Small is Big
Investigating Nanotechnology and its Applications
TEACHER NOTES

Lesson Overview
Nanotechnology is the science of studying and creating materials, devices, and systems using very small particles that measure from 1 to 100 nanometers. This investigation introduces students to the nanoscale. They work in cooperative groups to understand key ideas related to nanotechnology and identify examples of its use.

Inquiry – Students investigate key concepts and structures used in nanotechnology. They discover that matter at the nanoscale has different properties and behavior than the same matter at a larger scale. They learn that advances in technology spur innovation in product use and development.

NOS – Understand how nanotechnology is being applied to create new materials (science is a blend of logic and imagination).

STEM – Students conduct internet-based research using wireless technology to learn about nanotechnology; they determine how engineers apply nanoscale particles and systems to improve methods and develop new products.

Suggested Time
3 45-minute periods

Class Materials
20 cm nitinol wire
20 cm copper or other metal wire
4 250 mL beakers
laptop computers with internet access
hot plate
Bunsen burner or candle
test tube clamp
pot holder

Preparation
- ☑ Reserve a computer cart for classroom use.
- ☑ Identify and bookmark websites for student research.
- ☑ Shape nitinol (memory wire) for teacher demonstration. Bend the wire into a shape, such as a letter. Holding it with a pair of test tube clamps, heat the wire over a candle or Bunsen burner. Let the wire cool on a pot holder. Straighten out the wire.
- ☑ Boil water just before class
- ☑ Set up document camera for teacher demonstration.

Print and Electronic Resources
- National Nanotechnology Initiative http://www.nano.gov/
- Nanooze Magazine http://www.nanooze.org/main/Nanooze/English.html
- How Stuff Works http://science.howstuffworks.com/nanotechnology.htm#
- *Nanotechnology: Big Things from a Tiny World*, National Nanotechnology Initiative, July 7, 2008.
- Streaming video Powers of Ten http://www.youtube.com/watch?v=U04_1iKKC2c
- Applet based on Powers of Ten video.http://sciencenetlinks.com/tools/powers-of-ten/

Small is Big

Investigating Nanotechnology and its Applications

TEACHER NOTES

Key Terms

nanoscale
nanotechnology

Essential Understandings

Conceptual Understanding

- ► All matter has physical and chemical properties.
- ► The ability to manipulate the placement of individual atoms in tiny structures allows for the design of new type of materials with desired properties.
- ► Matter at the nanoscale has unusual properties and functions because of its small size and large surface area.

Procedural Knowledge

- ► A **nanometer** (nm) is one billionth of a meter. 1nm = 0.000000001 m (or 1.0×10^{-9}m). It takes about 3 - 10 atoms to span the length of a nanometer.
- ► **Nanotechnology** is the study and creation of functional materials, devices, and systems using matter that measures from 1 to 100 nanometers.
- ► Nanotechnology has produced new knowledge and innovations that were not previously possible.

Teacher Information

Why is there so much interest in nanotechnology? There is nothing especially new about it. Medieval artists used nanoscale gold salts to produce vibrant colors for their stained glass window designs and nature routinely manipulates nanoparticles to make proteins. The big difference is that modern advances in microscopy (such as the development of the scanning tunneling microscope and atomic force microscope) have given scientists the tools to understand how nanostructures work and, more importantly, why they work.

Researchers have found that particles in the range of 1 to 100 nanometers have significantly different properties from particles of the same substance in the visible range. Properties such as melting point, fluorescence, electrical conductivity, magnetic permeability (the ability of a material to support the formation of a magnetic field within itself), and chemical reactivity have been shown to change with the size of the particle. Gold particles, for instance, are usually gold on the visible scale, but appear red or purple at the nanoscale.

The difference in the properties of matter at the nanoscale has been attributed to their larger surface-to-volume ratios. As the surface area of matter increases, more of the substance contacts surrounding materials; this impacts reactivity. The ability to manipulate the structure of a substance at the nanoscale allows scientists to tailor-make materials with specific properties that can make them stronger, lighter, more durable, or better conductors of electricity. Over 800 consumer nanoproducts are currently available in the industries of sports equipment, textiles, cosmetics, food storage, automotive products, electronics, information technology, air and water filtration, and medical treatment and diagnostics.

