NanoSense: The Basic Sense behind Nanoscience

YEAR 2 ACTIVITIES

Activities conducted during second year of the NanoSense project are described below. We categorize the work in terms of 7 activities.

Activity 1: Instructional Materials Development

Overview

In the second year of the grant, we implemented major revisions to our Size Matters unit based on feedback from our teachers, findings from pilot testing, and recommendations from our advisors and site visitor. The Clean Sunscreen unit was also completed, pilot tested, and revised, and we began development on two new units: Fine Filters and Clean Energy. These units are described in more detail below.

Size Matters: An Introduction to Nanoscience

Exhibit 1 shows an outline of the Size Matters unit, which provides an introduction to nanoscience, focusing on concepts related to the size and scale, unusual properties of the nanoscale, and example applications. Upon completing this unit, students will understand:

1. The study of unique phenomena at the nanoscale could vastly change our understanding of matter and lead to new questions and answers in many areas, including health care, the environment, and technology.
2. There are enormous scale differences in our universe, and at different scales, different forces dominate and different models better explain phenomena.
3. Nanosized particles of any given substance exhibit different properties than larger particles of the same substance.
4. New tools for observing and manipulating matter increase our ability to investigate and innovate.

The Size Matters unit spans up to ten 50-minute classroom periods if all lessons are used. Not all lessons are required; the unit overview provides guidance on which lessons to use depending on teacher and student interests. A one-day version is also available. Available lessons and activities include demonstrations, labs on unique properties at the nanoscale, hands-on activities on size and scale, a black-box activity on probes, PowerPoint slides, readings, worksheets, quizzes, and a poster session performance assessment.

This unit was pilot tested in classrooms in 2005, and the results of this testing are described in the Year 1 report. Based on pilot test findings and suggested revisions by our teachers and advisors, the unit was significantly revised in the summer and fall of 2006. Major revisions included the following: revised the enduring understandings to be more specific; added a new lesson on tools of the nanosciences; added more history to the introductory lesson; added alignment charts, a unit overview, and table of contents; supplemented the teacher materials with more background reading and complete keys for all activities; revised the properties lab directions to include more details and safety information; revised the properties slides to map more closely to the student reading; created a 1-day version of the unit; and refined the ordering and reformat the unit with a new look-and-feel designed by a graphic designer. The Size Matters unit is available for download at http://nanosense.org/activities/sizematters/

Clear Sunscreen: How Light Interacts with Matter

Exhibit 2 shows an outline of the Clear Sunscreen unit, which explores issues related to size and scale, specifically the effect of the size of nanopowders on the interactions of energy and matter (e.g., the absorption of light, addressing the electromagnetic spectrum and associated wavelengths). For example, old sunscreens use "large" zinc oxide particles, which block ultraviolet light but scatter visible light, giving the cream a white color. If nanopowders of zinc oxide are used instead, the cream is transparent, because the diameter of each nanoparticle is smaller than the wavelength of visible light. Upon completing this unit, students will understand:

1. How the energies of different wavelengths of light interact differently with our skin and vision.
2. Why particle size can affect the optical properties of a material.
3. That there may be health issues for nanosized particles that are undetermined at this time.
4. That it is possible to engineer useful materials with an incomplete understanding of their properties.
5. There are often multiple valid theoretical explanations for experimental data; to find out which one work best, additional experiments are required.
6. How to apply their scientific knowledge to be an informed consumer of chemical products.

The Clear Sunscreen unit spans up to twelve 50-minute classroom periods if all lessons are used. Not all lessons are required; the unit overview provides guidance on which lessons to use depending on teacher and student interests. Available lessons and activities include a UV protection lab, ChemSense animation activities, Flash animations, an investigation of sunscreen labels activity, and a consumer information pamphlet project, PowerPoint slides, readings, and worksheets.

This unit was pilot-tested in a February 2006 workshop and significantly revised as a result of workshop findings, as described in the Findings section of this report. The unit is available for download on the NanoSense web site at http://nanosense.org/activities/clearsunscreen/

Clean Energy: Nano Solar Cells and Clean Hydrogen Production

Exhibit 3 shows an outline of the Clean Energy unit, currently under development. This unit focuses on how energy production is a pressing global issue and how nanoscience could enable important breakthroughs in energy generation and conversion. This unit will be pilot tested in fall 2006. Tentative enduring understandings for this unit include the following:

1. Energy production is one of the most pressing global issues that humanity must address over the next few decades.
2. Clean alternative energy technologies must be developed to provide sufficient energy to meet growing global demand, and must be sustainable both environmentally and economically.
3. Nanoscience could enable important breakthroughs in solar energy conversion by exposing high surface areas of light-absorbing substances to solar radiation.
4. Nanoscience could enable an important breakthrough in clean energy technology by using nanocatalysts to efficiently produce hydrogen fuel that can be stored and used in fuel cells.

5. Surface are to volume ratio is a function of particle size and shape. Increasing surface area normally increases the rate of reaction because there are more sites available for simultaneous reaction.
6. Energy is neither created nor destroyed—it can only be converted into different forms.

The Clean Energy unit will span three to four 50-minute classroom periods if all lessons are used. Not all lessons will be required; the unit overview will provide guidance on which lessons to use depending on teacher and student interests. Available lessons and activities include a solar cell lab, a ChemSense animation activity, PowerPoint slides, quizzes, readings, and worksheets.

