Teacher's Preparatory Guide

Creating and Testing Silver-Nanoparticle Socks

Overview: Many people consider nanotechnology to be the latest scientific revolution and it is utilized in many industries ranging from food preparation to clothing to military hardware. Students should be aware of this impact on their lives and need to understand at least the basic concepts of nanotechnology. This lab will allow students to use the pure silver nanoparticles they synthesize to create antibacterial socks. They will compare their socks with socks that have been treated with a commercial silver spray, socks that have been treated in a factory, and a control that was not been treated. After a 24-hour period in which the bacteria will be allowed to grow on the agar plates, each culture (which will contain a piece of sock) will be observed for a zone of inhibition. Socks are easy for students to relate to and show how nanoparticles can have simple relevant applications.

Purpose: Students will synthesize silver nanoparticles and observe their antibacterial properties when applied to socks. Students will also be able to compare the effectiveness of different types of nanosilver-containing socks in inhibiting bacterial growth and make conclusions based on data collected.

Level: High school biology and chemistry

Time Required: Three 50 minute periods

Big Idea of Nanoscale Science: Size Dependent properties; Science, Technology, and Society

Materials: (for groups of 2- 4)

- Safety materials - goggles and nitrile gloves (lab aprons are optional)
- Glassware (one per student group) - 50 mL Erlenmeyer flask, 10 mL graduate cylinder, small vial to store colloid solution
- Distilled water
- 0.001 M Silver nitrate solution - 20 mL per student group
- 0.003 M Sodium citrate solution - 2 mL per group
- Hotplate with stirrer
- Magnetic stir bar
- Four agar plates
- *Micrococcus* or *staphylococcus epidermidis* bacteria
- Bunsen burners
- L-shaped glass stirring rod (for spreading bacteria)
- 1 mL graduated pipettes
- Graduated cylinders (10 mL and 1 L capacity)
- Aluminum foil
- Ethanol for sterilization

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Development and distribution partially funded by the National Science Foundation
NNIN Document: NNIN-1280
REV :07/2012

- Nanosocks (Ex. Wigwam, Xstatic, or Xsystem)– 1 pair can be shared among group of 30 students
- Mesosilver Spray – 1 bottle
- Normal Socks – 1 pair can be shared among a group of 30 students
- Forceps / Tweezers
- Oven safe mitt
- Biohazzard waste container
- Artificial sweat (optional)

Safety: All individuals in the lab should be wearing safety goggles and closed-toed shoes. Students should wear nitrile gloves since they may come in contact with silver nitrate. A lab apron may also be worn by students at the teacher's discretion. When heating solutions, student should use caution when working with hot glassware, as hot and cold glassware look the same. Download the appropriate MSDS for the chemicals.

Advanced Preparation:

- Silver nitrate - Sigma Aldrich, Catalog number 35375-1L
    - This solution is 0.1M, so to create the 0.001M solution needed for this activity, place 10 mL of the 0.1M solution into a 1L container, and then fill the container with 990 mL of distilled water. Be sure store the container in a dark place or cover it with a reflective material such as aluminum foil, as the silver nitrate will react with light.
- Sodium citrate (reducing agent) - Fisher Scientific, Catalog number 7230-16
    - Molarity of the solution is 0.34M. To make 0.5 L of a 0.003M solution, take 5 mL of the 0.34M solution and add 495 mL of distilled water.
- *Micrococcus* or *Staphylococcus Epidermidis* - Carolina Biological Item # 155157
    - Bacteria should be grown at 37 degrees Celsius. Bacteria will be diluted 1/100 mL with distilled water before the students plate the cultures.
- Artificial Sweat (optional)
    - Per 100 mL of sweat need mix 108 g sodium chloride (Sigma Aldrich - S9888), 12 g lactic acid (Sigma Aldrich - W261106) and 13 g urea (Sigma Aldrich - U5378) into a 100 mL volumetric flask. Add distilled water to bring the solution to 100 mL. Mix well.

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Teaching Strategies: The following strategies will be used to teach this unit on the antibacterial properties of nanoparticles.