New processes and technologies carry both benefits and risks. Temperature, salinity, habitat, or other biological factors may transform nanomaterials released into the environment and change atmospheric, soil, or water chemistry producing unintended consequences that impact human health and the environment. As a result, the United States has created the National Nanotechnology Initiative (NNI) that coordinates the nanotechnology-related activities of 25 federal agencies in the areas of science, engineering, technology, and regulatory affairs. This coordinated research provides data needed to assess the risks to public health and the environment while pursuing the beneficial use of nanotechnology.

Teaching Suggestions

<u>Pre-Assessment</u>

Each student will name the biggest and smallest things with which they are familiar and list five other things that fall between them, in size order. Each student will also demonstrate the relationship between meters, centimeters, and millimeters using a variety of systems (e.g., fraction, decimal, and exponent).

<u>Before Investigation</u>

1. LINK – Ask students to list as many of the physical and chemical properties of matter they have studied in this unit as they can in two minutes. Record their responses on a large class chart that has been divided into two columns – one for each type of property.

2. Pass the nitinol wire around the room and allow students to describe its properties. Record their responses on the chart in the physical properties column. Repeat this same process with the other wire.

3. ENGAGE - Select a student volunteer to bend the nitinol wire into any shape. Select a second volunteer to bend the other wire into any shape. Display the shapes of the two wires for all students to observe.

4. Put both wires into a beaker and pour cold water over them; have the class observe the results. A document camera or other method of projection may be used so that all students clearly see the effect of the water on the metals (i.e., none).

5. Next, pour the cold water off and then pour <u>boiling water</u> over the wires in the beaker. Make sure that students can see clearly because they will observe that the nitinol wire will transform into the shape you molded before the start of class (see **Preparation**) whereas the other wire will not.

6. Ask students to observe the new properties of the wires and add them to the properties chart created earlier. Ask students to name the new property they have just observed (shape memory). Ask them to suggest practical uses for shape memory (e.g., repairing broken bones, straightening teeth, reinforcing arteries and veins,

maintaining the shape of golf clubs and eyeglasses, etc.).

7. EXPLAIN - Tell students they have just witnessed an example of nanotechnology. Ask them if they are familiar with the term. If anyone is, ask them to briefly share what it is, and how they know about it. Note: Students will conduct collaborative research on nanotechnology so the teacher does not need to explicitly teach about nanotechnology since that is what students will discover from their research.

8. Read together the opening paragraphs as well as the **Questions** for investigation. Ask students to complete the **Prediction** which asks them to identify which of the everyday products listed incorporate nanotechnology (all are examples of nanotechnology except the iPod and tiny camera).

9. Tell students they will collaboratively perform research designed to help them understand the way nanotechnology uses properties to improve the performance of materials.

During Investigation

10. ACTIVE LEARNING – Form groups of two to four students. Ask them to read the information on nanotechnology concepts (S 244-245) and to underline or highlight the main idea in each section (see highlighted sentences). Facilitate sharing between groups by supplying newsprint or other method for groups to show what they have identified as the key ideas in each passage. Have the class come to consensus on the key ideas for each of the eight key concepts of nanotechnology.

11. Read aloud **Step 1** (S 246) and explain to students that they will come back to apply what they learn about nanotechnology to these concepts after they have conducted their research about different types of nanotechnology.

12. Have students count off (1-8) and form new groups of 3-4 students based upon number (i.e., all the 1's in a group, 2's in a group, etc.).

13. Read **Step 2** (S 247) and assign one category of nanotechnology to each group. Students can use the online references listed in the investigation or other resources provided by you to conduct their research. Remind groups that they will need to be concise in their writing and just capture the main ideas of each type of nanotechnology and a few interesting examples. A word of caution, there is a lot of information available about nanotechnology. Periodically remind students to collect only the key ideas about each category of nanotechnology.

