NanoLeap

Investigating Static Forces in Nature: The Mystery of the Gecko
Lesson 3: What Are Your Ideas About Small Sizes?
Explore/Explain

Student Learning Objectives:

- Classify and compare objects in different size ranges to have a better understanding of objects at the nanoscale
- Understand relative size of objects at different scales
- Describe nanotechnology, some of its applications, and the positive as well as negative impacts of this technology to someone who is not familiar with the subject

At a Glance for Teachers:

- Comparisons of objects that range from the meter scale to the picometer scale
- Familiarization of small-scale objects
- *Nanoscale Me* interactive
- Powers of Ten Web sites
- Update Frayer Model
- Homework: *What is Nanotechnology?* Select reading on nanoscale science and technology, essay response to readings

Note: Some questions in the Student Journal are underlined as formative assessment checkpoints for you to check students' understanding of lesson objectives.

Estimated Time: Two 45-minute class periods.
Essay assessment approximately two additional hours to complete as homework

Vocabulary: Macroscale, Micrometer, Millimeter, Nanometer, Nanoparticle, Nanoscale, Nanotechnology
Refer to the end of this Teacher Guide for definitions.

Teacher Resource

In June 2006, *National Geographic* published an article entitled "Nano's Big Future" by Jennifer Kahn. Reading this article can offer you and your students additional insights into the life-changing impact of nanotechnology so that you can assist your students with the essay writing assignment.

For a preview of the article, go to: http://www7.nationalgeographic.com/ngm/0606/feature4/index.html

Web sites

The following resources can help students develop a perspective of the nanoscale in relation to other known scales:
http://www.mcrel.org/nanoleap/multimedia/Nanosize_me.swf

http://www.nanoreisen.de/

http://micro.magnet.fsu.edu/primer/java/scienceopticsu/powersof10/

http://microcosm.web.cern.ch/microcosm/p10/english/welcome.html

Nanoscale Background:

The activity in this lesson guides students as they begin to think about size and scale from macro to micro to nano. It builds on research by Tom Tretter[1] and his colleagues on the different ways that people understand and classify objects of different sizes. This research noted that students need to mentally manipulate new units, like a nanometer, in order to make sense of the numbers used during a comparison. In addition, Tretter discovered that high school students had difficulty ranking microscopic objects compared with gifted students or experts, who distinguished small-sized objects by grouping them into distinct landmarks such as small macroscopic items, microscopic, many atoms (nanoscale), and the size of an atom. This activity will provide students with an opportunity to use new landmarks as they compare images of very small objects.

Materials:

- PowerPoint for Lesson 3
- Student Journals for Lesson 3
- Computer with LCD or overhead projector
- Make arrangements for students to have access to the computer lab

Prepare Computers

Prepare links to above Web sites. Make sure Flash Player application is installed on each computer. If it is not currently on the computers, they may be downloaded from: http://www.adobe.com/shockwave/download/download.cgi?P1_Prod_Version=ShockwaveFlash&promoid=BIOW

Nanoscale Activity:

- Student Data Sheet
- *Nanoscale Me* interactive http://www.mcrel.org/nanoleap/multimedia/Nanosize_me.swf
- Optional Student Graph
- **Readings and Web sites for student essay responses:**
    - *National Geographic* article about nanotechnology entitled “Nano’s Big Future.” By Jennifer Kahn. http://www7.nationalgeographic.com/ngm/0606/feature4/index.html **(also included on CD)**
    - Other resources and Web sites found in the Student Journal, 3–7 and 3–8.

For Homework: Essay Assessment

- *What Is Nanotechnology?* Explanation of essay assessment (Note: These are the last 4 pages of the Student Journal for Lesson 3)
- For the instructor: Anchor Papers for Essay Assessment (See Appendix A of this Teacher Guide)

---

[1] Tretter, T. R., Jones, M. G., Andre, T., Negishi, A., & Minogue, J. (2006). Conceptual boundaries and distances: Students’ and experts’ concepts of the scale of scientific phenomena. *Journal of Research in Science Teaching* 43(3). 282-319.