1. Ask students to fill in the following KWL chart that they will complete by the end of the lesson.

K What I **K**now (about nanotechnology)	W What I **W**ant to Know (about nanotechnology)	L What I **L**earnt (about nanotechnology)

2. Ask students how many parts they think a meter ruler would have to be divided up to equal one nanometer. After fielding several responses, teacher can explain that the meter ruler would have to be divided into one billion equal parts to arrive at a nanometer.
3. Discuss the relationship between a nanometer and the width of a strand of human hair.
4. Using place value charts, students can examine the relationship and differences in scale between numbers like 10, 100, 1,000 , 1,000,000 and 1,000,000,000 on one end of the spectrum; and the relationship and difference between a tenth, hundredth, thousandth, millionth and billionth.
5. This learning activity could also be tied to money. One student wins $10 in a game. Another wins 10 times that amount (as so on).
6. Explain or review the steps of the scientific method.

Teachers can use

1. Whole group instruction to introduce students to the concept of nanotechnology. Discovery Education (www.discoveryeducation.com) has excellent videos that introduce the topic to students at middle or high school levels.
2. Cooperative learning and peer tutoring allow students to share responsibilities and engage in hands-on activities.

Teacher Background: Nanoparticles are made of thousands of atoms of an element and are extremely small, ranging from1 to 100 nanometers (nm) in size. The nanoparticles often have different properties than those associated with the element at the macroscale. Nanoscale silver has been used as an antibacterial agent, and can even kill harmful strains of bacteria which are resistant to antibiotics. Silver nanoparticles have been used in the dressing of wounds, surgical masks, food packaging, water treatment, and even socks which prevent the growth of bacteria that cause foul odor. By using the Ag nanoparticle synthesis to create their own antibacterial socks, students will be able to compare the effectiveness of their own product to those made by commercial means.

One topic that is difficult to measure quantitatively in a high school lab is the environmental impact of silver nanoparticles. Depending on the manufacturing process, anywhere from 1% to

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100% of the silver nanoparticles can be released from the socks during a single washing according to recent studies[1-3]. A qualitative measure which you may want to try is soaking/washing the socks in water, and trying to grow bacteria in the water. If silver nanoparticles have been released and kill the bacteria, the water should remain clear. If silver nanoparticles have not been released, or the amount released is insignificant, then the water will appear cloudy. If the silver nanoparticles are released into the environment they can disrupt helpful bacteria used in water treatment and can potentially harm other forms of wildlife such as fish. We must take care to prevent these particles from getting into the water supply and our soil. Students should learn that even if a particular type of sock is most effective for killing bacteria, it may not be the best product if it has negative environmental impact.

References:

1. Accessed at: http://www.empa.ch/plugin/template/empa/*/70057/---/l=2
2. Accessed at: http://cohesion.rice.edu/centersandinst/icon/emplibrary/ICON-Backgrounder_NanoSilver-in-the-Environment-v4.pdf
3. Accessed at: http://pubs.acs.org/doi/abs/10.1021/es2001248

Teacher Resources:

Site	Topic
Safety of Nanotechnology http://pbskids.org/dragonflytv/scientists/scientist65.html	Good video for students to see after the lab
Nano Index http://pbskids.org/dragonflytv/nano/index.html	Provides additional videos, experiments, and games
Nanoparticles.org http://www.nanoparticles.org	The information resource for particle technology
National Nanotechnology Infrastructure Network http://www.nnin.org	Source for additional lesson ideas and info
Silver Socks DIY http://www.purestcolloids.com/silver-socks.php	Information and products on silver nanoparticle spray
Washing of Silver Nanoparticle Socks http://www.nanowerk.com/spotlight/spotid=13362.php	Environmental impact of nanoparticles
Silver as an Antimicrobial Agent http://microbewiki.kenyon.edu/index.php/Silver_as_an_Antimicrobial_Agent#Current_uses	How nanosilver works

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Day 1 - Instructional Procedure
Synthesizing Silver Nanoparticles

Time	Instructional Activity
5 minutes	Greatest Inventions with Bill Nye: The Science of Materials. Thinkfilm Inc., 2007. Full Video. 13 July 2010. http://www.discoveryeducation.com.
or	
	Effect of nanosilver socks on bacteria video http://pbskids.org/dragonflytv/show/nanosilver.html (Stop video before the bacteria experiment at Cornell University. Finish video after students have completed the lab so they can compare the results)
10 minutes	Lecture on nanotechnology and nanoparticles. See teacher background.
25 minutes	Students break up into assigned groups and follow laboratory procedure for Day 1.
5 minutes	Students will store their solutions in aluminum foil and clean up the lab area.