14. Use a cooperative learning strategy, such as Gallery Tour (*Instruction for All Students, pp. 106*), to facilitate the sharing of information about each category of

nanotechnology between groups or allow the class to decide how they want to share information with one another.

15. To lead into the **Application** (S 249-250), access the Powers of Ten applet or streaming video. The Powers of Ten applet takes viewers on a journey through the Milky Way at 10 million light years from Earth moving in successive orders of magnitude until they reach a tall oak tree. After that, viewers look into a leaf into a microscopic world that reveals leaf cell walls, the cell nucleus, chromatin, DNA, and finally, the subatomic universe of electrons and protons. The video is similar. Use a round robin structure within and between student groups to discuss how scientific exploration and engineering spans the magnitudes of scale.

After Investigation

16. REFLECT– To help students think critically and connect what they have learned to key concepts related to nanotechnology, return to **Step 1** of the investigation (S 246). Consider using a "think aloud" strategy to model for students how to complete this section. Students' responses will vary and should demonstrate that they connect the key concepts to examples of nanotechnology. Use the Discourse Strategy Ranking in MS Science along with scaffolding as needed for background knowledge, language and discourse (i.e., Discourse Prompts) to facilitate student discourse.

17. NEXT STEPS - Students have studied the properties of matter on both the macro- and nano- scales. The next investigation will ask students to reflect on the major concepts about matter addressed in this unit. They will construct a physical model that shows the relationships between the concepts and explains their connections.

Formative Assessment

Given the following words, each student will place them in order from smallest to largest: nanometer, millimeter, centimeter, meter, quark, electron, proton/neutron, nucleus, atom, element, compound, cell, tissue, organ, organ system, organism, comet, moon, planet, galaxy, universe.

Reinforcement

To provide additional learning opportunities use reading strategy Question Swap, vocabulary strategy Show Me the Word and processing activity Line Up found in eCART.

Re-assess student understanding using performance assessment Analyze pH; Describe Properties of Acids and Bases; Describe a Neutralization Reaction and Classify Compounds as Acids, Bases, Salts; Describe a Salt and Explain its Formation found in eCART.

Refer to the table at the end of this lesson for resource numbers.

Extension

Scientists have an obligation to explore the societal and ethical issues associated with the introduction of new technology. Allow students to conduct independent and group research on these issues as they relate to nanotechnology and discuss their findings through a Socratic Seminar.

Small is Big
Investigating Nanotechnology and Its Applications

Are you ready for the next technological revolution? Three decades ago the computer was introduced, and it has quite literally changed the way we live. The next big idea actually turns out to be quite small. In fact, it focuses on objects that are measured in billionths of a meter or **nanometers**. The science of studying and creating functional materials, devices, and systems using very small particles that measure from 1 to 100 nanometers is called **nanotechnology**.

Why is anyone interested in anything so small? Researchers have found that matter at the nanoscale has different properties than the same matter at a larger scale. Materials constructed at the nanoscale may be stronger, conduct electricity better, reflect different colors, filter, insulate, or repel stains better than their larger counterparts. Biologists, chemists, engineers, physicists, and other specialists hope to use nanotechnology to develop better medical treatments, increase energy efficiency, improve pollution control, and develop novel consumer products.

In this investigation you will develop an understanding of key ideas related to nanotechnology and identify examples of materials created using nanotechnology.

Questions

1. How is nanotechnology being applied to develop new materials?
2. What are some current examples of nanotechnology?

Online References

National Nanotechnology Initiative http://www.nano.gov/

Nanooze Magazine http://nanooze.org/

How Stuff Works http://science.howstuffworks.com/nanotechnology.htm#

Key Terms

nanometer
nanotechnology

Prediction

Place an X in the box to indicate which of the products below you believe is an example of nanotechnology.