Fine Filters: Nanofiltration

Exhibit 4 shows an outline of the Fine Filters unit, currently under development. This unit focuses on the (uneven) scarcity of safe drinking water across the world, how water can be cleaned through a series of filtration steps, and how nanofiltration can be used as a cost-effective way to treat wastewater or as a pre-treatment before desalinization. This unit will be pilot tested in fall 2006. Tentative enduring understandings for this unit include the following:

1. A shortage of clean drinking water is one of the most pressing global issues.
2. How substances can be separated from heterogeneous and homogeneous solutions.
3. The smaller the particle that is to be separated from a solution, the smaller the required pore size of the filter. The smaller the pore size of the filter used for separation, the higher the cost of the process.
4. Technology can be used to help improve critical global health problems.

The unit will span two or three 50-minute classroom periods. Available lessons and activities include a filtration-mechanisms lab, a ChemSense animation activity, a performance assessment, PowerPoint slides, readings, and worksheets.

Activity 2: Teacher Meetings and Workshops

In the second year of the NanoSense project, we held 10 meetings with our partner teachers. Primary objectives of the meetings included gathering feedback on activities and planning use of materials in the classroom and in workshops. Meetings lasted from 2 to 4 hours, except for the February 11 workshop, which was a full-day workshop that included both teachers and students.

July 27, 2005: Review Size Matters and Clear Sunscreen units

Teachers provided oral and written feedback on new materials (Tools of the Nanosciences lesson materials, alignment and unit overview charts, nanofiltration reading) that were distributed a week prior to the meeting. Alyssa Wise also solicited feedback on the planned lab activities for the Clear Sunscreen. For each material discussed, we focused on the following questions: What are the core science concepts (and prerequisites) for this lesson? Where would it fit into what you teach? Are there revisions that would make it a better fit for you? What kind of visualizations on this topic would help your students?

September 12, 2005: Review Size Matters and Clear Sunscreen Units, Scheduling

Major updates to the Size Matters (including more teacher materials and keys, and a new layout/look) and updates to the Clear Sunscreen units based on teacher feedback were presented for discussion. Scheduling for pilot testing of activities in teacher classrooms was also discussed, with a goal of identifying a few days or a week in which our evaluator, Ellen Mandinach from EDC, could fly out and observe use of the materials in two or more classrooms. The earliest dates that the teachers could commit to were in late January, early February, or late May.

October 17, 2005: Review Size Matters and Clear Sunscreen Units

We handed out updated Size Matters unit binders and reviewed the One Day lesson plan, mesogold and ferrofluid demonstrations, and slide presentation. The teachers said they really liked the lesson, and two planned to use it in January. Alyssa Wise walked the group through the first draft of the Clear Sunscreen slides and the teachers provided detailed feedback on each slide. The teachers felt that the material was quite sophisticated, but that it worked well for building deeper knowledge. "It's beautiful science," one teacher commented.

December 5, 2005: Review Clear Sunscreen Unit, Visiting Guests, and Scheduling

Doris Mourad described a nanofiltration lab designed and conducted by her students, and we discussed minor updates to the Size Matters and Clear Sunscreen unit. Tina Stanford reported on her experience leading a NanoSense workshop at the Boston Museum of Science in November (see NanoTech 2005 below). Two guests—Miguel Aznar, Director of Education at the Foresight Nanotech Institute, and Celeste Carter, head of the Foothill College Biotechnology program—attended to learn more about the project and describe their work to the teachers. Because we wanted to pilot test the Clear Sunscreen unit with students soon, and our teachers were having difficultly finding time before May to cover the unit, we made a key decision to pilot test the unit with students and teachers in a one-day workshop on a Saturday in February. Our partner teachers both suggested and enthusiastically embraced this workshop alternative, and four of them volunteered to be responsible for teaching one or more of the five Clear Sunscreen lessons.

January 16, 23 and Feb 6, 2006: Student-Teacher Workshop Planning

Our next 3 meetings focused on planning for the February workshop. The teachers choose Clear Sunscreen lessons to lead (see agenda below), practiced with each other, asked questions about the unit, and recruited some of their students to attend the workshop. We coordinated with Maureen Scharberg to hold the workshop at training facilities at San Jose State University, publicized the workshop on our web site, and distributed a flyer about the workshop (see http://nanosense.org/documents/workshops/2006Feb11NanoWorkshopFlyer.pdf), to mailing lists for science teachers in the San Francisco Bay Area.

February 11, 2006: Student-Teacher Workshop

Seven teachers, two student teachers, two visitors, five NanoSense staff members, and 31 high school students attended the all day NanoSense workshop. See Exhibit 5 for the agenda, and the Findings section for a detailed description of student and teacher responses and student understanding based on data (e.g., from evaluation surveys, student work, and interviews) collected at the workshop, and recommended revisions to the Clear Sunscreen unit that were implemented as a result.