<u>Slide #</u> **Student Journal Page #**	*<u>Teacher Background Information and Pedagogy</u>* **"Teacher Script"**
Slide 1 Title Slide 2 Student Journal Page: 1–1	1) *Display Slide 2 of the Frayer Model template:* Your Thoughts About Nanoscale Science and Technology **"Remember this chart from Lesson 1? You will be revisiting this chart at the conclusion of this lesson so that you can add anything new you've learned."**
Slide 3 Student Journal Page: 3–1	*According to the National Nanotechnology Initiative, nanotechnology includes the science, engineering, and technology related to the understanding and control of matter at the length scale of approximately 1–100 nanometers.* 2) *Display Slide 3.* **"In nanoscale science, objects and phenomena are studied on a much smaller scale than we can see with our eyes. In this slide, familiar objects are divided into ten equal parts or one hundred equal parts. The resulting measurements are used to provide an example of a metric prefix from centimeter through nanometer. *Nano* is a Greek word for 'dwarf.' In modern times, it is used as a prefix to note one-billionth of a meter, 10^{-9} meters, or 1 nanometer (nm). One nm is about 14 hydrogen atoms long. Nano can be used with other measurements. A nanosecond, for example, is a billionth of a second. Have you heard the prefix nano used anyplace else? In popular culture, it may not always mean a billionth (e.g., Nano iPod)."**
Slide 4	3) *Display slide 4. Explain to students how the prefixes on this slide are related to those in which students are already familiar. You may want to have them define the prefixes that they have learned previously using the base unit for length, a meter.* **"This slide shows the metric prefixes and definitions in relation to a meter from "milli" through "pico."** *Optional: Use this slide as a poster that is kept in the room for future reference.*
Slide 5 Student Journal Page 3–1 Computer Lab	4) *Display Slide 5: What Are Your Ideas About Small Sizes? Assess student' prior knowledge about small objects. Typically you will find that students can easily sort objects into those that are visible and those that are invisible to the unaided eye.* **"Open the NanoScale Me interactive using the URL in your Student Journal. On the size line on Student Journal page 3–1, you may mouse over the images of objects and the name will appear. Circle the objects**

	that are smaller than a penny. Underline which of those objects would be considered microscopic (unable to be seen with the unaided eye).”
Slide 6 Student Journal Page 3–4 3–5	5) *Explain that in this activity, students will have some new experiences in classifying and ordering very small objects to better understand the size of objects in the nanoscale. Begin by having students review metric prefixes and define a nanometer by thinking about objects that can be divided into equal parts.* **“You are going on a journey into a new world through the use of imagery and artists’ animation. As you begin this journey, it will be important to understand some metric prefixes in order to navigate into this world. On the bottom of Student Journal 3–1, common objects are ranked from largest (one centimeter) to smallest (one nanometer). Compare the size of each object by reading the labels for each image.”**
Student Journal: Data Sheet/Student Responses: Pages: 3–2 3–3 3–4	*In the NanoSize Me interactive, students will be conducting five image sorts using an online interactive. The progression of the sort is increasingly smaller.* 6) *Model the use of the NanoScale Me interactive by providing a demonstration of the “Sort Meters” activity. (Access the activity through the navigation bar located at the bottom of the interactive screen.) Do this in conjunction with the Student Journal page 3–2 for the meter sort. Ask students to write their prediction in their journal (left column) before they sort with the interactive. Then, in the right column, they should record the actual order. There should be little disagreement on the objects order because students are familiar with this range.* **“In the interactive, click on “Sort Meters.” Move your mouse over the objects in order to determine their names. Note that the objects are not depicted in the same scale. In your journal, page 3–2, first record your predicted order largest to smallest based on the width of the object. Then see how well you did by completing the image sort in the interactive and recording the actual size orders.** **At the bottom of each screen is an instrument commonly used to study the objects at each range. Also the dominant force that acts on each object is listed. Simply record this information in your journal. We will be studying these ideas in more detail in future lessons.”** 7) *Working in small groups, have the students proceed to “Sort Millimeter.” Have them write their prediction in their journal (left column) before they sort with the interactive and then record the actual order on the right column.* *Repeat this process for the remaining ranges to sort.* 8) *When students have completed each range sort, have them compare the widths of each object at the same scale by using the “Exploring Scale” page. Then, complete the “Sort All.”* **“When you have completed all of the image sorts for each range, select the “Exploring Scale” link and view the images from largest to smallest. This time you can compare the relative size of each object.”**