Student answers will vary

Description of Product	
Paint that resists graffiti	
Colorless sunscreen	
iPod “nano”	
Self-cleaning toilet	
Stain-resistant clothing	
Wire that snaps back to its original shape	
Tennis balls that hold their “bounce” longer	
Ultra light car bumpers	
Cell phone screen	
Tiny cameras to see inside the body	
Odor-resistant sports clothing	

Eight Key Concepts that Unify Nanotechnology

Although there are now thousands of devices and products created using nanotechnology, and keeping track of them may seem overwhelming. There are just a few simple concepts that tie all products created with nanotechnology together. These concepts are -

Scale: You have learned how to measure the physical properties of matter using metric rulers, triple-beam and electronic balances, and electronic probes. These tools work nicely for objects at the macro (i.e., large) scale. However, it’s difficult to measure the properties of a sample of matter that is too small to even see – even with the smallest microscope.

Structure of Matter: All matter is made of atoms. Atoms combine to form molecules. The types and arrangement of atoms give matter its unique identity and properties. For example, the element carbon can combine to form glucose, a common sugar needed for living things to carry out their life processes. However, the same element is found in graphite (pencil lead) which is very slippery and diamonds, which are one of the hardest things in nature. Although all made of the same element – each substance has unique properties.

Properties: You have learned about physical properties such as color, density, conductivity, ductility, and more in this unit. You have also learned about chemical properties such as reactivity and pH. Although the properties you have studied apply at the macro scale, they may or may not be the same when particles of matter are only a few nanometers in size. Therefore, a key idea in the development of nanotechnology is that properties can be different at the macro and the nanoscale.

Forces and their Interactions: Forces describe all interactions of matter. Most of the forces you observe in your everyday life relate to the force of gravity. However, at the nanoscale, gravity really doesn't have much effect. At the nanoscale, electromagnetic forces play a major role influencing the interactions of matter.

Tools and Instrumentation: The development of the scanning tunneling microscope in 1981 allowed us to view individual atoms and their bonds. Based on the new information from this microscope, instruments were soon created to manipulate individual atoms and create new materials – one atom at a time. Without these technological advances the field would still be mere ideas and not the multi-billion dollar global industry it is today.

Self-Assembly: Like the DNA in your body and stars in outer space, a key idea in nanotechnology relates to the ability of some materials to organize themselves into organized structures. Self-assembly happens when the proper building materials are brought together under the right conditions producing organized structures.

Models and Simulations: You learned in "**The Invisible Atom**" about the importance of models in science as tools to visualize, study, explain, and make predictions about phenomenon. The field of nanotechnology uses computer and other models to help predict the properties and behavior of materials made at the nanoscale.

Science, Technology and Society: Because it's such a new field, and advances are occurring with lightning speed, no one is yet sure about the ways in which nanotechnology might impact nature or the environment. Debates are ongoing as to the possible positive and negative consequences of nanotechnology.

Directions and Responses

Step 1 Using the electronic resources listed at the beginning of this investigation, and others supplied by your teacher, read about nanotechnology and its applications. Summarize what you learn about the concepts that unify nanotechnology below.

Scale: How small is a nanometer? Create an analogy to explain to someone the "concept" of a nanometer. *Student answers will vary.*

Structure of Matter: Give one example of an atom that when combined in different ways has very different properties. *Student answers will vary.*
Sodium is a very reactive metal. When combined with oxygen and hydrogen, it forms the strong base, NaOH. When sodium combines with the toxic gas chlorine, it forms NaCl, which we use to season food.

Properties: Give three or more examples of properties of a material that are different at the macro and nano scale. *Student answers will vary.*
Copper at the macroscale is malleable, but at the nanoscale it is super hard. Gold is yellow at the macroscale, but deep red to black at the nanoscale. Silver is non-toxic at the macroscale, but nanoparticles are capable of killing viruses on contact.

Forces and their Interactions: How does scale influence the physical and chemical properties of a substance? *Student answers will vary.*
A greater surface area exposes more of the nanomaterial to other substances; this can affect its reactivity. Nanoscale substances also have smaller forces acting on them, i.e., gravity has no effect at the nanoscale.