April 8, 2006: Workshop Findings and Reflection

Alyssa Wise presented a summary of our workshop findings (see the Findings section of this report) and the teachers reflected on our findings and their experience of the workshop. In particular, the teachers expressed a desire for more structured practice time with the materials before introducing them to their students. Based on our discussions, we decided to focus this summer on polishing the Clean Energy and Nanofiltration units, and hold longer (e.g., 2-day) workshops—one for each of the four existing NanoSense units—at San Jose State University in the fall and spring of 2006/2007. In these workshops, the NanoSense team would (for example) present the materials on the first day, and the teachers would practice with the materials on the second day. We will recruit additional teachers who can commit to try at least one unit in their classroom and report on their experience.

April 24, and May 17, 2006: Review Clean Energy Unit

Prior to the meeting, the first draft of the learning goals for the new Clean Energy unit was distributed to our partner teachers by email. At the meeting, Anders Rosenquist presented the first draft of the PowerPoint slides for the unit, and the teachers provided detailed feedback on the slides and the learning goals.

May 24, 2006: Review Fine Filters Unit

Prior to the meeting, the first draft of the learning goals for the new Fine Filters unit was distributed to our partner teachers by email. At the meeting, Tina Stanford presented the first draft of the PowerPoint slides for the unit, and the teachers provided detailed feedback on the slides and the learning goals.

Meeting Participants

Attendees of the teacher meetings above included the following:

- NanoSense Team:
  - Patricia Schank, SRI International
  - Tina Stanford, SRI International
  - Anders Rosenquist, SRI International
  - Alyssa Wise, SRI International (summer intern) and Indiana University
  - Vera Michalchik, SRI International
  - Maureen Scharberg, San Jose State University

- Core Partner Teachers Attending Most Meetings:
  - Doris Mourad, Castilleja School, Palo Alto, CA
  - Carolina Sylvestri, Gunn High School, Palo Alto, CA
  - Miriam Motoyama, Gunn High School, Palo Alto, CA
  - Geri Horsma, Gunn High School, Palo Alto, CA

- Visiting Teachers Attending One or Two Meetings:
  - Victor Brandalais, San Jose State University (Teacher in Residence)
  - Joan Carter, San Jose State University (Teacher in Residence)
  - Nancy Day, Menlo-Atherton High School, Menlo Park, CA
  - Jeff DeCurtains, Menlo-Atherton High School, Menlo Park, CA
  - Irene Hahn, Miramonte High School, Orinda, CA

- Britt Hammon, Antioch High School, Antioch, CA
- Resa Kelly, San Jose State University
- Claudia Winkler, Gunn High School, Palo Alto, CA

NanoTech 2005 Workshop at Boston Museum of Science

In November 2005, Co-PI Tina Stanford lead a NanoSense workshop at "Nanotech 2005: A Symposium for Educators at the Museum of Science" held at the Boston Museum of Science. NanoSense was invited to lead a workshop by Carol Lynn Alpert, Director of Strategic Projects at the Museum of Science after discussions with Dr. Alpert at the NSF-sponsored Workshop K-12 & Informal Nanoscale Science and Engineering Education on October 19-20, 2005.

The Nanotech 2005 symposium introduced about 75 middle school, high school, and community college science and engineering teachers (mainly from the Boston area) to the basic concepts of nanoscale science and engineering through hands-on classroom workshop sessions and keynotes by Professors Eric Mazur and George Whitesides, both from Harvard University. This symposium was supported by NSF, through partnerships with two Nanoscale Science and Engineering Centers, and by grants from NIH. For more information on the symposium, see http://www.mos.org/doc/1894

Ms. Stanford led two 75-minute sessions on selected lessons from the NanoSense Size Matters unit. A wide range middle and high school, biology, chemistry, and physics teachers participated. Ms. Stanford handed out copies of the unit, walked the teachers through some of the size and scale activities (Cutting it Down and Number Line Card Sort), presented the slides for the One-Day Lesson, and did the Bubble Lab to illustrate self assembly. The teachers reported that the workshop helped them clarify their understanding of nanoscale science and imagine ways that they could fit activities into their existing curriculum. The middle school teachers especially liked the size and scale activities, viewing them as a good way to get their kids to think about "how small is small." After the workshop, several teachers who had not attended the session approached Ms. Stanford to request copies of the curriculum. It was exciting to see our materials met with interest from a wide range of teachers.

Activity 3: Evaluation

The focus of our Year 2 evaluation was on a 1-day NanoSense workshop for high school science teachers and their students, held at training facilities at San Jose State University (hosted by our subcontractor, Maureen Scharberg). The workshop agenda is shown in Exhibit 5. All lessons at the workshop were presented by our partner teachers, except as noted in the agenda (Alyssa Wise, the author of the Clear Sunscreen unit, introduced a couple of lessons). After a general introduction to nanoscience (the One-Day Introduction to Nanoscience lesson from the Size Matters unit), the students and teachers completed the Clear Sunscreen unit. A nanoscientist from SRI International also presented his work over the lunch hour. Participating teachers were given sets of materials to take back to their classroom and were encouraged to give feedback and input on the materials. Student worksheets and project artifacts, an extensive evaluation survey, and written comments and questions were collected from all participants. All participants were given a certificate of completion.

A detailed analysis of the workshop findings, including student and teacher responses and student understanding, is provided in the Findings section of this report.