	9) Once students have completed "Exploring Scale," ask them a question similar to the following: **"How did this interactive change the way you compare objects at different scales? Think about how you can use this to help solve the mystery of the gecko."** (*Students may comment that they did not know there were so many degrees of objects that were so small. This may prompt students to inquire about the surfaces of the geckos foot and a ceiling at a much smaller scale.*) *10) Revisit the "Sort All" tool to assess student understanding of the landmark images of the various ranges.*
Slide 7 Student Journal Pages: 3–4 3–5	*11) Display Slide 7. This is a whole class discussion in response to the questions on the slide. Allow each group to answer the questions in their Student Journals before sharing their responses with the rest of the class. Explain that it is difficult to tell the size of objects from many of the images we see because they look about the same size in the pictures. Use the "Exploring Scale" tool to assist students with question c.* a. Which of the image sort ranges was the easiest to rank? Why? b. Which range was the most difficult? Why? c. Circle the largest in each of the following pairs: Ant — Grain of Sand or Salt *(Ant)* Virus — White Blood Cell *(White Blood Cell)* Virus — DNA Molecule *(Virus)* Atom — DNA Molecule *(DNA Molecule)* d. <u>How do nanoparticles compare with cells in size</u>? *(Nanoparticles are smaller than cells.)* e. <u>How do nanoparticles compare with atoms in size?"</u> *(Nanoparticles are larger than atoms.)* *Some students will think that nanoparticles are smaller than atoms. Emphasize that all nanoparticles are made of atoms. Make reference to Slides 3 and 4.*
Slide 8	*12) If time allows, go to procedure step 14 to have the students extend their explorations at the nanoscale either in class or for homework. Then, return to this step to complete the lesson. Display slide 8 and review Making Connections:* **"Making Connections: The questions here are a chance for us to discuss what was learned during this lesson."** • **"How has your thinking about small sizes changed after completing the computer activity?"** *(Students should explain that their thinking has changed in that there are many ranges of different small-sized objects.)* • **"Are the instruments that are used for each of these size ranges the same? Explain."** *(No. Students should be aware that there are special tools to detect objects at very small ranges.)* • **"What should we explore next?"** *(Answers will vary.)*

Student Journal Page: 1–1	13) *Prompt students to return to the Frayer Model on page 1–1 in their journals.* **“Return once again to the graphic organizer on page 1–1. Make additions or revisions based on what you learned in this lesson.”**
Student Journal Page: 3–5 Optional	14) *Use the journal questions to provide structure to students’ interactions with the Web sites listed below. This optional activity allows students to elaborate on their exploration of nanoscale using Web resources. You may also do this activity as a whole class with the teacher leading the navigation.* *Web sites for Powers of Ten activity in Student Journal:* http://www.nanoreisen.de/ http://microcosm.web.cern.ch/microcosm/p10/english/welcome.html **“Complete the Powers of Ten activity on page 3–6 of your Student Journal. Use the Web sites to explore the world of small sizes. Focus your attention on smaller objects rather than larger objects. Complete questions in your journal that pertain to the appropriate Web site.”**
Homework: Essay Assessment— *What Is Nanotechnology?* Writing Prompt Student Journal Pages: 3–7 3–8	15) *In this formative performance assessment, students will demonstrate their learning by responding to the following writing prompt.* Explain the term “nanotechnology” to someone who has heard of it only on T.V. Then, explain how scientists and the general public should react to the latest research and applications in nanotechnology. • Define Nanotechnology. • Give examples of specific nanoapplications to help illustrate nanotechnology. These should come from the Internet resources you read as well as from what you have learned in this unit. • Describe nanotechnology’s impact on science and how the application involves research from many different science subjects (e.g., biology, chemistry, physics, engineering). • Explain why it is important for scientists to discuss the technology’s positive and negative impacts with each other and with the general public. • Include an explanation for why the general public should stay informed about the progress of nanotechnology. *Students will draft their written responses as homework and then participate in a peer-review activity during class time. Incorporating peer review transforms the “assessment” into a writing-to-learn opportunity that engages students in critical thinking with a more in-depth exploration of the content. Since students will likely focus on a range of nanoapplications, the peer-review process enables students to increase their awareness of the various possibilities for nanotechnology. Furthermore, feedback received through the peer-review process will help students to refine their writing before the final*