Day 2 - Instructional Procedure
Preparing Agar Plates

Time	Instructional Activity
5 minutes	Briefly review the student's accomplishments from the previous day.
5 minutes	Review the procedure for plating their sock samples on agar plates. Discuss what bacteria will be used.
30 minutes	Students will break up into assigned groups and follow laboratory procedure for Day 2.
5 minutes	Students will clean up the lab area and dispose of any biohazardous material in the proper waste containers.

Day 3 - Instructional Procedure
Examining Agar Plates for Bacterial Growth

Time	Instructional Activity
5 minutes	Teacher will review with the students what has been accomplished so far with the creation of the silver nanoparticles. Students will then record the observations for four agar plates into their lab notebooks.

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10 minutes Each student group will post their results on the blackboard. The teacher will lead a discussion on which method was most effective based on the class findings.

10 minutes Students will complete post lab questions regarding results and ethics of nanoparticle research and production.

15 minutes Students will work on designing their own experiment to test whether or not silver nanoparticles are removed from the socks when washing. Teacher will circulate and the students will discuss their ideas. If an idea has potential, it may be performed at a later time.

Homework Students will work on advertisement ideas for the nanosocks they created in their lab groups. The advertisements should also be worked on at home, and can be presented at a time of the teacher's choosing.

National Science Education Standards: Grades 9-12

A. Science as Inquiry
B. Physical Science - Structure of Atoms section
B. Physical Science - Structure and Properties of Matter section
B. Physical Science - Chemical Reactions section
C. Life Science - The Cell section
E. Science and Technology - Abilities of Technology Design section
E. Science and Technology - Understanding about Science and Technology section

K What I **K**now (about nanotechnology)	W What I **W**ant to Know (about nanotechnology)	L What I **L**earnt (about nanotechnology)

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Student Worksheet
(with answers)

Name:____________________________ Date:_______________ Class:__________________

Creating and Testing of Silver Nanoparticle Socks

Introduction
Nanoparticles are microscopic particles that have a width of about a billionth of a meter (10^{-9}m). These small particles often have different properties than their macro-size composition material. For example the color of elemental silver is gray, while silver nanoparticles in solution are yellow/orange. In this lesson you will be taking advantage of the antibacterial properties of nanosilver to create your own antibacterial socks! Socks such as these are currently on the market and can be found in stores where you probably shop. You can also buy a silver nanoparticle spray to treat the socks you already own. After creating your own silver nanoparticles you will treat a pair of socks and compare their effectiveness against bacteria growing in a petri dish. You will also be testing control socks that contain no nanosilver, socks treated with a commercial spray (Mesosilver), and commercially available nanosilver socks that were bought in a store.

Purpose

- To study the characteristics and uses of nanoparticles
- To produce a sample of silver nanoparticles
- To examine the antibacterial properties of nanosilver particles
- To compare the effectiveness of the particles with commercial sock treatments

Key Terms:

Nanoparticle: *A microscopic particle whose size is measured in nanometers and which may have properties that differ from the bulk material (macro scale).*

Nanotechnology: *The science and technology of devices and materials, such as electronic circuits or drug delivery systems, that are extremely small (1-100 nm).*

Synthesis: *The forming or building of a more complex substance or compound from elements or simpler compounds.*

Antibiotic: *Chemical substances that are produced by various microorganisms and fungi that have the capacity to kill or inhibit the growth of bacteria and other microorganisms. Silver nanoparticles have also been known to exhibit antibiotic properties.*

Culture: *The growth of microorganisms, such as bacteria, for scientific study and medicinal use.*

Zone of Inhibition: *A clear region on an agar plate treated with bacteria which indicates an area which is not suitable for bacteria to grow. Can be used to show the effectiveness of a substance with antibacterial properties.*

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NNIN Document: NNIN-1280

Rev: 07/2012

Environment: *The combination of external physical conditions that affect and influence the growth, development, and survival of organisms.*

Materials for Day 1: (for groups of 2- 4)

- Goggles and nitrile gloves (lab aprons are optional)
- Glassware: 50 mL Erlenmeyer flask, 10 mL graduate cylinder, small vial to store colloid solution
- Distilled water
- 20 mL 0.001 M Silver nitrate solution
- 2 mL 0.003 M Sodium citrate solution
- Hotplate with stirrer
- Magnetic stir bar
- Two 5 cm X 5 cm pieces of normal socks
- Mesosilver Spray – 1 bottle shared amongst class
- One small vial (10 ml) for silver particle solution
- Oven safety mitt
- Aluminium foil

Day 1 Procedure:

1) Retrieve an Erlenmeyer flask, a 10 mL graduated cylinder, a magnetic stir bar, and a hot plate with stirrer and bring them to your lab station.

