NanoSense: The Basic Sense behind Nanoscience

YEAR 3 FINDINGS

Executive Summary

We have categorized our observations, conclusions, and recommendations from the third year of the NanoSense grant in terms of six main findings: Experiment-driven revisions to the Clear Sunscreen unit, Clean Energy pilot study results, results of the June 14-16 Nanoscience Learning Goals workshop, participant evaluations of the Nano Learning Goals workshop, participant evaluations of the Dec 2 NanoSense workshop for high school teachers, and web statistics on downloads of NanoSense materials. These findings are summarized below and described in more detail in the body of the report.

Clear Sunscreen revisions. Based on data from the UV blocking experiment, we revised the unit to describe absorption as the only mechanism by which sunscreens block UV light from hitting our skin. Diffuse reflection due to scattering is discussed in the visible region to explain why traditional inorganic sunscreens are white and how clear sunscreens are made using nanosized particles. A few pending changes will be completed this summer.

Clean Energy pilot study. Data from the initial Clean Energy implementation study provided evidence of student learning and highlighted a number of ways we can improve the learning opportunities in the unit. Since the unit was tested, several additions (including animations that show how nanocrystalline and traditional solar cells work, a new reading that more deeply explores solar energy technologies, and adapted lab instructions) should address many of the identified needs. A few pending revisions, and recommendations from our May 2007 site visit with Larry Woolf, will be implemented this summer.

Learning Goals workshop results. Over the three days, 43 workshop participants worked in and across groups to identify eight "big ideas" in nanoscience and elaborate each idea into specific learning goals. These ideas and learning goals are currently being vetted by researchers and educators. We anticipate their release in a report (NSF monograph) later this year.

Learning Goals workshop evaluation. In a post-workshop survey, participants reported high satisfaction with the workshop. Generally, they thought it was very well organized and productive, and was a good first step to bring new science concepts to the K-12 curriculum. They also felt that more time and work unpacking the ideas and aligning them with standards was needed, and next steps needed to be elaborated.

December 2 NanoSense teacher workshop. Virtually all of the (22) teacher participants reported that the workshop was worthwhile and well organized, that the NanoSense materials were relevant to the classes they teach and they planned to use the materials in their classes, and that they wanted learn about future NanoSense professional development opportunities. To use the materials, they indicated that they would want kits and someone to call or email if they have questions. They also wanted field trip and guest speaker contacts, and ideas on how to incorporate the concepts into their curriculum.

Web statistics on downloads. The NanoSense Web site has received over 100,000 requests since it opened in February 2005. It receives about 125 requests per day on average, the majority of which are for specific NanoSense lessons posted on the site. (Note that requests from SRI staff and web indexing robots are excluded from these analyses; the reported site statistics aim to reflect requests from legitimate third parties.) NanoSense also appears in the top ten search results for "nanoscience education" on Google (as of May 2007, is it the sixth result).

Finding 1: UV blocking experiment and revisions to the Clear Sunscreen unit

The data on the UV blocking experiment described in the Activities section is graphed in Exhibit 7, light scattering from three sunscreens. This data supported the hypothesis that absorption alone is the mechanism responsible for the UV blocking by large ZnO and TiO2 particles. In particular:

Sunscreen 1

- Contains the organic ingredients octinoxate and oxybenzone. (The sunscreen is Walgreens SPF 15).
- Because organic molecules are small compared to the wavelengths of light used, little scattering in the visible range occurs and the line is basically flat.
- This sunscreen appears clear on the skin.
- It is not possible to estimate the size of the molecule from the information in the graph.

Sunscreen 2

- Contains nanosized zinc oxide. (The sunscreen is Skin Ceuticals SPF 30).
- Because nanosized zinc oxide clusters are less than half the size of the wavelengths of light used, very limited scattering in the visible range occurs.
- This sunscreen appears clear on the skin.
- The sharp drop in the curve at 380 nm is actually due to absorption (if all the light is getting absorbed, it can't be scattered) so we cannot estimate the size of the cluster. We only know that the curve would have peaked below 380 nm, so the cluster size is smaller than 190 nm.

Sunscreen 3

- Contains traditional titanium dioxide. (The sunscreen is Bullfrog SPF 45).
- Because traditional titanium dioxide clusters are about half the size of the wavelengths of light used, a great deal of scattering in the visible range occurs.
- This sunscreen appears white on the skin.
- Because the graph peaks around 450 nm, we would estimate the cluster size to be about 225 nm.

Based on this data, we revised the unit to describe absorption as the only mechanism by which sunscreens block UV light from hitting our skin. Diffuse reflection due to scattering is discussed in the visible region to explain why traditional inorganic sunscreens are white and how clear sunscreens are made using nanosized particles.

Specifically the changes involved:

- Eliminating Lesson 4 (How Sunscreens Block: Scattering) and moving the content related to the scattering mechanism to the unit of Stylish Sunscreens: How Sunscreens Appear (renamed How Sunscreens Appear: Scatting and renumbered from Lesson 5 to Lesson 4)

- Revising the Animation activities and animation files (ChemSense Activity, Sunscreens & Light Flash Animations with related worksheets) to reflect our revised understanding.
- Revising the Lesson 2 (All About Sunscreens) materials (PowerPoint, Teacher Notes, Sunscreen Ingredients Activity) to be consistent with our revised understanding
- Eliminating the Sunscreen Role Play Activity in Lesson 2 that was based on scattering as a UV blocking mechanism
- Adding an activity interpreting the actual graphs from our data in Lesson 2

In addition to revisions driven by the experiment, this round of revisions included all changes suggest by Maureen Scharberg based on a review of the July 2006 version. These revisions included clarifications to lab protocols and explanations of the scientific concepts given in the PowerPoint slides and teacher notes as well as copyediting.

The Clear Sunscreen lessons will undergo a final set of revisions this summer to fine tune the scientific explanations and visual representations. Once the experiment-driven content changes were complete, we complied a list of all pending comments from Larry Woolf (our NSF reviewer), two of Joe Krajcik's graduate students who reviewed the unit, and NanoSense team members (including Maureen Scharberg). The result was a nine-page table with 61 suggested changes. We then discussed and prioritized these changes based on importance and time cost, reviewing relevant items with our teachers or consulting SRI scientists. Based on this, we have a list of 40 changes to complete this summer. We estimate these changes will take about 80 hours of work. Most of these are minor content changes (wording) or small adjustments to the formatting and organization. The larger changes are listed below.

- Expanding the teacher's guide for the reflection sheets for each lesson to add an answer key of ideas that students should have at the end of each unit, explaining how the phenomenon encountered in the lesson are related to the overall goals for the lesson and the unit as a whole. Also add an introduction to help the teacher discuss whether the questions are scientific questions and how to approach different types of questions.
- Revising the different diagrams used to depict the Electromagnetic spectrum and energy level transitions to be simpler and consistent with each other. (These were originally gathered from different sources, but will be edited / re-created)
- Adding in an overview on light-matter interactions focusing on R+T+A=1
- Adding a more detailed explanation of the relaxation process for excited organic sunscreen molecules.
- Adding in a "breaking news" slide to include a newly FDA approved sunscreen ingredient.
- Expanding the student quiz to more comprehensively asses student learning
- Adding a list of "other resources" including ideas for background reading and lesson extensions and a list of goof Google search terms for finding others (this will address the problem of broken links and help them keep current.)

Finding 2: Clean Energy Pilot Study Results

Student Demographics and Science Background

Twenty-seven students from two classes in a single San Francisco Bay Area high school participated in using the NanoSense Clean Energy unit from February 9-16, 2007[1]. Both classes were sections of a first year Environmental Science course taught by one teacher.

Class 1 was included 8 girls and 7 boys of predominately Hispanic and Asian decent. The teacher characterized Class 1 as her "adorable" class that was social and engaging, but didn't necessarily test well. Class 2 included 7 girls and 14 boys, and was split evenly between Caucasian and Hispanic/Asian students. The teacher described this class as somewhat "sarcastic" and less well-mannered, but said they tested well. Class 2 also included several students with learning disabilities. In both classes, most of the students were sophomores, with a few juniors and only one senior. Biology is a prerequisite for the Environmental Science course. The majority of the students passed biology the first time around as freshmen.