Activity 4: Use of Materials by Others

University of Wisconsin

In December 2005, Janice Hall, a graduate student at the University of Wisconsin emailed the NanoSense team. She said that the "NanoSense materials have been extremely useful to me (and soon to many others I hope!)". She and her advisor, Dr. John Moore, are working on an online course about Nanoscience for high school teachers. Their goal is to provide teachers with a background on nanoscience and materials they can use in their current curricula. A colleague (Dr. Andrew Greenberg) told them about the NanoSense project and materials, and she has found them to be "so useful we'd love to include them in our course," with a link to the NanoSense website. Dr. Moore plans to offer the course during the summer of 2005, and Ms. Moore said that the NanoSense material "would be a wonderful addition, that clearly shows how teachers can implement this great new subject in their classrooms, and of how it can satisfy current scientific standards."

Christopher Newport University

In spring 2006, Professor S. Raj Chaudhury used the Size Matters unit in his introductory physics course at Christopher Newport University in Newport News, Virginia. The course—PHYS 104, Elementary Physics II—is part of the science breadth requirement for graduation of non-science majors, and emphasizes conceptual understanding and basic problem solving. The PowerPoint slides in the unit were used to introduce students to nanoscience concepts that do not appear in the curriculum or textbooks. Approximately 2-3 weeks were devoted to the topic. Activity sheets were used as homework, and the students were assessed with questions on quizzes and tests. The instructor reported that "the materials fit nicely after an introduction to quantum mechanics, which students had completed," and that "the students appeared to find the materials interesting as they connect to many modern-day applications." A shortened version of the Sunscreen unit, including the UV bead lab, was also used.

NCLT

Molly Yunker and Nikki Guthrie, PhD students working with Joe Krajcik, completed a constructive critique of the NanoSense Clear Sunscreen unit based on the Project 2061 criteria for evaluating curriculum materials. This critique was done as part of a spring 2006 course on designing learning environments. Molly and Nikki identified areas of the unit that they felt could be improved upon and offered their feedback to our Alyssa Wise, the lead developer of this unit, and to the NanoSense research team.

California Community Colleges

In December 2005, Diana Rude from Bina Consulting contacted NanoSense on behalf of California Community Colleges. As a component of their research, they are identifying existing workforce education and training programs/projects in this industry area. They requested use of our materials for their project on workforce training needs in nanotechnology industries. We discussed their need and welcomed them to download the materials on the NanoSense web site.

Feedback on Informal Use by Teachers

In December 2005, biology teacher Geri Horsma used the introductory 1-day overview of the introductory Size Matters unit with her biotech class at Gunn High School in Palo Alto, and reported that it was "a nice experience!" Her student teacher ran the power point presentation, and she did the narration. She said that "Students were very interested, asked questions, and I

really appreciated having the "script" to use as a help!" They were also "enthusiastic about seeing red gold" (a demonstration that is part of the 1-day version).

Activity 6: Synergistic Activities

A Workshop to Identify and Clarify Nanoscience Learning Goals

In November 2005, Patricia Schank (NanoSense PI) and Joe Krajcik (NCLT Co-PI) submitted a proposal to NSF to hold a national workshop to bring together leading experts and practitioners in nanoscience, learning science and science education to identify and clarify learning goals for nanoscience. The proposal was funded and is scheduled to be held at SRI International June 14-16, 2006. The major goals of the workshop are to obtain an informed consensus on the major concepts of nanoscience, clarify the meanings of these concepts, turn these concepts into learning goals, link the learning goals to national standards, and point out where links to the standards do not exist. The outcomes of the workshop will be documented in a public report and presented at various national conferences to benefit materials developers and push the research agenda in nanoscience education.

Proposal: Framework for Molecular Modeling Curriculum Project

Leveraging work from the ChemSense project at SRI International and the Modeling Across the Curriculum (MAC) project at the Concord Consortium, the NanoSense team submitted a proposal to produce a robust instructional framework and associated curriculum for grades 6-8 and 9-12 in the areas of modeling and the particulate nature of matter. The framework would detail what content knowledge, process skills, and techniques are developmentally appropriate at each grade level and help students learn how to construct, manipulate, and understand the functionality of models. This proposal was not funded.

Proposal: SCALE: Investigating a Multiscale Modeling Framework to Illustrate Issues of Scale in Introductory Engineering Courses

In August 2005, the NanoSense team submitted a proposal to NSF's Engineering Education Program (EEP) to test the hypothesis that integrated, multiscale, multidisciplinary modeling software can serve as the basis for student "cognitive apprenticeship" and "cognitive flexibility" in lower-division engineering courses. We proposed to develop a prototype, "proof-of-concept" application to be tested and refined with engineering students and instrumented with assessment tools geared to core concepts—focusing on how specific properties change as the size scale changes, since this relationship provides an easy access point for students to understand how different theoretical models represent different parts of the scale. This proposal was not funded.