Tools and Instrumentation: Give one example of technology not already mentioned above used in nanotechnology today. *Student answers will vary.*
Corning Gorilla Glass 3 is used in electronic devices such as TV and Smartphones. It cleans easily, is cool to touch, and is damage resistant.

Self-Assembly: Give two or more examples of how self-assembly is used in nanotechnology. *Student answers will vary.*
In the biological sciences, self-assembly has been used to regenerate human tissue and deliver drug treatments.

Models and Simulations: Give two examples of models and simulations that scientists use, or that you have used to help you understand some aspect of nanotechnology and its application. *Student answers will vary.*
The Pill Camera can be helpful in finding digestive diseases and water-resistant sportswear.

Science, Technology, and Society: List one example of a recent debate or publication that discusses the pros and cons of nanotechnology. *Student answers will vary.*
One con is that some people may lose jobs because manufacturing jobs will be completed by nanorobots. A pro is that nanotechnology may provide the ability to stop diseases, slow down aging, and rid our environment of harmful chemicals.

Step 2 Using the electronic resources given at the beginning of this investigation, and others supplied by your teacher, list characteristics and provide examples of each category of nanotechnology in the chart below.

Category	Characteristics	Examples
Nanocomposites	*Packaging items by using thinner material with lighter weight and greater shelf life.*	*Automobile parts, lightweight packaging material, tennis balls with a coating that keeps them bouncing longer, water-resistant materials, flame retardants, nitinol wire*
Nanocrystals	*Tiny particles of a semiconductor material that have unique optical and electrical properties different from larger particles.*	*Electronic sensors, antimicrobial bandages, magnets, cancer surgery, drug discovery, medical diagnostics*
Nanoparticles	*Particles where the size of the particle changes properties from the larger particles. Particles that measure 1-100 nm in diameter.*	*Stain resistant fabrics, graffiti-resistant paint, sunscreens*
Ferrofluids	*A fluid made of nanoparticles that is strongly magnetized in the presence of a magnetic field.*	*Sealants and aerogels for insulation, contrast agents for MRI, loudspeakers*
Nanostructured materials	*Improved and enhanced through nanotechnology engineering. Nanomaterials have different properties than those at the macro scale.*	*LED screens for cell phones, cameras, etc.*

Category	Characteristics	Examples
Nanotubes	*Long, hollow structures formed by one-atom thick particles often made of carbon; 100X stronger than steel, conduct electricity better than copper and silicone.*	*Sports equipment, semiconductor chips, imaging internal organs, body armor, concrete bridges*
Nanocatalysts	*Nanoparticles are used increasingly as catalysts to boost chemical reactions. They have high surface area and catalytic activity, are absorbent, natural and synthetic, and have a wide range of applications.*	*Automobile catalytic converters, explosives*
Nanofilters	*A filter that is capable of filtering the smallest of particles.*	*Sterilizing drinking water and medicines, aides in growth of bone, neurons, tendons, and ligaments*

Summary

1. Work independently or collaboratively to synthesize what you have learned about nanotechnology. Include reference to the unifying concepts, categories, characteristics, and give some relevant examples to help you give a comprehensive picture of this new field of science.

2. Look back at your responses to the Prediction. How might you categorize these items differently now? Explain.

Application

1. You are shown two different pairs of khaki pants. How might you determine if either has been manufactured using nanotechnology?
   Nanofabrics often have the same feel and texture as other fabrics. To identify if the fabric is manufactured with nanotechnology, test the properties of the fabric. For example, a cotton product wrinkles and absorbs water. Cotton fabric manufactured with nanotechnology may be wrinkle and/or water resistant.

2. In India a car company introduced an inexpensive four-passenger car it called the Nano. However, this car includes no nanotechnology. To what might the "nano" in the car's name refer? Does this mislead the public?


Courtesy of Nicolas Mirguet

   The Nano car is likely marketed to emphasize its small size. Its name seems may mislead some who expect the car to include some elements of nanotechnology in its design and operation.