The Environmental Science course is offered as another choice for students who may not be headed to a 4-year university, or who want to take chemistry or physics as juniors or seniors. The course satisfies the California physical science requirement for graduation, and qualifies as a lab science for admission into the California State University system (although for University of California admissions it is considered an elective.) The topics covered in the course include:

First Semester	Second Semester
1. Foundations of Environmental Science	7. Soil & Soil Dynamics
2. Internal Earth Processes	8. Land & Water Use
3. Atmosphere	9. Energy Resources
4. Oceans	10. Pollution
5. Ecosystems & populations	11. Global Change
6. EM spectrum	12. Economics & Policy (time permitting)

Classroom Implementation

The Clean Energy unit is comprised of two one-day class sessions, one on general energy issues and the other on solar technologies, plus a two-day lab in which students construct nanocrystalline solar cells. The teacher in this study chose to do the full, four-day progression.

On day 1, the students completed the pretest at the beginning of the class period. The teacher then presented the introductory slides and led a class discussion on global energy issues, top world problems as related to energy, and the need for alternative energy sources. Following the slide presentation and discussion, students completed the initial ideas worksheet in class. Following completion of the worksheet, students were given a reading homework—a short, energy-related article from Scientific American and associated worksheet.

During the slide presentation, the teacher used the accompanying teacher notes and prompted her students with engaging questions. She commented that her students were "pretty engaged" during the presentation, enough so that she didn't find it necessary to play the embedded videos of Richard Smalley presenting on the topic of energy. In the rare instance when she did play one of the videos, observing NanoSense team members felt that the content of the video was somewhat difficult to make out in the classroom due to sound quality and use of some sophisticated words. This observation has prompted the NanoSense team to rethink the use of the

[1] Depending on the particular measure implemented—pre/posttest or initial ideas worksheet—the sample size varied based on the number of students that were present during a particular day and/or who handed in their materials.

Smalley videos in the presentation, perhaps using fewer videos, requiring higher quality, and making sure a manageable number of concepts are being presented during any particular clip.

The teacher commented that she felt that the homework-assigned Scientific American article would be hard for her students to follow because it used vocabulary that was at too high of a level. She asked them to list vocabulary words that they didn't know on the reading worksheet so that she could better understand what terms they were unfamiliar with.[2]

On day 2, the teacher presented the second slide set (on solar energy) and led a class discussion on solar energy and technologies. The teacher commented that in general, the slides contained too much text, which prompted her to edit the slides to include animated bullets so that ideas appeared one at a time. She felt the animated bullets allowed her to better focus the discussion.

When asked how she thought it went, the teacher felt that the class session was “hit and miss,” but the students had more understanding of the material than she thought they would. She felt that the students seemed rather engaged in the material, but wasn’t sure that they understood the science well. Noting that her students had not yet taken general chemistry, she wasn’t sure that they all knew what an electron was, suggesting the need to reinforce understanding of atoms, ions, and other basic particles in the Clean Energy materials. On the first day, one student exclaimed that this class was “depressing” (regarding the world energy situation). The second day, the teacher felt that the students were more engaged and excited by the prospect of solar energy—during the slide presentation on new solar technology, the student who was “depressed” the first day exclaimed “I'm going to do that, I'm going to save the world!”

After the second slide presentation, the teacher read through the lab with her students, each taking a turn with a paragraph and asking and answering questions after each page. On days 3 and 4, the students conducted the nanocrystalline solar cell lab. The teacher noted that she felt the included directions in the stock lab kit needed considerable simplification for her students. She rewrote the lab instructions as a shorter list of “to do” steps to fit her students’ learning[3].

Data sources to measure student learning[4]

1. *Pretest-Posttest.* Prior to starting the unit, students completed a short (10-15 minute) pretest on energy issues, energy sources, solar cells, and clean energy. Students also completed an identical test approximately 2 ½ weeks after completion of the unit.
2. *Initial Ideas.* This worksheet asked students to write down their ideas about energy sources and clean energy before the unit began and to rate their certainty in these ideas.
3. *Student Notecards.* Students were given blank index cards to write down their questions and “aha” moments during the course of the lessons.

Pretest-Posttest

To measure student learning during the course of the unit, a repeated measures test was used. The pretest/posttest consisted of four questions. The following four questions were based directly on the content and learning goals of the unit and were administered to students in a paper and pencil format. Students had approximately 10 minutes to complete each test. The sample size for

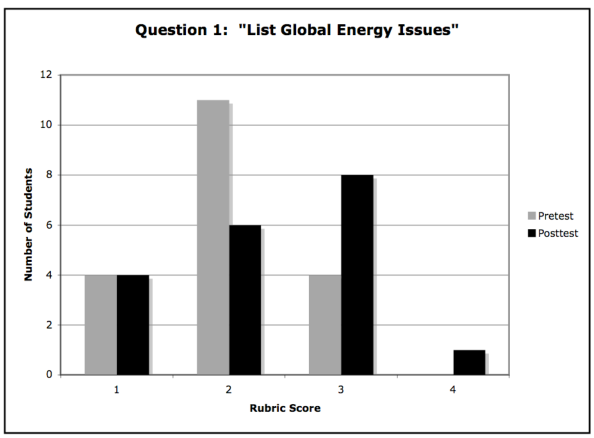
[2] In response, the NanoSense team has created their own energy reading, including a comprehensive glossary, which was included in the next release (April 2007) of the Clean Energy unit.
[3] Her rewritten lab was adapted by the NanoSense team and included in the April revision of the Clean Energy.
[4] As part of a homework assignment, students also read a short Scientific American article on the reality of global warming and completed a vocabulary worksheet created by the teacher. We did not analyze this worksheet data since the reading has since been dropped and replaced with a new reading developed by the NanoSense team.

the pretest-posttest combination was 19 students. The test were scored using the four-point scale shown in Chart 1.

Chart 1. Rubric for Scoring Student Responses			
1 No Understanding	**2 Limited Understanding**	**3 Basic Understanding**	**4 Solid Understanding**
Comments are absent or irrelevant.	Comments use some relevant terminology but many assertions are inaccurate or incomplete.	Comments use relevant terminology and are mostly accurate, but the overall explanation is incomplete or contains some inaccurate statements.	Comments use relevant terminology to provide an accurate and thorough explanation of the scientific concepts.

For the four questions, the depth of understanding of the pertinent science content is inferred based on the observable descriptors described below each heading. Below each test item is analyzed in detail. A scoring rubric was developed to capture changes in student responses between the pretest and posttest[5]. Changes in student responses between the two testing sessions are discussed next.

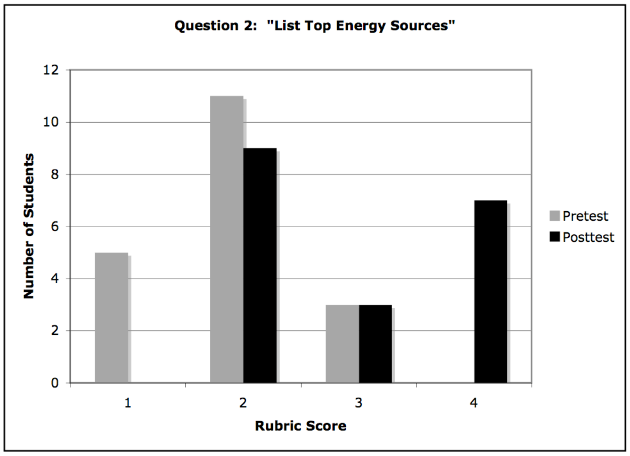
Question 1: List three global energy issues that you know about and provide two or three sentences describing each of them.



The results of this question indicate a positive shift in students' understanding of what some of the top energy issues are in the world today. However, it seems that a substantial number of students completed the unit with only partial understanding of global energy issues, and that 4 our of 19 students still had no understanding of these issues after the unit. We expected the results on this question to be more positive, since a substantial percentage of the unit focuses on global problems and how these tie into energy. We plan to review the "energy issue" parts of the unit and determine ways to improve this area. One idea is to provide additional question slides during the Day 1 PowerPoint presentation, along with additional teacher notes, to support a more directed class discussion on global problems and the link to energy. Another is to have students bring in a newspaper or magazine article to share with the class.

