3:32:34 PM <http://www.pbli.org/pbl/pbl.htm>
This site describes problem-based learning - what it looks like, how the teacher facilitates the strategy, and the desired results for students.

"Project Based Learning Checklists." <http://pblchecklist.4teachers.org/>
The use of these checklists keep students on track and allows them to take responsibility for their own learning through peer- and self-evaluation.

Ricca, Ezio, and Simon Cutting. "Emerging Applications of Bacterial Spores in Nanobiotechnology." Journal of Nanobiotechnology 1.6 (2003). 29, March 2009 <http://proxy.library.upenn.edu:2266/articlerender.fcgi?artid=317360>
An article that discusses development of bacterial spores as nanostructured surfaces for drug and enzyme delivery.

School District of Philadelphia. Coordinating Documents, 2006 - 2007. Philadelphia, PA, 2006.
The SDP offers a standardized Science Core Curriculum in kindergarten through 12th grade. This document will assist the teacher with instructional planning, pacing, identifying targeted objectives and standards.

SchoolNet, Inc. Instructional Management System. School District of Philadelphia: School District of Philadelphia. May 30, 2009
Helps the SDP analyze data, organize curriculum, track instruction, measure performance, and report results. Also it is an electronic resource to assist teachers with instructional planning, pacing, identifying targeted objectives and standards.

"Size and Scale-A measurement of Unit." National Nanotechnology Infrastructure Network. <http://www.nnin.org/nnin_k12sizeandscale.html>
An activity to help students understand the vast range of sizes of things in the universe, as well as the relative scale of many common things. It is suitable for middle schools students and requires no extra resources.

"The Surface Area-to-Volume Ratio of Nanoparticles." National Nanotechnology Infrastructure Network. <http://www.nnin.org/nnin_k12surfacevolume.html>
This activity 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.

Westover, Glenn. "The Jelly Bean Problem." The National Health Museum. School District of Philadelphia. <http://www.accessexcellence.org/AE/>
This activity will guide students in creating a model of endocytosis and exocytosis to enrich understanding.

Wright, Jim. "Introducing Academic Strategies to Students: A Direct-Instruction Approach." <http://www.interventioncentral.org/htmdocs/interventions/rdngcompr/dirinstr.php#topAnchor>
This site describes direct instruction - what it looks like, how the teacher facilitates the strategy, and the desired results for students.

Student Resources

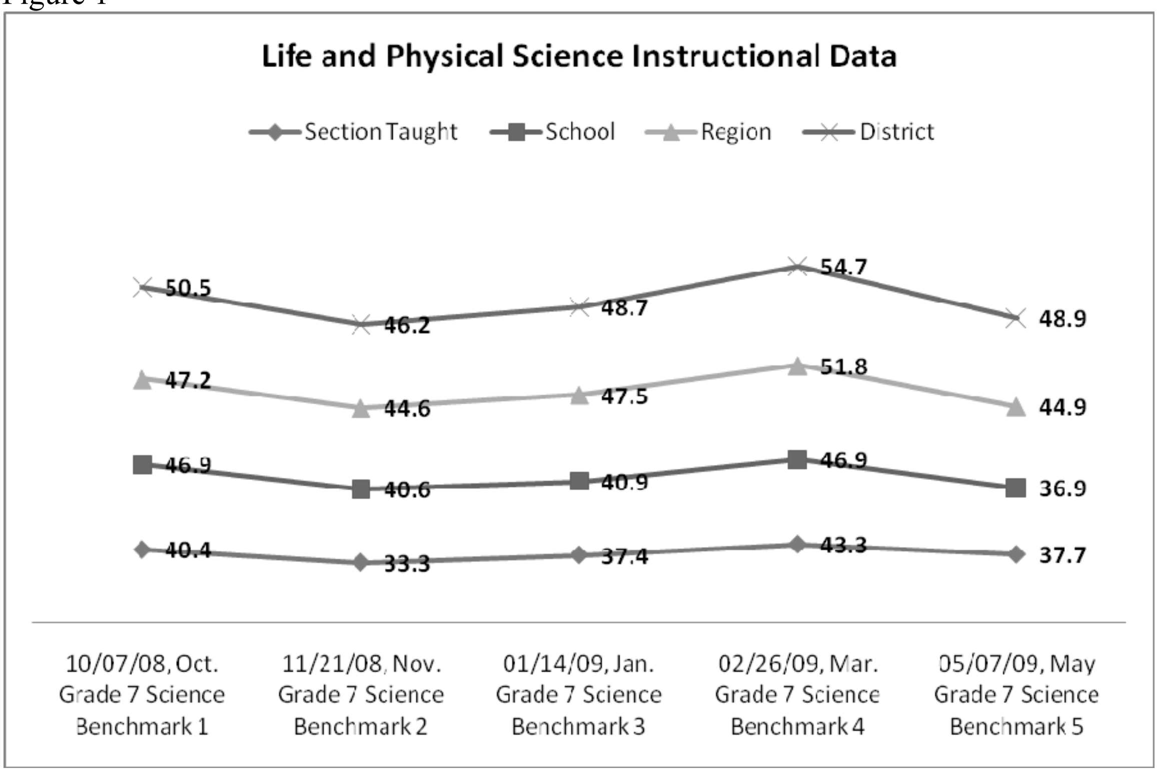
"Chem4Kids.com: Matter." Andrew Rader Studios. <http://www.chem4kids.com/files/matter_intro.html>
Interactive site for students to reinforce learning of matter.