Activity 6: Advisory Activities

On July 26, 2006, Dr. Lawrence Woolf from General Dynamics visited SRI to conduct a site visit of the NanoSense project, addressing several "big questions" including: What did you say you would do? What are you actually doing? How do you know you are doing it well? How can nanoscience help students obtain a coherent and comprehensive view of important science concepts? Before the meeting, Dr. Woolf reviewed our annual report, Size Matters unit, and early drafts of parts of our Clear Sunscreen unit. We also sent Dr. Woolf a document with our responses to the big questions and to other questions (e.g., about visualization, enduring understandings, topics covered in our materials, and the science behind clear sunscreen) that he and our program officer submitted. During the meeting, we discussed these questions in depth,

and with helpful suggestions from Dr. Woolf, refined our materials and processes. For example, we refined our enduring understandings to be more specific, added more organizing structure to our units (e.g., table of contents, unit overviews), included more history in the introductory unit, and refined our process for choosing topics to focus on those at the intersection of available expertise, common curricular gaps, engaging topics, and opportunities for innovative approaches. After the meeting, we sent Dr. Woolf a copy of the Clear Sunscreen materials (in development at the time) to which he provided extensive feedback via email. Dr. Woolf also sent us some final questions and submitted his site visit report, which we responded to in a separate document submitted to him and to our program officer.

In line with our refined plan for choosing topics for our upcoming units, we identified potential topics and then held meetings with SRI nanoscientists Grace Chou, Ted Mill, Brent MacQueen, and Marcy Berding to better understand engaging aspects of these topics, the science behind the topics, and the availability of expertise at SRI in the identified areas. These discussions (and follow-on question-answer sessions with the scientists) were very helpful in guiding the choice, focus, and development of two new units on nanofiltration and clean energy.

Grace Chou, a chemical engineer with expertise in membrane and process science, discussed with us a variety of filtration processes and applications of nanofiltration in food processing and water treatment. She explained how nanofiltration does not work for desalination (reverse osmosis is required), but it can be used to purify wastewater and as a pre-treatment before desalination. Grace emailed several references to the team after our meeting and offered to serve as an expert consultant on our proposed nanofiltration unit. We are currently developing a unit on water treatment (nanofiltration) that will fit into chemistry curriculum under the topic of separating mixtures.

Ted Mill described his research on oxidation of chemical organic compounds and how it can be applied to remove organics from water. He is currently looking at ways of treating water with sunlight or artificial light through photosemiconductors (using nanoparticles of TiO2 as a catalyst) to oxidize organic compounds. He noted that oxidation may work better than filtration in some instances, since odor-causing compounds are often organic. Ted and Grace agreed that catalysis and optical phenomena are promising areas of nanoscience, since chemical and optical properties fundamentally change in the nanoscale size range. Ted recommended that we consider a unit on mechanical properties, for example, of carbon nanotubes. Finally, they described ways that nanoscience could impact research in clean energy (energy produced without pollutants) and renewable energy (such as solar energy), noting that this is a very promising field of research and that SRI has expertise in this area.

Brent MacQueen described in depth the science and technology behind clean and renewable energy. Brent explained how nanoscience could enable important breakthroughs in (renewable) solar energy conversion by exposing high surface areas of light-absorbing substances to solar radiation. Nanoparticulate titanium Graetzel cells are an example of such a technology. He explained how conventional solar cells work, how Graetzel-cell-based solar cells work, and the advantages and disadvantages of each. He also described how nanocatalysts could be used to efficiently produce hydrogen fuel that could be stored and used in fuel cells. After the meeting, Brent sent us additional references, we asked clarifying questions via email, and he reviewed the learning goals that we developed for the Clean Energy unit for scientific accuracy.

Activity 7: Dissemination and Outreach Activities

Papers and presentations

NanoSense activity development progress and current findings were presented at AERA, ICLS, the Exploratorium, the Workshop on K-12 & Informal Nanoscale Science and Engineering Education, and at the annual IMD meeting. At the IMD conference, Tina Stanford highlighted year 2 activities of the NanoSense project, materials that were developed, challenges and opportunities, and our implementation approach.

Publication citations

- Hsi, S., & Sabelli, N. (2006). Learning at the nanoscale: Research questions that the rapidly evolving interdisciplinarity of science poses for the learning sciences. Innovative Session, *7th International Conference of the Learning Sciences*, Bloomington, IN. Available online at http://nanosense.org//documents/papers/ICLS2006HsiSabelli.pdf

- Sabelli, N., Schank, P., Rosenquist, A., Stanford, T., Patton, C., Cormia, R., & Hurst, K. (2005). Report of the workshop on science and technology education at the nanoscale (PDF). DRAFT Technical Report, Menlo Park, CA: SRI International. Available online at http://nanosense.org//documents/ reports/NanoWorkshopReportDraft.pdf

Presentation citations

- Schank, P., Wise, A., Stanford, T., & Rosenquist, A. (2006, April). Teaching nanoscience to high school students: A tale of the NanoSense project. Poster presented at the *Annual Meeting of the American Educational Research Association (AERA)*, San Francisco, CA.

- Wise, A., & Schank, P., Stanford, T., & Rosenquist, A. (2006, April). The many challenges of designing and teaching nanoscience. Roundtable discussion at the *Annual Meeting of the American Educational Research Association (AERA)*, San Francisco, CA.

- Stanford, T., Ristevy, J., Schank, P., & Morrow, C. (2006, February). Size and scale: Research and recommendations. Roundtable discussion presented at the Instructional Materials Development Conference, Washington, DC.
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- Schank, P., Wise, A., & Stanford, T. (2006, February). NanoSense: *Developing activities to teach high school students about nanoscience principles, applications, and implications*. Presented at the Instructional Materials Development Conference, Washington, DC. Available online at http://nanosense.org/documents/presentations/NanoSensePosterFlyer.pdf

- Schank, P. (2006, February). Overview of the NanoSense and ChemSense projects. Presented at the *Nanoscale Informal Science Education Network (NISE) Visualization Laboratory Meeting*. February 17-18, San Francisco, CA.