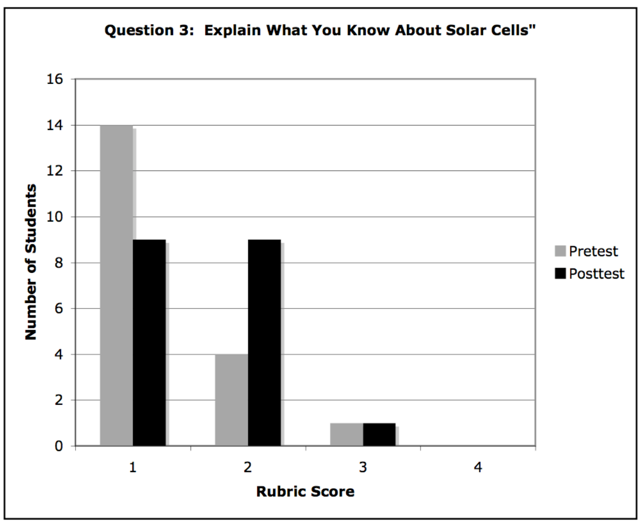
[5] In the analysis of the pretests and posttests, one student's scores were dropped due to an irregularity in the data. This student had (by far) the highest score in the class on the pretest (13 our of 16), but handed in a blank posttest.

Question 2: List what you think are three of the top energy sources currently used in the world.



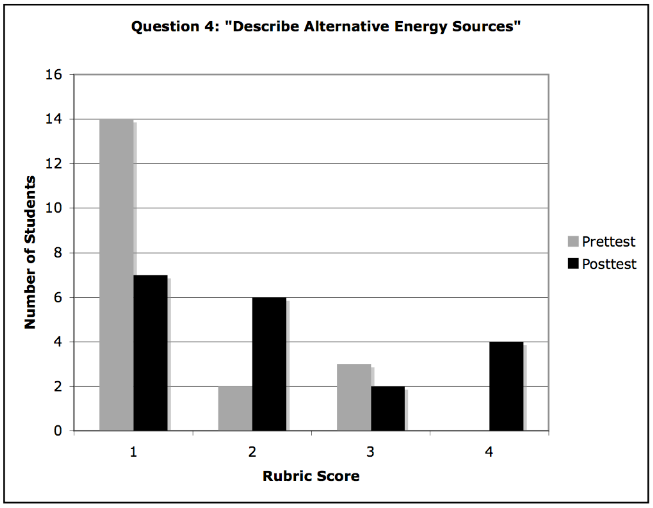
Responses to the second question suggest a fairly strong positive shift in students' understanding, but there still seems to be confusion around what an energy source is (e.g. coal, sun) and what it is converted into (e.g. electricity). In our revisions, we will elaborate the idea that there are many potential energy sources such as coal, oil, gas, wind, water, and sun. These sources are harnessed and converted into more directly usable forms (e.g. converting chemical potential energy from coal into electricity).

Question 3: Explain what you know about solar cells. Include a diagram with words that shows how you think a solar cell works.



Few students understood how solar cells work prior to engaging in the unit, and while responses indicate a mild positive shift in students' understanding, many students walked away from the unit still without a clear understanding of how solar cells work. In some cases, students described surface details of the nanocrystalline lab (e.g. the apparatus, the layers of the cell they had to construct), but seemed to not understand the actual mechanisms involved in solar cells. This insight will be used to revise the parts of the Clean Energy unit where the mechanisms of solar cells are discussed. Note that animations of how silicon-based solar cells and nanocrystalline solar cells work have been developed since the conclusion of this initial implementation study, and are included in latest release of the unit. During his May 2007 site visit, Larry Woolf also provided some excellent suggestions on how to address this issue in our revisions.

Question 4: Besides solar energy and the top energy sources you listed in question 2, provide two examples of other (alternative) energy sources that you know about with a short description of each.



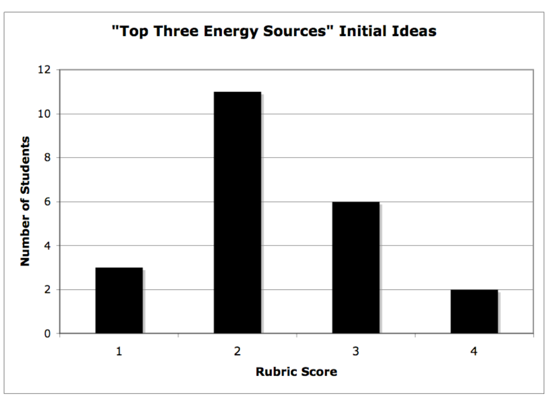
The results of this question highlight that many students had little understanding of what alternative energy sources were before the unit, but that many developed a sense of at least one or two types of alternative energy sources. Note that while the unit highlights alternative energy sources such as wind energy or hydroelectric energy, the major focus on the unit is on discussing solar energy and solar technologies.

Initial Ideas

On day one after the introductory slides were presented, students were asked three questions; one about the top three sources of energy in the world today, one about characteristics of clean energy, and one about current and future clean energy sources. Students' answers to each question were rated on the same four-point scale as used for the pretest/posttest (see Chart 1).

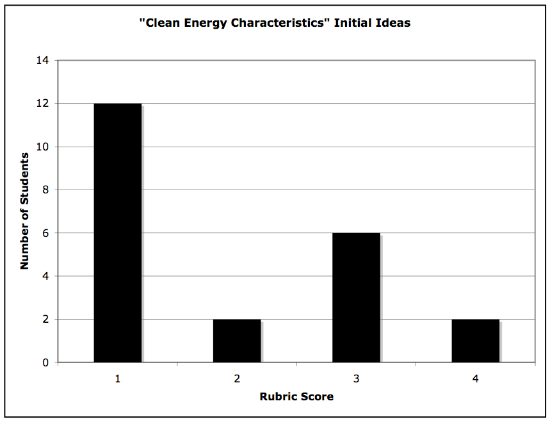
For the three questions, the depth of understanding of the pertinent science content is inferred based on the observable descriptors described below each heading.

Question 1: What are the top three sources of energy in the world today?



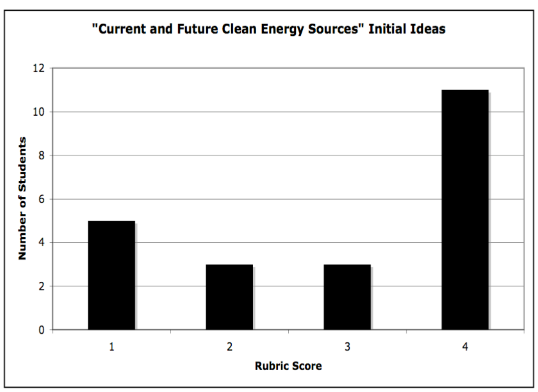
For this question, the majority of students listed at least one correct top energy source, fossil fuels (including coal, oil, natural gas). Common responses other than these top three were alternative energy sources such as solar power, water (hydroelectric), and wind. These student responses suggest that many students are aware of some top energy sources in use today, but are not clear as to what extent alternative energy sources (including also biomass, nuclear) are in use in the world.

Question 2: What are some characteristics of clean energy?



Students in general had a hard time listing characteristics of clean energy sources. Frequent answers for this question included a listing of alternative sources rather than their characteristics, suggesting that students either misunderstood the question or were not sure what "clean energy" actually means. In our revisions, we will clarify what is meant by "clean energy" and "alternative sources" and also note that no source is perfectly clean if you consider the entire manufacturing process, from cradle to grave. For example, solar panels may not produce greenhouse gases during operation, but greenhouse gases may be released during the process of manufacturing solar panels.

Question 3: What are some current and future clean energy sources?



Half of the students answering this question had a clear sense of alternative energy sources such as solar, wind, and hydro. In tandem with the findings of Question 2 above, we may want to provide more background information for students on what clean and alternative energy sources are (solar, wind, biomass, nuclear, and others) and how they are used.

Student Notecards

As part of our data gathering strategy during the classroom implementation of the Clean Energy unit, we handed out two kinds of index cards to students. White cards were used for students to write down things they found confusing or had questions about during class; yellow cards were used for sharing "light bulb" or "aha" moments. Students were asked to fill out the cards at any point during the unit and cards were collected at the end of each day.

We received a total of 24 question cards and 13 idea cards on day 1, and 19 questions cards and 9 idea cards on day 2. Note that cards with text that was incomprehensible were left out of the analysis. The questions and ideas were compiled into categories, shown below. (We may also use such questions to create a FAQ to accompany the unit.)