3. A nanometer is one-billionth of a meter. Use scientific notation (i.e., exponential notation) to state the following. Show how you arrived at your answer.

   (a) 1 nanometers = __1.0×10^{-9} ________________ m

   (b) 1 meter = ___*1.0×10^{9}*_____________________ nm

4. Science and engineering are two very important fields. They both require creativity and use more than just one method. Science investigations often try to better understand the natural world. Engineering investigations usually attempt to solve a practical problem.

The quest to improve human lives is at the heart of engineering. Many practical problems face humankind such as how to reduce the cost or effects of energy production, producing safe, clean water and air, providing high quality and low cost medical treatment, etc.

In your opinion, which nanotechnology product is making the greatest positive difference in the world? Support your opinion with specific examples.
Student answers will vary but should tie a major problem with its nanotechnology solution. For example, if students feel that clean drinking water is a major problem in the world, they might believe the "nanostraw" will make the biggest difference – especially for those living in parts of the world without access to clean, safe drinking water.

Small is Big
Investigating Nanotechnology and Its Applications

Are you ready for the next technological revolution? Three decades ago the computer was introduced, and it has quite literally changed the way we live. The next big idea actually turns out to be quite small. In fact, it focuses on objects that are measured in billionths of a meter or **nanometers**. The science of studying and creating functional materials, devices, and systems using very small particles that measure from 1 to 100 nanometers is called **nanotechnology**.

Why is anyone interested in anything so small? Researchers have found that matter at the nanoscale has different properties than the same matter at a larger scale. Materials constructed at the nanoscale may be stronger, conduct electricity better, reflect different colors, filter, insulate, or repel stains better than their larger counterparts. Biologists, chemists, engineers, physicists, and other specialists hope to use nanotechnology to develop better medical treatments, increase energy efficiency, improve pollution control, and develop novel consumer products.

In this investigation you will develop an understanding of key ideas related to nanotechnology and identify examples of materials created using nanotechnology.

Questions

1. How is nanotechnology being applied to develop new materials?
2. What are some current examples of nanotechnology?

Online References

National Nanotechnology Initiative http://www.nano.gov/

Nanooze Magazine http://www.nanooze.org

How Stuff Works http://science.howstuffworks.com/nanotechnology.htm#

Key Terms

nanometer
nanotechnology

Prediction

Place an X in the box to indicate which of the products below you believe is an example of nanotechnology.

Description of Product	
Paint that resists graffiti	
Colorless sunscreen	
iPod "nano"	
Self-cleaning toilet	
Stain-resistant clothing	
Wire that snaps back to its original shape	
Tennis balls that hold their "bounce" longer	
Ultra light car bumpers	
Cell phone screen	
Tiny cameras to see inside the body	
Odor-resistant sports clothing	

Eight Key Concepts that Unify Nanotechnology

Although there are now thousands of devices and products created using nanotechnology, and keeping track of them may seem overwhelming. There are just a few simple concepts that tie all products created with nanotechnology together. These concepts are -

Scale: You have learned how to measure the physical properties of matter using metric rulers, triple-beam and electronic balances, and electronic probes. These tools work nicely for objects at the macro (i.e., large) scale. However, it's difficult to measure the properties of a sample of matter that is too small to even see – even with the smallest microscope.

Structure of Matter: All matter is made of atoms. Atoms combine to form molecules. The types and arrangement of atoms give matter its unique identity and properties. For example, the element carbon can combine to form glucose, a common sugar needed for living things to carry out their life processes. However, the same element is found in graphite (pencil lead) which is very slippery and diamonds, which are one of the hardest things in nature. Although all made of the same element – each substance has unique properties.

Properties: You have learned about physical properties such as color, density, conductivity, ductility, and more in this unit. You have also learned about chemical properties such as reactivity and pH. Although the properties you have studied apply at the macro scale, they may or may not be the same when particles of matter are only a few nanometers in size. Therefore, a key idea in the development of nanotechnology is that properties can be different at the macro and the nanoscale.