- Schank, P. (2005, October). The NanoSense project: Overview. Presented at the *Workshop on K-12 & Informal Nanoscale Science and Engineering Education* sponsored by the National Science Foundation. October 19-20, Washington, DC. Available online at http://nanosense.org/documents/presentations/NIMDNanoSenseOverview.ppt

- Schank, P. (2005, October). The NanoSense project: Design challenges and

opportunities. Presented at the *Workshop on K-12 & Informal Nanoscale Science and Engineering Education* sponsored by the National Science Foundation. October 19-20, Washington, DC. Available online at http://nanosense.org/documents/presentations/NIMDWorkshopOct2005.ppt

NanoSense Web site

Activities developed by the NanoSense team are made available to the public on the NanoSense Web site (http://nanosense.org) as they are pilot-tested and vetted by our partner teachers. The introductory Size Matters unit and the Clear Sunscreen unit are currently available on the Web site, and 2 more units (Clean Energy and Fine Filters) will be posted in 2006. The units are also distributed at conferences and teacher workshops.

Exhibit 1. Size Matters unit materials.

Overview of Unit
Teacher Materials
- For Anyone Planning to Teach Nanoscience…Read This First!
- Size Matters Overview and Learning Goals
- Unit at a Glance: Suggested Sequencing of Activities
- Alignment Chart: Enduring Understandings
- Alignment Chart: Key Knowledge and Skills

Lesson 1: Introduction to Nanoscience
Teacher Materials
- Introduction to Nanoscience: Teacher Lesson Plan
- Introduction to Nanoscience: PowerPoint with Teacher Notes
- Introduction to Nanoscience Worksheet: Teacher Key

Student Materials
- Introduction to Nanoscience: Student Reading
- Introduction to Nanoscience: Student Worksheet
- Scale Diagram: Dominant Objects, Tools, Models, and Forces at Different Scales
- The Personal Touch: Student Reading
- The Personal Touch: Student Worksheet

Lesson 2: Scale of Objects
Teacher Materials
- Scale of Objects: Teacher Lesson Plan
- Number Line Activity: Teacher Key
- Scale of Objects Activity: Teacher Key
- Cutting it Down Activity: Teacher Key
- Scale of Small Objects Quiz: Teacher Key

Student Materials
- Visualizing the Nanoscale: Student Reading
- Scale Diagram: Dominant Objects, Tools, Models, and Forces at Different Scales
- Number Line Activity: Student Instructions
- Scale of Objects Activity: Student Instructions
- Cards and Line Markers for Number Line and Scale of Objects Activities
- Cutting it Down Activity: Student Instructions
- Scale of Small Objects: Student Quiz

Lesson 3: Unique Properties at the Nanoscale
Teacher Materials
- Unique Properties at the Nanoscale: Teacher Lesson Plan
- Unique Properties at the Nanoscale: PowerPoint with Teacher Notes
- Unique Properties Lab Activities: Teacher Instructions
- Unique Properties at the Nanoscale: Teacher Reading
- Unique Properties at the Nanoscale Quiz: Teacher Key

Student Materials

- Size-Dependent Properties: Student Reading
- Unique Properties Lab Activities: Student Instructions
- Unique Properties Lab Activities: Student Worksheet
- Unique Properties at the Nanoscale: Student Quiz

Lesson 4: Tools of the Nanosciences
Teacher Materials
- Tools of the Nanosciences: Teacher Lesson Plan
- Scanning Probe Microscopy: Teacher Reading
- Scanning Probe Microscopy: PowerPoint with Teacher Notes
- Black Box Activity: Teacher Instructions
- Seeing and Building Small Things Quiz: Teacher Key
- Optional Extensions for Exploring Nanoscale Modeling Tools: Teacher Notes

Student Materials
- Black Box Lab Activity: Student Instructions and Worksheet
- Seeing and Building Small Things: Student Reading
- Seeing and Building Small Things: Student Quiz

Lesson 5: Applications of Nanoscience
Teacher Materials
- Applications of Nanoscience: Teacher Lesson Plan
- Applications of Nanoscience: PowerPoint with Teacher Notes
- What's New Nanocat? Poster Session: Teacher Instructions and Rubric

Student Materials
- What's New Nanocat? Poster Session: Student Instructions
- What's New Nanocat? Poster Session: Student Topic List
- What's New Nanocat? Poster Session: Peer Feedback Form

One Day Introduction to Nanoscience
Teacher Materials
- One Day Introduction to Nanoscience: Teacher Lesson Plan
- One Day Introduction to Nanoscience: Teacher Demonstration Instructions
- One Day Introduction to Nanoscience: PowerPoint with Teacher Notes

Exhibit 2. Clear Sunscreen unit materials.