Question Card Topic: Introduction to Clean Energy (Day 1)

Use of fossil fuels/non-renewables

- How much oil do we use every year?
- Why do we still use non-renewable sources?
- Wow – we are in trouble!!!
- If we use up all the oil then what?
- How did we start making everything rely on energy?
- Why do we have to burn fossil fuels? What would happen if we didn't?
- What would happen if we didn't have renewable resources?
- Can natural gases be eliminated if we use it too much?

Alternative energy sources

- What is an alternative to fossil fuel use?
- What are some countries who use turbines and generators to produce electricity?
- What is the scientific name for wind power?
- What is biomass? Why do we need biomass?

Solutions

- Can a car be invented that uses CO_2 in the atmosphere and turns it into energy to run the car?
- Why don't scientists find a way to solve the energy problem?
- What are some countries who use turbines and generators to produce electricity?
- Why can't every building have a solar panel so we can save some energy?
- Is there another way cars could work without oil?
- Is the energy issue going to be solved within the next 80 years?
- If all of the oil is used, can we use nuclear to produce energy? Is it safe?
- Couldn't we use the ocean waves to produce energy?
- I read that there is a car that was invented that works with water instead of gasoline – can that be possible?
- Could it be possible to have someone turning the turbines? Why or why not?
- Why doesn't the government just stop using fossil fuels and start working on less harmful energy sources (like water or wind)?

Effects on the environment/Global warming

- Won't it be good if the world's fossil fuels get depleted? Won't it save global warming?
- How can we stop global warming without affecting our life routines badly?

Miscellaneous

- What if all the animals die?
- Can an island sink? (6 students asked this – referring to Hawaii?)
- Why is democracy a global problem? How does a democracy related to the environment?
- If all the animals die, do we all die?
- If we use the rainforest to get our wood then wouldn't that be resource depletion?
- Can you solve energy problems or can they get worse?
- Even if we reduce how much energy we use we'll still completely deplete it later. What will happen then? A depression?

Review of the day 1 questions highlight students' interest in solutions to energy issues. More specifically, even though the day 1 Clean Energy materials include relatively little material on potential solutions to global energy issues, a considerable number of students were interested in ways to address our energy problems. A fair number of students were also interested in the question of why we are so dependent on fossil fuels. We may include more information on these topic in the future.

Question Card Topic: Solar Energy (Day 2)

Making of Solar Cells

- How much are solar cells? How much do they cost to make? Why is silicon so expensive?
- Why are solar cells so hard to make?

Use/Application of Solar Cells

- Why are the solar cells in Texas mostly?
- How is the energy used from solar energy?
- What is a nanocrystalline cell?
- Why can't we just have solar panels on every house? Why not cover every roof? How much would it cost?
- Why don't we just cover states with solar panels?
- Why don't we put the photovoltaic panels in the desert?
- Why don't we make solar powered cars in hot places? Cars with photovoltaic solar cells to power the car.
- How do solar panels work?
- Can a silicon-based solar cell charge an ipod if placed on the back?
- Will solar energy work as efficiently in the winter as it does in the summer?
- Why can't people use sunlight to drive car and stop using oil to drive cars? I know some people use sunlight to drive their car, but not all people! And people use oil to drive their car, it is polluting the air, but if people use sunlight, it will not pollute the air.

Miscellaneous

- If moving air turns the turbines to create electricity, then is that how windmills work? When wind blows to move the windmill is that how energy/electricity is made
- What is thylakoid?

Review of the day 2 question cards highlight a handful of interesting student inquiries. First, students had a considerable number of questions regarding how solar cells can and are being used. In particular students seemed interested in the use of solar cells as part of an energy solution. We plan to include additional supports in the day 2 materials to provide students the opportunity during the class discussion to share these ideas.

A few students also had questions regarding how solar cells are made and why they are so expensive and difficult to manufacture. We may add more information on these topic in the slides, the teacher notes, or both.

One student expressed a misconception around "solar cells being mostly in Texas." This misconception was most likely prompted by a particular slide in the day 2 PowerPoint slides that shows an example of solar panels being placed over a percentage of the United States. We will explore alternative representations to reduce such confusion.

Understandings & Interesting Things Cards

The following table shows responses on notecards where students expressed things they know and/or things they found interesting ("aha's") in the Clean Energy unit.

Day 1: Introduction to Clean Energy	***Day 2: Solar Energy***
Global issues • Energy is the #1 problem today. • Energy is the world's top issue. • We are in trouble! Pollution/Environment • Fossil fuel (burning) cause pollution • Global warming is happening! Energy use • All laptops and microwaves use up a lot of energy and light bulbs. • 1000 barrels of oil every second is being used. • Energy #1 source. • Microwaves uses a lot of energy than a light bulb. • A laptop and playstation takes less than twice the time than a microwave General comments • "Disease" was number 7. • The energy sources that we are using are non-renewable. • Democracy to be related to environmental problems. • Fission is nuclear power.	Characteristics of solar energy • Solar energy is energy from the sun. • Clean energy does not pollute. • Solar panels are expensive. • We get energy directly from the sun. • Photovoltaic cells generate electricity. Solar cell/panel applications • Solar cells are used to heat water. • Put stuff on our backpacks to generate our cellphones and stuff like that. • Cars with photovoltaic solar cells to power the car. • Put solar panels on the Sahara Desert. • We should put solar cells on our backpacks to generate our cellphones and stuff like that. General comments • The United States use 25% of world's energy.

In general, student comments spanned a wide range. But it is somewhat surprising that there were no comments on nanocrystalline solar cells and/or the specifics of nanotechnology as applied to energy. The revised unit includes more focus on how nanocrystaline and traditional solar cells work, through a Flash animation and a new reading. Based on our May 2007 site visit with Larry Woolf, we are also revising the unit to better motivate why we want to use nanocrystalline solar cells and why they are designed the way they are (i.e., incorporating an engineering design perspective). These changes will hopefully evoke more "aha's" related to the specifics of solar energy technology.

Summary

The use of pretests/posttest, initial ideas worksheets, and student question and understandings notecards as part of our initial Clean Energy implementation study have provided information on student learning and a number of ways we can improve the learning opportunities in the unit.

Below is a list of changes to the unit we plan to make based on these findings, which will be implemented in the next iteration of the Clean Energy unit.

- Improve the "energy issue" parts of the unit.
- Add greater emphasis on the need for efficient and cost-effective ways to harness the energy from clean energy sources.
- Add greater emphasis on the "conversion" and "infrastructure" aspects of electrical energy.
- Expand the discussion of the mechanisms of silicon-based and nanocrystalline solar cells
- Increase discussion of alternative energy sources besides solar.
- Include supports for student discussion and reflection of potential energy solutions.
- Provide greater emphasis on basic definitions such as "clean energy" and "alternative sources".
- Include additional information on the world's dependency on fossil fuels.
- Provide more opportunities for students to discuss and reflect on how solar cells can and are currently being used.
- Include information on how solar cells are made and why they are expensive/difficult to manufacture.
- Clarify the day 2 slide showing solar panels placed over the state of Texas.
- Include more specific information and discussion points on "nano" topics such as the importance of surface to volume ratio.

Finding 3: Results of the Nanoscience Learning Goals Workshop

Forty-three participants attended the workshop, representing a range of roles (e.g., nanoscientists, nanotechnologists, science educators, informal educators). Over the three days, participants worked in small groups to identify and elaborate big ideas and learning goals, reached consensus within the working groups, and then (with a lot of discussion and debate) reached consensus across the working groups. The big ideas that emerged from this working meeting include the following:

- *Size and scale:* Concepts of size and scale form the cognitive framework used to make sense of nanoscale phenomena.
- *Particulate nature of matter:* All matter is composed of atoms.
- *Dominant forces:* The forces that govern interactions tend to change with the scale of the objects involved.
- *Properties of matter:* The properties of matter can change with scale. In particular, as the materials approach the nanoscale in size, they often exhibit unique functionality and properties. The source of these unique properties may be surface-or bulk-related.
- *Models:* Models help us understand, visualize, predict, hypothesize and interpret data about natural and manufactured nanoscale objects and phenomena, which by their very nature are too small to see.
- *Tool*s: Recently developed tools allow the investigation, measurement and manipulation of matter, leading to the development of new understandings and creation of new structures. These tools drive the scientific progress in nanoscale science and technology.
- *Technology and society:* Nanotechnology is driven by the processes of science and engineering to solve problems. The products of nanotechnology may impact our lives in

both positive and negative ways.