	essays are submitted. Through this process, students will also become very familiar with the scoring rubric and expectations for the writing, thereby encouraging them take responsibility for evaluating their own work. Subsequently, the teacher's paper load in this module can be minimized; you may only need to intervene and evaluate the writing when there is a large discrepancy among peer reviews.
Slide 9 Introducing the Assessment Student Journal Pages 3–6 3–7 3–8 3–9 June 2006, *National Geographic* published an article entitled "Nano's Big Future" by Jennifer Kahn	*16) Display the "Nanotechnology: Life Changing?" slide of the PowerPoint presentation and read aloud the following two quotes:* **"Nanoscience and technology will change the nature of almost every human-made object in the 21st century."** **–M.C. Roco, R. S. Williams, & P. Alivisatos, 1999** **"The government and funding agencies have recognized that the societal and ethical implications of this new field must be explored right alongside research in the lab."** **–Kristen Kulinowski, Executive Director** **Rice University's Center for Biological and Environmental Nanotechnology** *17) Explain to students that while many people have heard of "nanotechnology," few could explain exactly what it is or why it may have "life-changing" effects. The homework assignment for the week will be to spend some time reading about current nanoapplications and carefully consider both the positive and negative impacts of this new technology. Then, students will write an explanation of nanotechnology, provide one or more examples of how this technology can be used, and describe the benefits and potential drawbacks to someone who is not familiar with nanotechnology.* *18) Instruct students to turn to the Essay Assessment: What Is Nanotechnology? section of their Lesson 3 Student Journal (pages 3–7through 3–10). Explain to students that they will write a brief essay that demonstrates what they have learned in the module so far as well as from reading several select articles.* *19) Review the prompt to ensure students understand the writing assignment. The bulleted list provides scaffolding to assist students in fully addressing the prompt. Written responses should not exceed one typed page (or one handwritten page front/back).* *20) Review the instructional rubric that will be used to assess the written response. The more familiar students are with the expectations of the assessment, the more responsibility they can assume for their own work.* *21) The National Geographic article can be used by students to respond to the essay writing prompt. The pilot teachers indicated that the National Geographic article presented reading challenges for some students. Therefore, we included a list of Internet-based resources that students can use as alternatives. If you choose the Internet-based resources,*

	decide whether to assign students specific articles to read or to allow them the freedom to choose those that most interest them. Note: The list of resources capture a range of reading levels. The texts offered by the Center for Responsible Nanotechnology are suitable for a high-school reading level. Those from Science News for Kids and Nanooze are less challenging. *22) To facilitate active reading and to assist in preparing their essays, students will use the SQ3R (Survey, Question, Read, Recite, Review) strategy (Robinson, 1961 as cited in Billmeyer & Barton, 2002). Pages 3–9 through 3–10 of the Student Journal provides guidance in using this reading strategy. If students are not familiar with SQ3R, it may be helpful to model the process for them. Students should plan to spend one hour at home reading the National Geographic article or their selected resources and completing the SQ3R strategy.*
Drafting the Essay	*23) Invite students to refer to their journals to help them plan their responses. While the assessment is "Open Journal/Notes," emphasize to students that their essay responses should not simply repeat journal responses or language from the articles they read. The journals are intended to help students recall their learning experience. The writing should be in students' own words and reflect a sophisticated understanding of the content.* *24) Instruct students to refer to the rubric as they draft their written responses.* *25) It should take students an additional hour of homework to write their essay. Explain to students that they should be prepared to share their essays in class the next time you meet.*
Classroom Presentations and Peer Reviews Student Journal Page 3–9	*26) Explain to students that rather than a formal peer review, students will share their work in small groups of four students.* *27) Each member of the group of four should have a rubric.* *28) During this informal peer review, students should share aloud the results of their SQ3R and/or their draft essays. Other members of the group should provide feedback to the student who is presenting either in written form or orally. Students can then use this information to refine their essays.* *29) Allow about five minutes for each person to share out for a total of about 20 minutes for this review process.*
Refining and Evaluating the Final Essays	*30) Encourage students to revise and polish their writing according to the feedback they received. Assign a due date for completing their final draft.* *31) On the due date, collect the rough and final drafts from each student.* *32) Refer to the Anchor Papers for Essay Assessment to assist in evaluating the final essays (available in the Appendix A*