"Inside a Cell." The University of Utah, Genetic Science Learning Center. <http://learn.genetics.utah.edu/content/begin/cells/insideacell/>
Interactive site for students to reinforce learning of part of the cell.

"Nanotech Resources for K-12 Students - NNIN." National Nanotechnology Infrastructure Network. <http://www.nnin.org/nnin_k12.html>
A website dedicated to students. Various links provide information and activities geared to students.

Appendix-Content Standards

Figure 1



(Data taken from School District of Philadelphia Instructional Management System)

This checklist was developed using www.4Teachers.org customizable checklists for problem-based learning. Use of a check list is recommended as it helps guide student progress and promotes ownership of learning.

SAMPLE
Project: Nanotechnology

Student Name:____________________ Reviewer Name: ______________________
Date: _________________

Top of Form

CATEGORY	RESPONSIBILITIES
Background Research	☐ I used a variety of helpful resources. ☐ I used information from scientific journals. ☐ I used information from textbooks. ☐ I used internet resources. ☐ I found recent materials so my information is up-to-date. ☐ I collected enough information to get a good understanding of my topic. ☐ I wrote down where I got each piece of information.
Cooperative Work	☐ I worked well with my group members. ☐ I showed respect and support for fellow team members. ☐ I listened to my partner's ideas. ☐ I did my share of the work. ☐ I contributed both time and effort. ☐ My work made this project better.
Experimental Research	☐ I figured out a question I wanted to answer. ☐ I thought of a way to answer my question. ☐ I made a hypothesis.

- [ ] I gathered information.
- [ ] I thought of some things (variables) that could mess up my experiment.
- [ ] I tried to control things (variables) that could mess up my experiment.
- [ ] I performed the experiment carefully.
- [ ] I recorded the results of the experiment.
- [ ] I summarized the results and told what they meant.
- [ ] I wrote a descriptive title for my experiment.
- [ ] I displayed my project neatly.
- [ ] I made an attractive display for my project.

Laboratory Work

- [ ] I created a storyboard to organize my lab project.
- [ ] I followed the scientific method to do my project.
- [ ] I used suitable equipment for my project.
- [ ] I answered all lab questions as well as I could.
- [ ] I returned all lab materials and equipment to where they belonged.

Lab Safety

- [ ] I cleaned up any mess I made, using safe procedures.
- [ ] I reported any accidents to my teacher, no matter how minor I thought they were.
- [ ] I walked and did not run in the lab.
- [ ] I did not throw things in the lab.
- [ ] I did not horse around or roughhouse.

Relating Concepts

- [ ] I know how this project relates to what we are studying.
- [ ] I know how this project relates to history.
- [ ] I know how this project relates to business or technology.

Academic Standards for Science and Technology, Pennsylvania Department of Education

7th Grade Science focuses on cell theory during the first marking period. The standards that relate to description of the cell as the basic structural and functional unit of living things as listed under part 3.3.7.B are:

- Describe the cell as the basic structural and functional unit of living things
- Identify the levels of organization from cell to organism.
- Compare life processes at the organism level with life processes at the cell level
- Explain that cells and organisms have particular structures that underlie their functions.