- *Self-assembly*: Under certain conditions, some materials can spontaneously assemble themselves into organized structures at a lower energy state. This process provides a useful means for manipulating matter at the nanoscale.

Each of these learning goals was elaborated (Why is it a big idea? What are the core science concepts and principles behind the big idea?), contentious issues were recorded, and the idea was expanded into 5-10 specific learning goals for middle school and high school. A group Wiki was created at https://wiki.sri.com:1800/display/NanoLearningGoals/Home where each working group continued elaborating their learning goals, linking them to national standards, and indicating where links to the standards do not exist. Below we summarize one example learning goal on the properties of matter:

Big idea: Properties of matter can change as you approach the nanoscale [and through the nanoscale].
Associated learning goals:

1. By the end of 9-10th grade, all students will know and understand that the characteristic properties of matter can change with particle size as you approach and go through the nanoscale.
2. By the end of 12th grade, students will know and understand that
   a. the surface area-to-volume ratio increases as particles become smaller. As a result, the fraction of the atoms that are on the surface increases, and surface-related properties become more important as a particle's size approaches the nanoscale.
   b. that unique shapes and structures occur at the nanoscale, leading to unique properties.

After the learning goals (and recurring themes) were vetted by our workshop participants, they were shared (for feedback) with nanoscience educators and middle school and high school teachers and participants in the 2007 Workshop on K-12 & Informal Nanoscale Science and Engineering Education. See Krajcik et. al (2007) for an elaborated report on the big ideas and learning goals identified from the workshop. This report will also be released as an NSF monograph written for teachers, administrators, and policymakers. Future work includes developing potential learning progressions and obtaining research evidence for the learning goals and learning progressions.

Finding 4: Participant Evaluations of Nanoscience Learning Goals Workshop

Participants were asked to complete a workshop evaluation survey at the end of the workshop. The full survey is available in the Exhibit 8. Nineteen completed surveys were collected, and participant responses are summarized below. Generally, participants:

- thought the workshop was very well organized
- thought that we identified the big ideas in nanoscience, and that it was a good first step to bring new science concepts to the K-12 curriculum
- felt we needed to do more work unpacking the ideas and aligning with standards
- really liked the productivity of the interdisciplinary working groups interspersed with whole-group discussion

- wanted even more time (even while the second day got a bit long)
- wanted more biologists, cognitive scientists, and K-12 teachers there
- suggested next steps that aligned with our existing plans
- thanked us for a great experience

Question 1: What is your primary role?

Most survey respondents were science educators or scientists, but a wide range of roles was represented, as shown in Figure 2. (Gender figures are for all participants, not just those who returned the survey.)

Chart 2: Learning Goals Workshop Participant Demographics

Roles		Gender	
Science educator	11	Female	18
Nanoscientist	7	Male	25
University faculty	5		
Physicist	3		
Chemist	3		
Postdoc	3		
Biologist	2		
High School teacher	1		
Graduate student	1		
Industry representative	1		
Policy maker	1		
Other (science education research/evaluation, science museum exhibit developer, earth science)	3		

* Note that participants often reported multiple roles.

Questions 2-10: Rate how strongly you agree with the following statements

Participants were asked to indicate how strongly they agreed with the following statements, on a scale from 1, strongly disagree, to 5, strongly agree. The vast majority of ratings were positive, as indicated by the mean ratings usually falling between agree and strongly agree.

Chart 3: Summary of Workshop Ratings

	Mean	Max	Min	N
2. The workshop was well organized.	4.61	5	4	18
3. The workshop met my expectations.	4.33	5	4	18
4. Presenters communicated effectively.	4.53	5	3	19
5. The content presented was of value to me.	4.47	5	3	19
6. The working sessions were of value to me.	4.68	5	3	19
7. We identified the big ideas in nanoscience relevant to K-12 education.	4.21	5	3	19
8. The workshop was a good first step to bring new science concepts into the K-12 curriculum.	4.47	5	3	19
9. The workshop was helpful in showing how nanoscience ideas relate to current ideas that are in the standards.	3.72	5	2	18
10. We made good progress in unpacking all of the ideas associated with the big ideas.	3.83	5	2	18

Question 11: What did you like best or find most useful about the workshop?

The most common response related to the productivity of the interdisciplinary working groups interspersed with whole-group discussion. All responses are shown below.

- All the working sessions, 5-8 people in each group is the perfect amount—very productive.
- My collaborative working groups were great. We accomplished a great deal and because they were interdisciplinary I really learned a lot.
- I liked the debates that occurred among the whole group that really shed light on the important challenges that exist to really incorporate nanoscience into K-12 curricula.
- Interacting with a stimulating mix of persons/backgrounds.
- Colleagues.
- I found discussion with professionals from various disciplines useful in clarifying key concepts for size and scale as it applies to nanoscience.
- The chance to spend enough time dealing with a topic to get somewhere.
- Jo Ellen was in our group and helped us ground concepts to standards from the beginning. Diversity of the small group. Having long time intervals to brainstorm.
- Exchange of ideas.
- Connections I made with other scientists and educators.
- Working in small groups.
- Cross-discipline representation.
- The extensive small-group work interspersed with whole group discussion. Particularly helpful was the variety of perspectives in my small group.
- I thought the free exchange of ideas was one of the conference highlights. Working in groups also encouraged debate and exchange.
- The discussions—both small group and large group.
- The wide interaction with people from different fields.

Question 12: What changes would you make to the workshop to make it better next time?

Common responses included inviting more cognitive scientists, biologists, and K-12 teachers, and even more time (more than our 3 days) for workshop activities. Participants were so engaged that they voluntarily stayed after the official end of the day in order to participate in whole- and small-group discussions. All responses are shown below.

- More time? Better strategy for followup and completion of the workshop tasks.
- Include cognitive scientists and K-12 teachers.
- I think having groups that were more diverse in the sense of having a scientist, a cognitive expert, an educator, a teacher, etc. This may assist in making tackling the problem more cohesive and input from different fields (in a structured way) should be more successful.
- Include cognitive scientists.
- Invite cognitive scientists, invite master teacher(s).
- I would have liked to have been more involved in other groups' discussions. Maybe more time to report, discuss, get feedback on each others results on the second and third days. First day report out was enough time since we only had the big idea at that point.
- If it would be possible to do the brainstorming before the meeting, we might be able to do some additional preparation and be more focused.
- Follow-up procedures to refine statements based on feedback from large group.

- We needed more time to discuss the various concepts that we identified as small groups. We also needed more time to discuss them as a large group and try to reach a consensus on condensing concepts to 2-3 key concepts.
- More focus.
- Projectors or printers on hand to see immediate versions of our working documents.
- Invite cognitive scientists. Invite K-12 teachers! Students to get their voice.
- Could include science teachers and cognitive scientists as participants.
- The entire workshop was very well organized. The only comment I had was to maybe have students invited next time for more diversity.

Question 13: What would you suggest that we do with the outcomes of this workshop? What next steps would you like to see?

Common responses for this question aligned with our intended next steps, which include summarizing our work, vetting it with the group, and then vetting it with a broader audience, including K-12 teachers. All responses are shown below.

- Full writeup. More discussion and vetting of learning goals.
- Get feedback/input from teachers, others.
- I think that some of the ideas presented are good, but many are still primitive. The participants made tremendous effort in developing big ideas and we should take it upon ourselves to finish the work here. The next step is using our work to modify or write new benchmarks/standards.
- Share with the participants for feedback. Share with larger community of interested people, including classroom teachers. Solicit interested individuals for collaboration on research on pieces of interest. Design and test curriculum for different aspects.
- Compile and vet to this group. Massage and vet to colleagues. White paper. Use to guide curriculum development not only for 7-12 but bridge to undergrad courses (progression).
- I would like to get copies of all of the groups' big ideas and learning goals.
- Consolidate and define the results and do some give and take with participants online.
- I think the next steps already described are ambitious and will be very valuable to the field.
- Finalize the various concepts and open it to the whole community to reach some agreement on the key concepts to incorporate in middle and high school education.
- Get buy-in from other nano groups.
- Vetting, reworking, publishing/dissemination.
- Run these standards by K-12 teachers and/or students to see what they think—i.e., initial reactions.
- Present documents to other content experts and teachers for critique. Get feedback and then publish.
- I would like to see/have a copy of the Word documents of each of the break-out sessions. Maybe available through CLTNet web site?

Question 14: Any additional comments or suggestions?