	section of this guide). The instructional rubric is found on page 3–11 of the Teacher Guide.
Slide 10	*33) Make sure students update their graphic organizers in their student journal (page 1–1) with new information learned from this assignment.*
Slide 11	*34) The pilot-test teachers highly recommend using this flow chart at the end and/or beginning of each lesson. The end of each lesson contains this flow chart that provides an opportunity to show students the "big picture" and where they are in the lesson sequence. The following color code is used:* *Yellow: Past Lessons* *Blue: Current Lesson* *Green: Next Lesson* *White: Future Lessons*

Appendix A: Anchor Papers for *What Is Nanotechnology?* Essay

Purpose:
The anchor papers can assist you in using the rubric to score students' culminating essays. Please refer to the rubric as you read through the various anchor papers.

Writing Prompt:
Explain the term "nanotechnology" to someone who has heard of it only on T.V. Then, explain how scientists and the general public should react to the latest research and applications in nanotechnology.

- Define Nanotechnology.
- Give examples of specific nanoapplications to help illustrate nanotechnology. These should come from the article you read as well as from what you have learned in this unit.
- Describe nanotechnology's impact on science and how the application involves research from many different science areas (e.g., biology, chemistry, physics, engineering).
- Explain why it is important for scientists to discuss the technology's positive and negative impacts with each other and with the general public.
- Include an explanation for why the general public should stay informed about the progress of nanotechnology.

NanoLeap

Instructional Rubric for Essay Assessment

Criteria	Advanced (4)	Proficient (3)	Partially Proficient (2)	Novice (1)
Writing Style and Mechanics	• **Concise, clear, and engaging explanations** with **flawless** spelling, punctuation, and grammar.	• **Concise and clear** explanations with **minor errors** that do not interfere with communication.	• **Appropriate writing** format. • Writer does **not appear to have carefully proofread**.	• **Demonstrates little or no attention** to the writing format. • Has great difficulty communicating.
Understanding of Content	• Explanations about the impact of nanotechnology applications on science and society **are complete* and insightful.** • **Gives detailed examples to help explain points.** • Writes in **own words.** *Responses include answers to all five bullet points in the prompt.	• Explanations about the impact of nanotechnology applications on science and society **are complete* and reasonable.** • **Gives examples to make points. Could be more detailed.** • Writes in **own words.** *Responses include answers to all five bullet points in the prompt.	• Explanations about the impact of nanotechnology applications on science and society **are obvious.** • Does **not always write in own words**.	• Explanations about the impact of nanotechnology applications on science and society **are irrelevant.** • Copies from the article.

4

You now see the word “nano” everywhere like the nano iPod, but the word nano has a more specific meaning in science. First, the word nano is Greek for “dwarf.” It is one billionth of a meter, a comma such as this one is about half a million nanometers. In addition, a nanometer is to an inch the same as an inch is to 400 miles. That is very small! The naked eye cannot see this, not even a regular microscope can. That is why scientists use what is called the AFM (Atomic Force Microscope) to see and work with things that small.

So, in nanotechnology you are studying things that are very small. For example, we didn’t understand why a gecko could stick on a wall. Well, with a special microscope, scientists saw that geckos have about one million hair-like seta on their feet. The gecko can stick to the ceiling because their tiny spatulas get into the bumps on the surface of the surface. Even if the surfaces looks flat at nano level, it is full of bumps resembling small hills. The spatulas fit into the small hills. The molecules at this level are positively, negatively, or neutrally charged. The positives are attracted to the negatives and the neutrals. The negatives are attracted to the positives and the neutrals. This generates a very tiny force, but lots of the little forces create a lot of force for the gecko to stick on anything.

In another example, there is the carbon nanotubes. Scientists have been able to take carbon atoms and arrange them to make a tube. They are 50 to 100 times stronger than steel and 1/6 the weight, and great conductors of electricity. Currently, nanotubes have been used to make sporting equipment stronger. But, since they conduct electricity better than copper and aluminum, they could possibly be used to create more efficient electrical wires. So, they could help solve the world’s energy problem. But, we are not there yet, because the carbon nanotubes break.