Forces and their Interactions: Forces describe all interactions of matter. Most of the forces you observe in your everyday life relate to the force of gravity. However, at the nanoscale, gravity really doesn't have much effect. At the nanoscale, electromagnetic forces play a major role influencing the interactions of matter.

Tools and Instrumentation: The development of the scanning tunneling microscope in 1981 allowed us to view individual atoms and their bonds. Based on the new information from this microscope, instruments were soon created to manipulate individual atoms and create new materials – one atom at a time. Without these technological advances the field would still be mere ideas and not the multi-billion dollar global industry it is today.

Self-Assembly: Like the DNA in your body and stars in outer space, a key idea in nanotechnology relates to the ability of some materials to organize themselves into organized structures. Self-assembly happens when the proper building materials are brought together under the right conditions producing organized structures.

Models and Simulations: You learned in "**The Invisible Atom**" about the importance of models in science as tools to visualize, study, explain, and make predictions about phenomenon. The field of nanotechnology uses computer and other models to help predict the properties and behavior of materials made at the nanoscale.

Science, Technology and Society: Because it's such a new field, and advances are occurring with lightning speed, no one is yet sure about the ways in which nanotechnology might impact nature or the environment. Debates are ongoing as to the possible positive and negative consequences of nanotechnology.

Directions and Responses

Step 1 Using the electronic resources listed at the beginning of this investigation, and others supplied by your teacher, read about nanotechnology and its applications. Summarize what you learn about the concepts that unify nanotechnology below.

- Scale: How small is a nanometer? Create an analogy to explain to someone the "concept" of a nanometer.

- Structure of Matter: Give one example of an atom that when combined in different ways has very different properties.

- Properties: Give three or more examples of properties of a material that are different at the macro and nano scale.

- Forces and their Interactions: How does scale influence the physical and chemical properties of a substance?

- Tools and Instrumentation: Give one example of technology not already mentioned above used in nanotechnology today.

- Self Assembly: Give two or more examples of how self-assembly is used in nanotechnology.

- Models and Simulations: Give two examples of models and simulations that scientists use, or that you have used to help you understand some aspect of nanotechnology and its application.

- Science, Technology, and Society: List one example of a recent debate or publication that discusses the pros and cons of nanotechnology.

Step 2 Using the electronic resources given at the beginning of this investigation, and others supplied by your teacher, list characteristics and provide examples of each category of nanotechnology in the chart below.

Category	Characteristics	Examples
Nanocomposites		
Nanocrystals		
Nanoparticles		
Ferrofluids		
Nanostructured materials		

Category	Characteristics	Examples
Nanotubes		
Nanocatalysts		
Nanofilters		

Summary

1. Work independently or collaboratively to synthesize what you have learned about nanotechnology. Include reference to the unifying concepts, categories, characteristics, and give some relevant examples to help you give a comprehensive picture of this new field of science.

2. Look back at your responses to the Prediction. How might you categorize these items differently now? Explain.

Application

1. You are shown two different pairs of khaki pants. How might you determine if either has been manufactured using nanotechnology?

2. In India a car company introduced an inexpensive four-passenger car it called the Nano. However, this car includes no nanotechnology. To what might the "nano" in the car's name refer? Does this mislead the public?

3. A nanometer is one-billionth of a meter. Use scientific notation (i.e., exponential notation) to state the following. Show how you arrived at your answer.

   (a) 1 nanometers = ______________________________ m

   (b) 1 meter = ______________________________ nm

4. Science and engineering are two very important fields. They both require creativity and use more than just one method. Science investigations often try to better understand the natural world. Engineering investigations usually attempt to solve a practical problem.

The quest to improve human lives is at the heart of engineering. Many practical problems face humankind such as how to reduce the cost or effects of energy production, producing safe, clean water and air, providing high quality and low cost medical treatment, etc.

In your opinion, which nanotechnology product is making the greatest positive difference in the world? Support your opinion with specific examples.