NanoSense: The Basic Sense behind Nanoscience

YEAR 3 ACTIVITIES

Executive Summary

We have categorized activities conducted during the third year of the NanoSense project in terms of 5 activities: materials development, teacher meetings and workshops, evaluation, dissemination and outreach, and synergistic activities. These activities are summarized below and described in more detail in the body of the report.

Materials Development. The Clear Sunscreen lessons were revised this year based on results from an experiment (suggested by Larry Woolf, designed by the NanoSense team, and run by an SRI scientist) to empirically investigate UV blocking mechanisms, and the lab data is used in a new student activity. Our partner and workshop teachers are quite interested in the new Clean Energy and Fine Filters units and their focus on energy and water issues. The Clean Energy and Fine Filters units were pilot tested and revised based on teacher, student, and scientist feedback. We have a high-school teacher working with us full-time over the summer, with funding supported by grants from IISME (see iisme.org) and SRI human resources. The teacher has expertise in curriculum development, and created her own module on water treatment. She will help us refine and test the Fine Filters unit and map NanoSense activities to existing curriculum.

Teacher Meetings. We held ten meetings with our partner teachers to gather feedback on materials and use of the materials in the classroom and in workshops. We also held a 1-day teacher workshop with 22 teachers at SJSU in December, and will be holding a 1-week workshop with about 20 teachers at San Jose State University in late June. A separate USDE Teacher Quality Enhancement grant is covering teacher stipends for the week.

Evaluation. Evaluations were conducted for the Nanoscience Learning Goals workshop at SRI International, the NanoSense workshop for high school science teachers at San Jose State University, and pilot studies of the Clean Energy and Fine Filters units. Generally, the workshops were very well received. Pilot testing revealed promising student learning and a number of possible improvements to the Clean Energy unit, most of which have been implemented. Analyses of data from the Fine Filters study are currently underway. We also worked with our external evaluator to provide a summary of our work for the NSEE Portfolio Evaluation project.

Dissemination and Outreach. We engaged in several dissemination activities, including outreach through other national- and state-funded nanoscience education initiatives (e.g., NNIN, CNSI, CPN) and a local university and community college "Nanotechnology in Schools" initiative; posting our materials on NCLT's NanoEd portal and NanoSense web site; publishing a book chapter titled "Can Nanoscience Be a Catalyst for Education Reform?" in an anthology of nanoethics essays by Wiley and an article in the APS summer newsletter; and being featured in *Nanotechnology 101*, a new book to be published in early 2008 by Greenwood Publishing.

Synergistic Activities. We worked with NCLT to hold a working meeting (funded by NSF) to identify and clarify nanoscience learning goals, the outcomes which were presented at the 2007 Workshop on K-12 & Informal Nanoscale Science and Engineering Education and documented in a separate NSF Foundations Monograph. Under NSF STTR funding, we are conducting a formative evaluation (with college-level instructors as the subjects) of an online educational resource system that provides automatically-constructed courseware in the area of nanoscience.

Activity 1: Instructional Materials Development

In the third year of the grant, we implemented minor revisions to our Size Matters unit and major revisions to the Clean Sunscreen unit. We also completed development on two new units: Fine Filters and Clean Energy. These units and the changes implemented in the third year of the grant 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, tools of the nanosciences, 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 materials exhibit some size-dependent effects that are not observed in bulk materials.
4. New tools for observing and manipulating matter increase our ability to investigate and innovate.

The Size Matters unit was described in more detail in last year's report. Based on feedback from teachers, findings from pilot testing, and recommendations from our advisors and site visitor, the PowerPoint slide presentations were revised for each lesson to tie the presentation more directly to related readings in the unit, and to insert driving questions throughout the presentation to stimulate and focus classroom discussion. The wording of learning goal 3 was also revised based on feedback from our site visitor, Larry Woolf. 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). Upon completing this unit, students will understand:

1. How different wavelengths of light interact differently with different kinds of matter.
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.