So, you see in both examples different sciences have to work together. With the gecko, biology works with physics. With the carbon nano-tubes and electricity, chemists need to know electricity.

The impact nanotechnology is having on science and the world is tremendous. It has the potential to help us with so many things. Some examples are, scientists can engineer many new materials like plastic that reacts to electricity, coatings that prevent rusting on iron, or clean up pollutants in water! A “new plastic” will be everywhere, in our clothes we wear, the cars we drive, the tools we use in surgery, mainly the things we use in our everyday lives. So we and the government need to stay informed because there is so much potential to solve problems that we haven’t figured out totally.

But, it is important for scientists to discuss these things with other scientists, because other scientists may be able to improve what the scientists have done. Also, we need to stay informed as well as the government. Why? Because nano particles can also be harmful very fast. In one example, small amounts of bucky balls (balls of carbon) were exposed to some cells and the cells died. So, maybe exposure could cause cancer and be toxic. Bucky balls can be made less toxic, but more research needs to be done! But, because people are so excited about the positive aspects of nano technology, scientists do not often really study the negative. We all need to stay informed and we need more research.

3

You now see the word nano everywhere like the nano iPod, but the word nano has a more specific meaning in science. A nano is one billionth of a meter. It is very small! The naked eye cannot see this, not even a regular microscope can.

For example, we didn't understand why a gecko could stick on a wall. Well, with a special microscope, scientists saw that geckos have about one million hair-like seta on their feet. This generates a very tiny force, but lots of the little forces create a lot of force for the gecko to stick on anything.

Another example is using nanotubes. They can be engineered to be light weights, strong sporting equipments, and energy efficient power lines across the country which could boost energy amazingly high. The negatives are that scientists finally conduct the right nantotube and create a world of amazingly high electrical energy, people think that if Mother Nature allows it, nano-tubes could restring the electrical power grid of the world and create too much energy. But facts are scientists don't have the right type of carbon nanotubes and aren't able to construct the bottom up assembly of the nanotubes. Many different sciences have to work together to try to understand all of these things.

It is important to discuss the positive and negative impacts of nanotubes with each other and the general public because it could create a world wide energy source and that's important. It's good to know that buckyballs can be made into an efficient composition which we can use for many things. But, people need to know how the carbon nanotube work and how they produce energy so we don't end up with an overload of electrical energy in the future.

Because they are so small, It is not good to keep it secret, because in case they made a mistake, then other scientist won't be able to fix it and it could affect the lives of the all the people on earth.

2

Nano allows us to see things at the nanoscale level which is much smaller. In the gecko we could see how they look like small ridges but are made of very small feet. In the National Geographic article it brings up many things nanotechnology can be used for. The application that affected me the most is Glowing Potential. We could find a cure for cancer in Nano. Discovering this would have a huge impact on science. Scientists have worked hard for many years. Being able to see things at a smaller rate helps us learn more about how atoms and molecules behave at the nano level. This would have a very positive affect on society. It would be saving lives and keeping loved ones with their families. The negative affects of this are still being explored. It is very important for scientists for share and discuss their findings. They need to share them with each other so that they can check the findings to make sure no one missed anything vital. They need to share them with the public because if they have negative side affects they could be endangering lives.

Appendix B: NanoLeap Physical Science Vocabulary for Lesson 3

Macroscale
1. The length scale that is observable with the unaided eye
2. The description of objects and actions at a size visible to the unaided eyes

Micrometer
One-millionth (10^{-6}) of a meter

Millimeter
One-thousandth (10^{-3}) of a meter

Nanometer
One-billionth (10^{-9}) of a meter

Nanoparticle
A solid particle, 2–100 nm in size, that usually contains between 10 and 70,000 atoms, ions, or small molecules

Nanoscale
1. The scale between systems of a few atoms and small sized molecules
2. The description of objects and actions that occur at sizes of 1–100 nanometers (the size of a few atoms)

Nanotechnology
Manipulating and building new materials, structures, devices, and machines at the nanoscale level