Most responses thanked us for the workshop experience. All responses are shown below.

- Dynamic, engaging discussions that were fruitful.
- Thank you!!

- Maybe you could throw some hands-on activities into the workshop just for fun, and to mix it up a bit.
- This was a great experience. Thanks for including me.
- Not clear how the parts fit together or whether there are holes between the final topics.
- Thanks.
- Second day was too long (esp. when expected to work through lunch).
- There was an absence of biologists. I think that inclusion in further meetings is necessary.
- Nice job with hotels, meals. Could focus on 'work" without cares about logistics!
- I really enjoyed the workshop. I don't have strong content knowledge at all and learned a great deal during the course of the workshop. I thought the whole group interacted well together and I really enjoyed working with members of my small workgroup.

Finding 5: Evaluation of Dec 2, 2006 Workshop for High School Teachers

Participants were asked to complete a workshop evaluation survey at the end of the workshop. The full survey is available in the Exhibit 9. Twenty-two teachers pre-registered, 18 teachers attended, and 17 completed surveys were collected. Participant responses are summarized below. Virtually all of the participants reported that the workshop was worthwhile and well organized, that the NanoSense materials were relevant to the classes they teach and they planned to use the materials in their classes, and that they wanted learn about future NanoSense professional development opportunities.

Teacher Demographics and Background

Eighteen teachers from 15 different schools attended the workshop. All of the teachers were from the San Francisco Bay Area, most within 20 miles, but some came from as far away as Marin and Santa Cruz. Eleven attendees were women, and 7 were men. All but one participant taught high school; one taught grades 7 and 8. Physics, chemistry, biology, and integrated science were the most frequently taught subjects, but earth science, science research, and physiology were also represented (see Chart 4).

Chart 4: Teacher Demographics

Grade Level Taught		Courses Taught		Gender	
Grade	**Number of Teachers***	**Biology**	**5**	**Female**	**11**
7	1	**Physics**	**6**	**Male**	7
8	1	**Chemistry**	**7**		
9	9	**Integrated/Gen Science**	**5**		
10	**12**	**Earth Science**	2		
11	**11**	**Science Research**	2		
12	**13**	**Physiology**	2		

* Note that teachers often taught multiple grade levels.

Participants had, on average, 8 years of teaching experience, ranging from 0 years for one participant who was currently in school to get his credential to 26 years for a high school physics teacher. Most participants had no previous experience with nanoscience. The three teachers who reported some background mentioned (1) reading Prey by Michael Criton, (2) taking a middle-school workshop from the Center for Probing the Nanoscale at Stanford, and (3) attending two workshops at the Exploratorium in San Francisco. The most common college majors represented were biology/life science, chemistry/biochemistry, engineering, physics, and psychology, respectively (see Chart 5).

Chart 5: Teacher Background

Years of Teaching		Previous Experience with Nanoscience?		College Major	
Mean	**8**	**Yes**	3	**Chem/Biochem**	5
Median	6.5	**No**	**14**	**Biology/Life Sci**	**8**
Min	0			**Physics**	2
Max	26			**Engineering**	4
				Psychology	2

Workshop Feedback

Overall, participants liked the workshop, found it interesting and a good use of their time. A breakdown of responses to specific questions is shown in Chart 6, and written responses are summarized below.

Chart 6: Summary of Workshop Feedback

	Yes	Somewhat	No	No Response
Did you find the workshop worthwhile?	**16**	1	0	0
Was it well organized?	**16**	1	0	0
Was the content of value?	**15**	2	0	0
Were there ideas or concepts that were confusing or needed further explanation?	**1**	6	9	1

Regarding what ideas or concepts needed further explanation, participants' responses included a range of logistical and content topics, but a couple of teachers specifically mentioned wanting more explanation about nanofiltration and the nanogold colloids. Ideas mentioned included the following:

- Quantum mechanics was mentioned and I'm barely familiar with it.
- Basic background, but the information provided was helpful.
- How exactly do the filters work (ceramic); do they really get rid of heavy metals? Will we someday see a pattern to Brownian motion? How are the colloids produced and would all "substances" display this property of scattering light differently when finely dispersed?
- Would like more time to discuss clean energy, clean water.
- Better idea of nanofiltration.
- We probably need more time on every part.
- Label the classroom station, give the rotation, have time for short breaks.
- What keeps the gold (or silver) nanoparticles in the colloidal suspension from clumping together? Are Van der Waal's forces too weak?

What did you learn today about nanoscale science that you didn't know before?

Teacher responses ranged widely, but interesting, relevant applications and nanoscale properties were often mentioned:

- It's used for physiology—delivering drugs, finding tumors. I found the size scale of familiar objects to be interesting: it left much potential to manipulate objects and microorganisms on a nano-level.
- Pretty much everything.
- I learned that I could use nanoscience concepts to make the physics content that I teach more interesting to my students by providing visuals and demonstrations.
- Nanoscience is a new frontier of investigation with applications that will impact every individual.
- The 4 reasons for property changes: SA/V ratio, quantum effects, EM effects, Brownian motion.
- I learned about nanoscale-related technologies that affect our society at levels highly relevant to our students, such as clean energy.
- I have to modify descriptions for elemental properties to address property changes of nanoparticles.
- That "stuff" behaves differently on a small scale as compared to bulk amounts.
- Sunscreen lotions are molecular screen blocking UV. Scanning probe model.
- Pretty much everything :) Scales, uses and specific activities for the classroom.
- Where and what areas of research that can be made "tangible" for teaching high school students.
- Changes in behavior/interaction with light changes with size of particle of materials such as gold. The general concepts were familiar to me but it's good to be reminded and to have information organized around this particular theme.
- Perhaps more awareness of the effect of area reduction as a nano effect and how it can be carried into truly nano size situations.
- Applications in so many different areas. Activities I can do in class.
- I didn't realize that there is some topics that I (we) teach in biology that is "nanoscience" such as DNA, etc.
- Varying colors of gold and silver, dependent upon size. What nanotubes are. Differences of behavior between macro vs. nano particles.

What questions, if any, do you have about teaching or understanding nanoscale science?

Most teacher responses focused on how to fit nanoscience into the current curriculum, communicate with other teachers, and to get additional materials and equipment:

- None. I think it can be integrated into many of the CA science standards.
- How can I get in touch with physics teachers that are using the nanoscience concepts that were introduced today?
- How to make it interesting/relevant to younger (7^{th}-8^{th} grade) students. How to help students understand the scale.
- Seems like a great unit to tie other concepts together—more of an application of technology than science?
- I would like to have seen comparisons to cotton fibers, human hair, and spider webs since nanofibers are topical items for discussion.
- My greatest concern is availability of the materials and equipment required (some stuff is expensive)—also time, given the present NCLB constraints.
- None at the moment, but I'm anxious to try it out in my classroom and I'm sure I'll have lots of questions then. How do I make space in the curriculum to fit it all in?

- Since I am new to high school teaching, how and where/when incorporate into the curriculum is a question for me.
- Is it possible to get copies of PowerPoints for clean water and clean energy components?
- Am wrestling with questions of where to fit nanoscience into current curriculum or should I try to develop a stand-alone course.
- I would like to know information on the solar cell kit.

What did you like best or find most useful about the workshop?

Teachers generally liked the presentations and activities, and having interesting examples of nanoscience that they can use in their classroom:

- PowerPoint presentations were great. Mini-labs and activities were fun, and students would really enjoy them.
- Magnetic domains of refrigerator magnet—especially the magneto-optical film for visualizing fields [Kyle Cole's lab station].
- What was most useful to me about this workshop was the demonstrations on UV light and magnetic fields that I could use to gain my students' interest.
- Applications of nanoscience, like clean water, UV sun protection.
- The hands-on activities, getting curriculum materials to take and use in classroom right away.
- Getting ideas for activities/lessons.
- I liked the inter-science and inter-culture disciplines covered by the workshop.
- PowerPoints and information.
- Hands-on.
- Increased awareness (enthusiasm) of/about nanoscience.
- The modules that are available to bring into the high school teaching are fantastic.
- I found most interesting and highly relevant to teaching about hugely important global issue the units in development on clear water (nanofilters) and clean energy (solar cells). I also liked the demo of the surface scanner sensitive to magnetic fields. I also appreciate that this addresses reality of new science, applications and questions for which answers may not yet be available. Finally, it's also good to be reminded of shifting relevant forces ad different scales. Thanks! Great topics!
- It was all great. As a physicist, I was particularly interested in Kyle's two magnetism works.
- All the activities. Things we can do in our own classroom.
- The various hands-on items/small labs.
- Got me thinking and questioning. Reminded me of demos or experiments I have done or know about already.