2) Carefully place the magnetic stir bar in the flask. Measure out 20 mL of silver nitrate ($AgNO_3$) into your Erlenmeyer flask. ***Silver nitrate will stain your skin. Wear gloves and clean all spills immediately.**

3) Heat the silver nitrate solution on the hot plate on medium heat. The magnetic stirrer will mix the solution while it heats.

4) While the silver nitrate is heating, clean your graduated cylinder with soap and distilled water.

5) Measure out 2 mL of sodium citrate using the graduated cylinder.

6) Once the silver nitrate is at a rolling boil, add the 2 mL of sodium citrate solution.

7) Observe and record any changes that take place in the solution. Why do you believe these changes are occurring?

8) Five minutes after adding the sodium citrate, carefully remove the flask from the heat source with an oven-safe mitt and wait for the solution to cool.

9) Continue to watch for 2-3 minutes and record any changes that occur to the solution as it cools.

10) Once your solution is cooled, transfer the contents to your vial. Wrap the vials in aluminum foil to protect the solution from light.

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Cleanup Ask your teacher about the disposal of chemicals. Solutions will be collected in a labeled container designated by your teacher.

Analysis Questions:

1. How many nanometers are in one meter? One billion nanometers = one meter

2. Why did the colloid solution begin to change colors once the sodium citrate was added? A chemical reaction took place between the silver nitrate and the sodium citrate. As more silver nanoparticles were being produced, the solution became a dark orange/yellow color.

3. What are the potential benefits of wearing socks with silver nanoparticles in them? Silver nanoparticles have antibacterial properties. This means you can wear the socks for days and your feet won't smell.

4. Based on your scientific knowledge, make a prediction as to whether you think bacteria will grow in the presence of these four types of socks (*this will be done later in the lab).* Explain your reasons for your predictions below the table.

TYPE OF SOCKS	PREDICTION
Regular Cotton Sock	
Mesosilver Sock	
Nanoparticle Sock	
Store Bought Silver Sock	

Answers will vary. Make sure a reasonable explanation is given for each prediction.

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Materials for Day 2: (for groups of 2- 4)

- Goggles and nitrile gloves (lab aprons are optional)
- Four prepoured nutrient agar plates
- Bacteria (Micro coccus or Staphylococcus epidermidis)
- Ethanol
- L-shaped glass stirring rod (to spread the bacteria)
- 5 cm X 5 cm piece of nanosilver sock
- 5 cm X 5 cm piece of normal sock (NOT TREATED WITH SILVER)
- 5 cm X 5 cm piece of Mesosilver treated sock
- 5 cm X 5 cm piece of Silver particle sock
- Forceps / Tweezers
- Pipette for bacteria
- Biohazard waste container
- Bunsen burner
- Artificial sweat - optional

Day 2 Procedure:

1) Put on safety goggles, gloves, and tie any lose hair back. Set up a bunsen burner, and then obtain four agar plates and the bacteria. Label the plates as control, mesosilver, nanosilver, and store bought silver sock.

2) Use a pipette to pour 0.1 mL of bacteria into the center of each agar plate. Dip the glass stirring rod into a beaker of ethanol, and then pass it through the flame of the Bunsen burner to sterilize. ***(Ethanol is highly flammable. Keep the part that was dipped in ethanol facing down)***

3) Allow the stirring rod to cool on the inside of the agar plate. Then swipe gently along the surface to spread the bacteria onto the entire plate. When the plate is covered, use the same stirring rod to coat the other three plates. When all four plates are covered, leave the stirring rod in a small beaker of ethanol to sterilize.

4) Sterilize your forceps by soaking it the ethanol and carefully heat it in the Bunsen burner. Be sure to repeat when using a new sock sample to avoid contaminating your samples.

5) Optional Sweat Procedure-Before placing each of the socks on the bacteria plate, dip them in an artificial sweat solution. This may be done at your teacher's discretion.

6) Soak a normal sock piece in distilled water and place on the bacteria plate labeled control.