Overview of Unit
Teacher Materials
- For Anyone Planning to Teach Nanoscience…Read This First!
- Clear Sunscreen Overview, Learning Goals & Standards
- Unit at a Glance: Suggested Sequencing of Activities
- Alignment of Unit Activities with Learning Goals
- List of Sunscreen Products that use Nanoparticle Ingredients

Lesson 1: Introduction to Sun Protection & Initial Ideas
Teacher Materials
- Clear Sunscreen Introduction to Sun Protection & Initial Ideas: Teacher Lesson Plan
- Nano Sunscreen – The Wave of the Future?: PowerPoint with Teacher Notes
- Clear Sunscreen Initial Ideas: Teacher Instructions
- Ultra-Violet (UV) Protection Lab Activity: Teacher Instructions & Answer Key

Student Materials
- Kinds of Sun Radiation: Student Handout
- Clear Sunscreen Initial Ideas: Student Worksheet
- Ultra-Violet (UV) Protection Lab Activity: Student Instructions & Worksheet

Lesson 2: All About Sunscreens
Teacher Materials
- All About Sunscreens: Teacher Lesson Plan
- All About Sunscreens: PowerPoint with Teacher Notes
- Sunscreen Ingredients Lab Activity: Teacher Instructions & Answer Key
- Reflecting on the Guiding Questions: Teacher Instructions

Student Materials
- Sunscreen Ingredients Lab Activity: Student Instructions & Worksheet
- Summary of FDA Approved Sunscreen Ingredients
- Reflecting on the Guiding Questions: Student Worksheet

Lesson 3: The Science Behind Sunscreen Protection: Absorption
Teacher Materials
- The Science Behind Sunscreen Protection: Absorption: Teacher Lesson Plan
- The Science Behind Sunscreen Protection: Absorption: PowerPoint with Teacher Notes
- Reflecting on the Guiding Questions: Teacher Instructions

Student Materials
- Absorption of Light by Matter: Student Reading
- Reflecting on the Guiding Questions: Student Worksheet

Lesson 4: The Science Behind Sunscreen Protection: Scattering
Teacher Materials
- The Science Behind Sunscreen Protection: Scattering: Teacher Lesson Plan
- The Science Behind Sunscreen Protection: Scattering: PowerPoint with Teacher Notes
- Scattering of UV Light Animations: Teacher Instructions & Answer Key

- Ad Campaign Project I (ChemSense Activity): Teacher Instructions & Rubric
- Reflecting on the Guiding Questions: Teacher Instructions

Student Materials

- Scattering of Light by Particles: Student Reading
- Scattering of UV Light Animations: Student Instructions & Worksheet
- Ad Campaign Project I (ChemSense Activity): Student Instructions
- Reflecting on the Guiding Questions: Student Worksheet

Lesson 5: Stylish Sunscreens: What Determines Sunscreens' Appearance

Teacher Materials

- Stylish Sunscreens: What Determines Sunscreens' Appearance: Teacher Lesson Plan
- Stylish Sunscreens: What Determines Sunscreens' Appearance: PowerPoint with Teacher Notes
- Scattering of Visible Light Animations: Teacher Instructions & Answer Key
- Ad Campaign Project II (ChemSense Activity): Teacher Instructions & Rubric
- Reflecting on the Guiding Questions: Teacher Instructions

Student Materials

- Scattering of Visible Light Animations: Student Instructions & Worksheet
- Ad Campaign Project II (ChemSense Activity): Student Instructions
- Reflecting on the Guiding Questions: Student Worksheet

Lesson 6: Summary & Culminating Activities

Teacher Materials

- Culminating Activities: Teacher Lesson Plan
- Consumer Choice Project: Teacher Instructions & Rubric
- The Science Behind the Sunscreen: Teacher Answer Key to Quiz
- Final Reflections: Teacher Instructions

Student Materials

- Consumer Choice Project: Student Instructions
- Consumer Choice Project: Peer Feedback Form
- The Science Behind the Sunscreen: Student Quiz
- Final Reflections: Student Worksheet

Exhibit 3. Proposed Clean Energy unit materials.

Overview of Unit
Teacher Materials
- For Anyone Planning to Teach Nanoscience…Read This First!
- Clean Energy Overview, Learning Goals & Standards
- Unit at a Glance: Suggested Sequencing of Activities
- Alignment of Unit Activities with Learning Goals

Lesson 1: Introduction & Initial Ideas
Teacher Materials
- Clean Energy Introduction & Initial Ideas: Teacher Lesson Plan
- Clean Energy – The Potential of Nanoscience for Energy Production and Use: PowerPoint with Teacher Notes
- Clean Energy Initial Ideas: Teacher Instructions

Student Materials
- Clean Energy Initial Ideas: Student Worksheet

Lesson 2: Solar Energy and Nanoscience
Teacher Materials
- Solar Energy: Teacher Lesson Plan
- Solar Energy – The impact of nanoscale science on solar energy production: PowerPoint with Teacher Notes
- Graetzel Solar Cell Lab Activity: Teacher Instructions & Answer Key
- Reflecting on the Guiding Questions: Teacher Instructions

Student Materials
- Graetzel Solar Cell Lab Activity: Student Instructions & Worksheet
- Reflecting on the Guiding Questions: Student Worksheet

Lesson 3: Hydrogen Fuel Cells and Nanoscience
Teacher Materials
- Hydrogen Fuel Cells: Teacher Lesson Plan
- Hydrogen Fuel Cells – The impact of nanoscale science in hydrogen fuel cell technology: Teacher Instructions & Answer Key
- ChemSense Lab Activity: Teacher Instructions
- Hydrogen Fuel Cells: Teacher Answer Key to Quiz
- Reflecting on the Guiding Questions: Teacher Instructions

Student Materials
- ChemSense Lab Activity: Student Instructions
- Hydrogen Fuel Cells: Student Quiz
- Reflecting on the Guiding Questions: Student Worksheet

Exhibit 4. Proposed Fine Filters unit materials.