What changes would you make to the workshop to make it better next time?

Teachers wanted more time or follow-up workshops to go in-depth on some of the materials, and made some minor logistical recommendations (like lab rules, having ready kits, more Q&A time, and coffee!):

- "Ready kits": have the simple, inexpensive items for the labs given to the teachers so they can use them in the class right away. (Scale cards, film canisters, UV beads, sticks, etc.).
- More in-depth general introduction presentation.
- Make the workshop longer and provide more interesting physics demonstrations.

- Thank you!
- If everything is on disk maybe provide less paper for us (but then I know others would want both)
- Although I liked the workshop very much, perhaps establishing "lab rules" among partners/teams to model the teaching style might be useful.
- It would be nice to have a differentiated unit on nanoscience that ties to state standards. A class project type thing.
- Even though we are supposed to be mature adults, animating the PowerPoints makes them more fun. Just a crazy suggestion. Otherwise, it was great!
- More time for Q&A for lab "stations".
- Some suggestions on possible areas (units) that would work well with "injecting" nano.
- Break it down to several workshops so that we can really work on each part and know exact what we can use when we go back.
- Coffee, please!
- Demo the solar cell procedure and show one set up. For another workshop, go into how the solar cells work. I need more info about how solar cells work in order to know how to implement solar cells into my curriculum.

Materials Feedback

Overall, participants thought the materials were relevant to the classes they teach, expressed plans to use the materials in their classroom, and welcomed more contact with the project. One participant said that she would like to do some lessons as a field test, especially making nano-photovoltaics, and that she could field test any other ones.

A breakdown of responses to specific questions regarding the materials is shown in Chart 7, and written responses are summarized below.

Chart 7: Summary of Materials Feedback

	Yes	Maybe	No	No Response
Are the NanoSense materials relevant to the classes you teach?	**13**	4	0	0
Do you plan to use the NanoSense materials in any of your classes?	**12**	5	0	0
Would it be okay for us to contact you about experiences you have using NanoSense materials in your classroom?	**15**	(n/a)	1	1
Would you like us to contact you with information about other NanoSense professional development opportunities?	**17**	(n/a)	0	0
	Yes	**Maybe**		
I would like to attend NanoSense teacher meetings (about every 6 weeks, after school)	**4**	1		
I would like to join the NanoSense group in Tapped In to share ideas online with other educators	**13**	0		
I would like to be added to the nanosense-announcements mailing list to hear about updates to the NanoSense curriculum materials and future events by email	**17**	0		

Are there particular materials that are more relevant to your classes than others?

All of materials and activities were mentioned, including all of the NanoSense curriculum units that focus on applications (Clear Sunscreen, Clean Energy, Fine Filters), and the introduction to tools (probes) and underlying concepts (related to scale, surface area to volume ratio, unique properties at the nanoscale) in the Size Matters unit:

- In integrated science, all the materials are relevant. In biology, photosynthesis analogy with UV beads—photovoltaics, surface area and nanoscale.
- NanoSense curriculum [Size Matters?] is more relevant to my classes than the Clear Sunscreen curriculum because I can better link the NanoSense curriculum to the content that I need to teach.
- I found it fascinating how properties of materials change when moving from the macroscale to the nanoscale.
- SA/V, clean water, clean energy.
- Nanoparticles and the corresponding information is most relevant to my classes, such as the introductory ideas of how particles behave at different sizes (surface area to volume ratio, etc.).
- Lecture materials. Need more hands-on stuff that is less superficial. I'll be able to use the Size Matters stuff but need something a bit more involved.
- The sunscreen, UV stuff.
- Sunscreen/UV beads. Magnetic probe.
- Scaling—number line activity with cards.
- Clean energy—solar/photosynthesis, water and filters, UV, general concepts (surface area to volume ratio).
- Magnetism, UV.
- All the activities are relevant.
- Surface area, electron probes (microscope).
- Particle size, magnets analogy to sensing poles.

If you do not plan to use the NanoSense materials in any of your classes, what are your concerns?

Available time and money were the only reported concerns, by three teachers:

- Time (as always).
- Finding the time to inject this area.
- The actual constraints of time and money.

How can the developers make the NanoSense materials better or more useful for your classes?

Teachers most often mentioned having free "ready kits" available, making adaptations and fitting nano into the current curriculum, and mapping to standards:

- Have small "ready kit" available (cost less than $15) to get teachers started on using lessons in the class.
- At this point, I can't answer this question because I haven't had a chance to thoroughly go through the NanoSense materials. But, I'll keep in touch and give you more feedback.
- Make kits available. Make them free!
- Suggest adaptations for large-classroom implementation or different learning modules.
- More formal lesson plans with objectives, materials, and assessments [these are included in the units but we didn't point them out explicitly so perhaps she missed them].

- Make them more available to cash-strapped teachers!!
- Fix the slide re: energy and combustion of coal. Give me a bit of time to practice in my classroom then I should have some suggestions.
- Some suggestions on possible areas (units) that would work well with "injecting" nano
- Very good start. Booklets, CDs, etc. are a good resource. Guides to cheap materials and kits when possible are good. Have time for teachers to brainstorm alternative materials or versions at the end of day or end of each lab component?
- If we can get one set of materials for each activity. It will get us started more easily.
- Make sure they relate to CA science standards. Also, need to make sure to start the idea very simple, because many of the students will only know limited ideas.
- I prefer activities that can be inserted into current curriculum. That way I keep on touching back on the idea of nano throughout the year, not just in one "blob".

If you are interested in integrating some nanoscale science concepts and materials into your classroom, what kind of support would you like to have from the NanoSense team?

Teachers most often indicated that they would want materials (e.g., kits, posters) and someone to call or email if they have questions; they also mentioned field trip and guest speaker contacts, and ideas on how to incorporate the concepts into their curriculum:

- Just someone to call if I am confused about something. Maybe have introduction PowerPoints on DVD or video most of us don't have in focus projectors.
- I would like to be able to call or email someone if I have questions about the materials. I would like contacts for arranging field trips related to nanoscience (companies, academic research facilities, etc.).
- I would like to have information such as lesson plan ideas on how to incorporate these concepts into my physics class. I would also like to be kept informed on educational materials that I could use to demonstrate physics concepts.
- Email support with questions.
- Materials? Everything else about lessons seems to be provided—cool!
- Material/kits provided is best. Guest speakers? Posters :)
- Lesson plans, activities and experiments.
- Id' like to borrow some of the expensive material.
- It would be great to have an "expert" whom I could call or email with specific questions
- Providing materials for demos/lab?
- Free kits? (In my dream world).
- Where to fit nanoscience into current curriculum or should I try to develop a stand alone course.
- Email contact, we can ask questions down the road. Thanks.
- Info on how solar cells work. Info on what the UV beads are sensitive to.

Finding 6: Web Statistics

The NanoSense Web site has received over 100,000 requests since it opened in February 2005. On average, the site receives about 125 requests per day. The overwhelming majority of referring URLs are from Google searches. The top search terms (often used in combination with each other) are: properties, nanoscience, nano, electrical, sunscreen, nanotechnology, nanosense, lesson, application, nanorobot, introduction, light, magnetic suspension, materials, solar, absorption, powerpoint, pdf. NanoSense also appears in the top ten search results for "nanoscience education" on Google (as of May 2007, is it the sixth result).

Requests for the NanoSense homepage account for almost 10% of web site activity, followed by requests the overview of activities (3%), workshops (3%), and papers (2%). The majority of requests are for specific NanoSense lessons posted on the site, as show in Chart 8. Note that requests from SRI staff and web indexing robots are excluded from these analyses; that is, the reported site statistics aim to reflect requests from legitimate third parties.