7) Soak a piece of normal cotton sock in the mesosilver solution. Then place the sock on the bacteria plate labeled "mesosilver."

8) Soak a piece of normal cotton sock in the nanosilver solution you prepared. Then place the sock on the bacteria plate labeled "nanosilver."

9) Soak a piece of your store bought sock in distilled water and place it on the bacteria plate labeled "store bought silver sock."

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10) The samples should be placed in an oven at 37 degrees Celsius for 24 hours. During the next class you will examine the growth on the plates and determine which, if any, of the socks inhibited bacterial growth.

Clean-up: Ethanol can be poured down the drain with excess water. All bacteria waste should be disposed of in a biohazard container and not in a regular garbage can.

Analysis Questions:

1. Why is it important to use a normal cotton sock as your control?
You must use a normal cotton sock as a control to ensure that the bacterial growth is caused by the added bacteria, and not some other bacteria which could have been present on the socks.

2. Why did you need to place the L-shaped glass stirring rod into ethanol and heat it prior to spreading the bacteria? *To kill off any bacteria that was on the L-shaped glass stirring rod.*

3. Why were Micro coccus or Staphylococcus epidermidis used as the bacteria for this testing?
Micro coccus is the bacteria that is in your sweat. Staphylococcus epidermidis is a bacteria found in human skin.

If you did the artificial sweat portion of the lab answer the following question
4. Why would it be more appropriate to use artificial sweat instead of distilled water?
Sweat contains salts and other chemicals, which are not present in distilled water. Using the sweat would create more of a real-life scenario in testing the various socks.

Materials for Day 3: (for groups of 2- 4)

- Goggles and nitrile gloves (lab aprons are optional)
- Four agar plate samples with bacteria and socks
- Biohazard waste container

Procedure for Day 3:

1) Put on safety goggles and gloves. Retrieve your four agar plates and record any observations. Where is there bacteria growth? Did the bacteria cover the entire plate? Are there any sections that did not have bacteria growth? For the following table if there was a zone of inhibition write in "yes" and if there is no noticeable zone of inhibition write in "no". The zone can be very thin.

Expected results as follows:

TYPE OF SOCKS	RESULTS
Regular Cotton Sock	*No*
Mesosilver Sock	*Yes*
Nanoparticle Sock	*Yes*
Store Bought Silver Sock	*Yes or No**

**The store bought silver sock may have a hydrophobic property which prevents silver from reaching the agar plate, resulting in no zone of inhibition.*

2) Record your results on the blackboard including your group name, and what was observed on each of the four agar plates. The plates should be labeled control, mesosilver, nanosilver, and store bought silver sock.

3) When you are finished with your plates, they should be disposed of in a biohazard container (NOT a regular garbage can). Clean up your lab area and then return to your seats for a discussion of the results

4) As a class, discuss and answer the following questions:

Which pair of socks was most effective in preventing bacterial growth? Why do you believe there was a difference if they all contained silver nanoparticles?

Was there any growth that looked different from the rest of the bacteria? If it was different, where did it come from?

5) Your teacher will lead a short discussion on the potential damage nanoparticles can cause in the environment. Think about whether you feel nanotechnology research should be banned, regulated, or left alone. Are the potential rewards worth the risk? After the discussion, read and work on the following prompt:

PROS OF NANOTECHNOLOGY	CONS OF NANOTECHNOLOGY
Could cure some diseases (cancer)	*Nanoparticles entering the water system*
New jobs can be created	*Could induce adverse health effects*
Less waste	*Chemicals are more expensive*
Lead to greater medical imaging	*Nanoparticles are only utilized for a few elements*

Analysis Questions and Activities:

1) According to the makers of Mesosilver, you should reapply the spray after each wash. Why do you need to reapply? What do you believe happened to the silver nanoparticles? Do you believe store bought nanosocks also need silver nanoparticles to be reapplied for them to continue to work? Explain.

Between washings, much of the Mesosilver is washed off of the sock and remains in the water. While some nanosocks have minimal silver particle leeching, others lose a significant amount of the nanoparticles when washed. This will lead to the product being less effective over time, and the silver nanoparticles entering the environment.