Overview of Unit
Teacher Materials
- For Anyone Planning to Teach Nanoscience…Read This First!
- Fine Filters Overview, Learning Goals & Standards
- Unit at a Glance: Suggested Sequencing of Activities
- Alignment of Unit Activities with Learning Goals

Lesson 1: Introduction & Initial Ideas
Teacher Materials
- Fine Filters Introduction & Initial Ideas: Teacher Lesson Plan
- Fine Filters – A Nanotechnology Application used to Prepare Clean Drinking Water: PowerPoint with Teacher Notes
- Cleaning Jarny's Water: Teacher Instructions & Rubric
- Fine Filters Initial Ideas: Teacher Instructions

Student Materials
- Fine Filters Initial Ideas: Student Worksheet
- Cleaning Jarny's Water: Student Instructions & Worksheet
- Introduction to Filtration: Student Reading

Lesson 2: Filtration Mechanisms
Teacher Materials
- Filtration Mechanisms: Teacher Lesson Plan
- Animating Filtration Methods (ChemSense Activity): Teacher Instructions & Rubric
- Comparing Nanofilters to Conventional Filters Lab Activity: Teacher Instructions and Rubric
- Reflecting on the Guiding Questions: Teacher Instructions

Student Materials
- Animating Filtration Methods (ChemSense Activity): Student Instructions
- Comparing Nanofilters to Conventional Filters Lab Activity: Student Instructions and Worksheet
- Reflecting on the Guiding Questions: Student Worksheet

Exhibit 5. Agenda for nanoscience workshop for high school teachers and students.

Saturday, February 11, 2006

8:45 am	**ARRIVAL AND CONTINENTAL BREAKFAST** *Duncan Hall 505* Arrive, pick up materials and make a name badge. Muffins and juice will be available.	
9:00 am	**INTRODUCTION TO NANOSCIENCE** *Geri Horsma and Carolina Sylvestri* *Duncan Hall 505* How small is a nanometer? What are some unusual properties of the nanoscale? How might nanotechnology impact our lives? These and other questions will be addressed through presentation and hands-on activities.	
10:00 am	**INTRODUCTION TO CLEAR SUNSCREEN** *Alyssa Wise* *Duncan Hall 505* How do "nano-sunscreens" differ from traditional sunscreens? What is the best kind of sunscreen to use and why? Alyssa will give introduce the clear sunscreen unit and issues related to such questions.	
10:30 am	**BREAK** Divide into two groups and make your way to the lab rooms.	
10:45 am	**HANDS-ON ACTIVITY: SUNSCREEN LABELS** *Carolina Sylvestri* *Duncan Hall 507*	**HANDS-ON ACTIVITY: ULTRA-VIOLET BEADS** *Miriam Motoyama* *Duncan Hall 506*
11:30 pm	**LUNCH AND GUEST SPEAKER** *Brent MacQueen, Nanoscientist from SRI International* *Duncan Hall 505* We'll have sandwiches, chips and drinks. From 12-12:30, Brent will present and answer questions on the topic of "Nanotechnology: What it is, is not, and where it's going to have an impact."	
12:30 pm	**THE SCIENCE BEHIND THE SUNSCREEN** *Doris Mourad and Carolina Sylvestri* *Duncan Hall 505* A presentation and discussion of the core ideas behind how sunscreens block UV light and why they appear the way that they do.	
1:30 pm	**SCATTERING OF LIGHT BY**	**SCATTERING OF LIGHT BY PARTICLES: SUNSCREEN**

	PARTICLES: CHEMSENSE ACTIVITY *Tina Stanford and Patti Schank* *Duncan Hall 246* Students use the ChemSense Animator to create an animation for an advertisement that shows consumers how nano sunscreen particles don't scatter visible light and thus are transparent.	**ANIMATIONS** *Alyssa Wise* *Duncan Hall 246* Students view and discuss animated models of how visible light interacts with "large" and nano-sized zinc oxide particles.
2:00 pm	***(CHEMSENSE ACTIVITY, CONTINUED)***	**CONSUMER CHOICE PAMPHLET** *Geri Horsma, Tina Stanford, and Alyssa Wise* *Duncan Hall 246* Students create a pamphlet to inform consumers about nanoparticulate sunscreens, how they work, and their benefits and drawbacks.
3:00 pm	**COOKIES AND WORKSHOP SURVEY** *Duncan Hall 505* Enjoy cookies and drinks while completing a short survey about the workshop.	
3:15 pm	**SMALL GROUP REFLECTIONS** *Duncan Hall 505* In small groups, reflect on the day and discuss ideas that were particularly interesting or perhaps unclear.	
3:45 pm	**GET CERTIFICATES AND ADJOURN** Teachers and students pick up their certificates of participation. Teachers remember to pick up your classroom kits!	