As reported last year, the unit was pilot-tested in a February 2006 workshop and significantly revised as a result of workshop findings. The unit underwent significant revisions again in

October 2006. The impetus for the October round of revisions was the result of a suggestion from our site visitor, Larry Woolf, that we empirically investigate UV blocking mechanisms and the subsequent results from an experiment (designed by the NanoSense team and run by SRI scientist James Snyder) that demonstrated absorption, and not a combination of absorption and scattering, as the primary UV blocking mechanism of "large" ZnO and TiO_2 particle sunscreens. Learning goal 1 was also slightly revised based on feedback from Larry Woolf.

The issue of whether these sunscreens blocked via absorption, scattering or both has been a source of confusion and debate since development of the unit began. While all of our consulting scientists agreed that ZnO and TiO_2 can absorb light with wavelengths less than 380 and 365 nm respectively, and that the nanosized particles should block mainly via absorption (because they are too small to scatter effectively) they disagreed as to whether absorption was *solely* responsible for UV blocking in "large" particles (~200nm) or whether reflection due to diffuse scattering also played a role. Some suggested that despite the particles being the appropriate size to scatter UV light, the main mechanism will still be absorption because scattering involves the light interacting with so many particles, it will certainly get absorbed before it is scattered back out of the sunscreen. No answer to this question could be found in the literature, thus we followed Larry Woolf's suggestion that we empirically investigate the question.

Specifically, we tested one sunscreen with a "large" inorganic ingredient, one sunscreen with a "nano" inorganic ingredient and one sunscreen with no inorganic ingredients. A similar thickness of each of the three sunscreens was dried on a glass slide. The transmittance through the film and DHR from the film surface was measured using an integrating sphere for the 300-500 nm range. Absorption was calculated as =1-(Reflectance + Transmission). The UVA I region (~340-400 nm) was our key area of interest since no organic ingredients (except for Avobenzone which was not present in any of the samples) block in this range and thus all blocking here could be attributed to the inorganic ingredient.

The results of this experiment and the experiment-driven revisions to the unit are described in the Findings section of this report. The revised Clear Sunscreen unit is available for download at http://nanosense.org/activities/clearsunscreen/

Clean Energy: Converting Light into Energy

Exhibit 3 shows an outline of the Clean Energy unit, which explores the issue of energy production as a pressing global issue and how nanoscience could enable important breakthroughs in energy generation and conversion. Upon completing this unit, students will understand:

1. Clean alternative energy technologies must be developed to provide sufficient energy to meet growing global demand, and must be sustainable both environmentally and economically.
2. Nanoscience could enable important breakthroughs in solar energy technology through low cost, novel energy conversion mechanisms.
3. Surface area 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.
4. Energy is neither created nor destroyed—it can only be converted into different forms.

Based on feedback from our partner teachers and recommendations from our site visitor, Larry Woolf, the unit was shortened to focus on traditional and nano solar technologies. The learning goals were cut from 6 down to 4, and the wording of all of the goals were revised. The unit was also pilot testing in a local high-school classroom in February 2007 and revised based on the study to add a new student reading, additional lab instructions, answer keys, and rubrics. The revised unit includes two lessons that span three 50-minute classroom periods if all activities are used. Available lessons and activities include a solar cell lab, PowerPoint slides, quizzes, readings, and worksheets.

The results of pilot testing are described in the Findings section of this report. We are also incorporating suggestions from a recent (May 2007) site visit meeting with Larry Woolf. The unit will be adapted 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). The Clean Energy unit is available for download at http://nanosense.org/activities/cleanenergy/

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 solve filtration problems. Upon completing this unit, students will understand:

1. A shortage of clean drinking water is one of the most pressing global issues.
2. Solutes can be separated from heterogeneous and homogeneous solutions by a variety of filtration methods.
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. Nanotechnology can solve critical filtration problems in a cost-effective way that allows for widespread use.