Chart 8: Top 15 most frequently downloaded materials, as of May 1, 2007

Top Downloads (SM = Size Matters; CS = Clear Sunscreen)

Material	Downloads (% site hits)
SM One Day Introduction – Teacher Materials	3204 (3.5%)
SM Lesson 3: Unique Properties – Teacher Materials	3120 (3.4%)
SM Lesson 5: Applications of Nanoscience – Student Materials	2891 (3.2%)
SM Lesson 1: Introduction to Nanoscience – Student Materials	2338 (2.6%)
SM Lesson 1: Introduction to Nanoscience – Teacher Materials	2255 (2.5%)
SM Lesson 5: Applications of Nanoscience – Teacher Materials	2073 (2.3%)
SM Lesson 2: Size and Scale – Student Materials	1993 (2.2%)
SM Lesson 3: Unique Properties – Teacher Materials	1746 (1.9%)
SM Lesson 2: Size and Scale – Teacher Materials	1352 (1.5%)
SM Full unit	1990 (1.3%)
SM Lesson 4: Tools of the Nanosciences – Student Materials	1009 (1.1%)
SM Lesson 4: Tools of the Nanosciences – Teacher Materials	905 (1%)
CS Lesson 2: All About Sunscreens – Teacher Materials	873 (.9%)
CS Lesson 1: Introduction to Sun Protection – Teacher Materials	826 (.9%)
ChemSense Animator Guide	756 (.8%)

Exhibit 7. Data from sunscreen experiment.

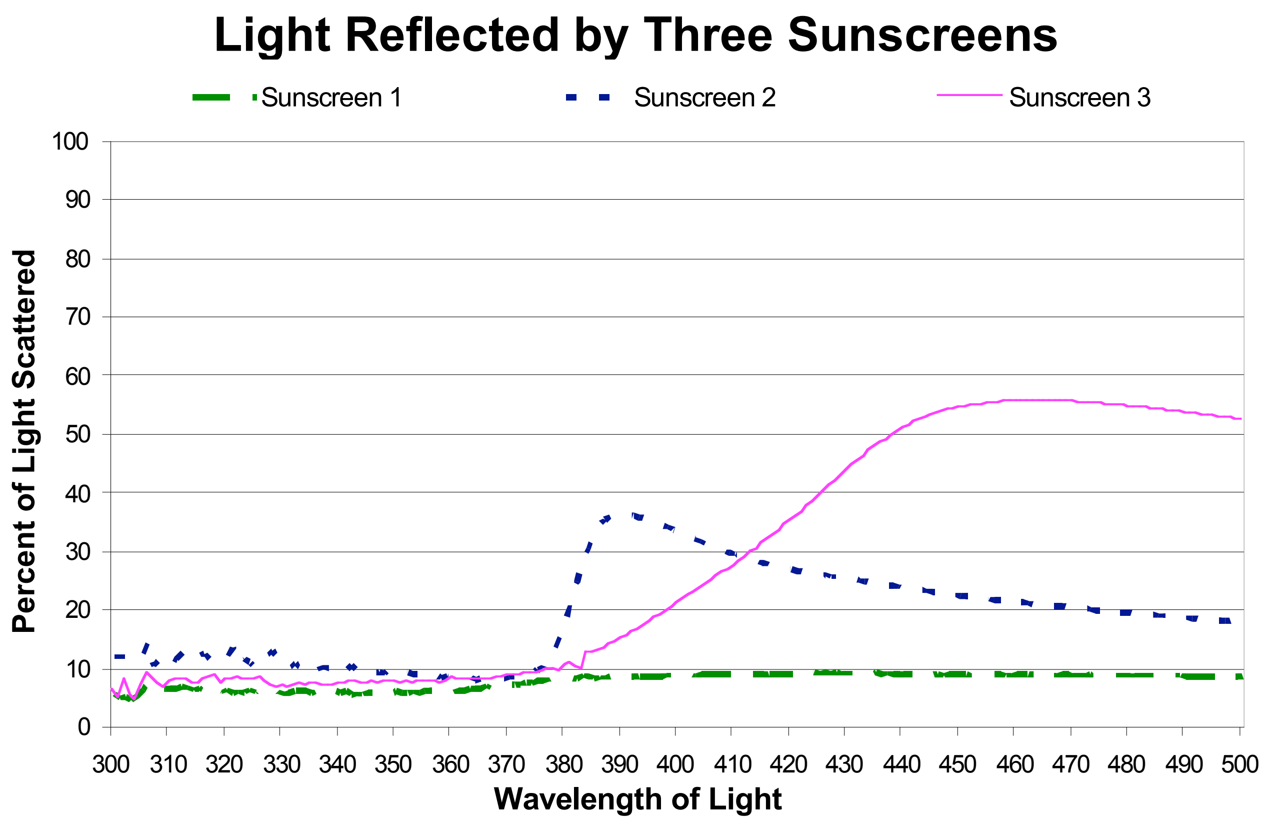


Exhibit 8. Evaluation survey for Nanoscience Learning Goals workshop.

Please help us evaluate the effectiveness of the Nano Learning Goals Workshop. Responses are voluntary, but greatly appreciated.

Name (optional): ____

1. My primary role(s) are…
   a. High school teacher
   b. Community college instructor
   c. University faculty
   d. Graduate student
   e. Postdoc
   f. Learning scientist
   g. Science educator
   h. Chemist
   i. Biologist
   j. Physicist
   k. Nanoscientist
   l. Industry representative
   m. Policy maker
   n. Other: ___________________________

	Strongly Disagree	**Disagree**	**Unsure**	**Agree**	**Strongly Agree**
2. The workshop was well organized.	1	2	3	4	5
3. The workshop met my expectations.	1	2	3	4	5
4. Presenters communicated effectively.	1	2	3	4	5
5. The content presented was of value to me.	1	2	3	4	5
6. The working sessions were of value to me.	1	2	3	4	5
7. We identified the big ideas in nanoscience relevant to K-12 education.	1	2	3	4	5
8. The workshop was a good first step to bring new science concepts into the K-12 curriculum.	1	2	3	4	5
9. The workshop was helpful in showing how nanoscience ideas relate to current ideas that are in the standards.	1	2	3	4	5
10. We made good progress in unpacking all of the ideas associated with the big ideas.	1	2	3	4	5

11. What did you like best or find most useful about the workshop?

12. What changes would you make to the workshop to make it better next time?

13. What would you suggest that we do with the outcomes of this workshop? What next steps would you like to see?

14. Any additional comments or suggestions?

Exhibit 9. Evaluation survey for teacher workshop at SJSU.

NanoSense Workshop Evaluation for Teachers
December 2, 2006

Your feedback will help us improve our materials and future workshops. Please help us by answering the following questions about yourself and your thoughts about the workshop.

Background

1. Your school:
2. Grades and courses you teach:
3. Number of years teaching:
4. College Major:
5. Have you had previous experience with nanoscience? Yes No
   If yes, please describe:

Workshop Feedback

6. Did you find the workshop worthwhile?	Yes	Somewhat	No
7. Was it well organized?	Yes	Somewhat	No
8. Was the content of value?	Yes	Somewhat	No
9. Were there ideas or concepts that were confusing or needed further explanation? If yes, which parts?	Yes	Somewhat	No

10. What did you learn today about nanoscale science that you didn't know before?

11. What questions, if any, do you have about teaching or understanding nanoscale science?

12. What did you like best or find most useful about the workshop?

13. What changes would you make to the workshop to make it better next time?

Materials Feedback

14. Are the NanoSense materials relevant to the classes you teach?	Yes	Somewhat	No

15. Are there particular materials that are more relevant to your classes than others?
If so, which ones?

16. Do you plan to use the NanoSense materials in any of your classes?	Yes	Maybe	No

17. If you circled "Maybe" or "No", what are your concerns?

18. How can the developers make the NanoSense materials better or more useful for your classes?

Integration of Materials into your Classroom

19. If you are interested in integrating some nanoscale science concepts and materials into your classroom, what kind of support would you like to have from the NanoSense team?

Future Events

20. We are interested in hearing about any experiences you have using NanoSense materials in your classroom. Would it be okay for us to contact you about this?	Yes	No
21. Would you like us to contact you with information about other NanoSense professional development opportunities for teachers?	Yes	No

22. If you answered "Yes" to either question above, please tell us your email address:

and check any of the following that apply (from high to low level of involvement):

___ I would like to attend NanoSense teacher meetings (about every 6 weeks, after school) at SRI International in Menlo Park, CA. (You will be added to the nanosense-teachers mailing list.)

___ I would like to join the NanoSense group in the Tapped In community to share ideas online with other educators. (You will receive an invitation by email.)

___ I would like to be added to hear about updates to NanoSense curriculum materials and future events by email. (You will be added to the nanosense-announce mailing list.)

Thank you for your help! We hope you enjoyed today's workshop.