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2) Just when you thought it was safe to go back in the water...
As a responsible chemist who knows that nanosilver can be harmful for the environment, it is your responsibility to find a way to test how much silver is removed from your nanosocks when washed. For exact measurements there are precise detectors, but they are also very expensive. Your group's task is to design an experiment to test whether or not nanosilver is removed from your socks when washed and remains in the water. The measurements can be qualitative, so complicated calculations are not necessary. You may use resources, including the Internet, but your activity must be original. If the procedure is detailed and has potential for success, your teacher may allow you to perform the experiment with the class.

Based on the PBS kids video that you may or may not have shown your students, the graduate student at Cornell University was able to use the wash water from the sock along with bacteria and a nutrient broth to tell if nanoparticles had been left in the water. This could be an interesting activity for the students to try, but they may also come up with some other creative way test for bacteria. Increasing the pH of the water may have an effect on the amount of silver nanoparticles which are removed. If water has taken up the silver then bacteria should not grow. If bacteria does grow, the water will appear cloudy. THE WATER IS STILL NOT SAFE TO DRINK EVEN IF FREE OF BACTERIA.

Extension: (optional activity)

3) Show me the money!

"Many a small thing has been made large by the right kind of advertising."
Mark Twain

You have successfully created silver nanoparticles, and used them to inhibit bacterial growth on socks. Now you must find a way to market your socks to the public so that you can pay back your investors. For this project you can create a magazine, radio, or television advertisement or infomercial. Other advertising methods are valid as well, but make sure your project idea is checked by your teacher first. This is your chance to really be creative, so make it count. You should be aware of the following:

Who is your target audience? Are you trying to sell the socks to teenagers such as yourselves, or adults? What kind of balance do you need between the science of how they are made and how they work versus how awesome and cool they are? Would they be great for sports, hunting, or just lounging around the house? What price would you sell them at and why? Use the internet to research prices of nanosocks that are on the market.. Are there any other product lines you might consider and why (use your imagination)? Do you think you will be facing a very competitive market in the long run? Also think about medical conditions where the socks may be beneficial. You do not need to market your socks to everyone, but you can.

[1]This activity is an extension of the lab "Study of Silver Nanoparticles" created by a 2009 MRSEC RET group at Penn State University. During that lab, students created silver nanoparticles and used sugar and salt to formulate an understanding of the interactions between the particles.

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Assessment

Pre/Post Test Name: ___________________________________

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This test will assess how well you understand the main topics covered in the Silver Nanosocks lab. Try your best on the pretest as many of the items you may not have heard before. For the post-test, answer the questions being asked based on what you learned from the laboratory activity.

1. How many nanometers are in one meter? One billion or $1x10^9$

2. What are the potential benefits of wearing socks with silver nanoparticles in them? Answers will vary but at a minimum the answer should include the reduction of order caused by sweat and microbial growth.

3. Why is it important to prevent bacteria while wearing socks? Answers will vary but the student should discuss the prevention of bacterial growth and hence less odor. They may talk about the length of use between washings.

4. How can you tell if bacteria growth has occurred? For the petri dish it is visible. For the socks, it would be from smell.

5. What other uses of silver nanoparticles can you think of? Answers will vary but may include other articles of clothing such as athletic wear. They may think about coating of materials used in an environment where you don't want microbial growth such as food containers and packaging. They may discuss its use in bandages to keep down infections while wounds are healing.

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Assessment

Assessment *for* Learning

At the beginning of the unit students will be introduced to nanotechnology through a short video and will review key terms. Once they have been given an overview, they will create their own silver-nanoparticle infused sock by using their silver-nanoparticle colloid solution and a normal cotton sock.

Assessments *of* Learning

Description	What is Assessed	Feedback
The students will complete a lab handout throughout the laboratory investigation for the creating silver-nanoparticle socks. Students will be assessed on several levels of Bloom's Taxonomy. Defining key terms and straightforward questions are used as well as analysis of lab results. Analysis questions will be asked at the end of the each day requiring students to understand the difference between concentration and amount. Students will also be given a pre and post-test to show the knowledge gained through the laboratory activity.	This laboratory requires the students to set up a controlled experiment and determine if the silver-nanoparticle sock created a zone of inhibition. This investigation demonstrates the antibacterial properties of silver nanoparticles by creating a zone of inhibition on a bacteria agar plate.	Students will receive instant feedback on their laboratory technique and their lab results. They will also receive constant guidance and advice to improve their skills in "wet" chemistry and biology. Leading questions will be utilized to guide students in their experimentation and developing conclusions.

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NNIN Document: NNIN-1280

Rev: 07/2012