The wording of learning goals 1 and 3 was revised based on feedback from our site visitor, Larry Woolf. The unit was further refined based on feedback from our partner teachers during our teacher meetings. The revised unit includes two lessons that span two 50-minute classroom periods if all activities are used. Available lessons and activities include a filtration-mechanisms lab, a ChemSense animation activity, a performance assessment, PowerPoint slides, readings, and worksheets. The unit was pilot testing in a local high-school classroom in May 2007, and we are currently analyzing the results of this study. The Fine Filters unit is available for download at http://nanosense.org/activities/finefilters/

Activity 2: Teacher Meetings and Workshops

In the third year of the project, we held ten meetings with an expanding base of 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.

June 21, 2006: Review Clean Energy materials

Anders Rosenquist presented major updates to the Clean Energy unit, including the updated introductory slides, the unit overview, and a student reading, for discussion and feedback. The teachers provided detailed feedback on the materials.

July 6, 2006: Review Fine Filters materials, mapping content to traditional science classes

Major updates to the Fine Filters unit, including the overview and chemistry of water PowerPoint slides, were presented by Tina Stanford for discussion. We also discussed where the material for the Clear Sunscreen and Size Matters units mapped to content in traditional science classes (chemistry, physics, biology, and integrated science). The teachers felt that placing our curriculum units into an already packed high school curriculum would be difficult, and came up with an idea to try to "nanotech" an already established unit at our next meeting.

August 19, 2006: "Nano-izing" your existing curriculum

Following a suggestion from our partner teachers, we held a special session in which participants were asked to pick a regular lesson from the classes they teach and "nano-ize" it, that is, integrate some element of nanoscience into their lesson. Participants worked as a group, sharing ideas, then in pairs on two units (oxidation- reduction and electrochemistry, ending with a group discussion. The teachers were enthusiastic about this model for integrating nanoscience into the regular classroom curriculum.

October 18, 2006: Review Clean Energy unit updates

Anders Rosenquist presented major updates to the Clean Energy unit, including the unit overview and student reading, for discussion. We outlined our plans for the upcoming SJSU teacher workshop and coordinated with Maureen Scharberg to hold the workshop at training facilities at San Jose State University. The workshop was publicized on our web site, and an announcement distributed to several mailing lists for science teachers in the San Francisco Bay Area.

November 14, 2006: Boston Workshop report, review Clean Energy solar lab, and SJSU teacher workshop preparation

Tina Stanford gave a quick report on the Boston Museum of Science workshop (see below), and Anders Rosenquist walked participants through the Clean Energy solar lab. We finalized the agenda for the December SJSU workshop, and teachers choose demonstrations to lead as part of the workshop (see the agenda in Exhibit 5 below).

December 2, 2006: SJSU teacher workshop

Twenty-two teachers attended the workshop at SJSU; see Exhibit 5 for the agenda. After an introductory presentation on nanoscience, participants rotated through three labs stations: One for Size Matters, one for Clear Sunscreen, and one for units in development, Fine Filters and Clean Energy. The day culminated with reflections and feedback from teachers, discussion of challenges of teaching nanoscience, and an evaluation survey. A detailed description of participant responses from the survey is provided in the Findings section of this report.

January 23, 2007: Workshop reporting, Clean Energy update

We reported on the December SJSU workshop, January NSF nanoscale science workshop, and on discussions with CNSI (see outreach, below). Anders Rosenquist presented updated slides for the Clean Energy unit, and we discussed pilot study plans for the unit. A visiting teacher, Maria Powell, volunteered to test the unit in two of her environmental science classes in February. Kyle Cole from the Stanford CPN also attended, and we discussed plans for NanoSense and Stanford CPN workshops and how we could participate in each other's sessions.

March 20, 2007: Clean Energy animations, Pilot Study results, and SJSU summer workshop

Anders Rosenquist and Maria Powell reported on the pilot test of Clean Energy with Maria's two classes in February. Generally, Maria was very happy with the slide presentations and student interactions; she thought that they understood the material better than she predicted. However, the Scientific American article was at too high a level for her students and the lab activity had some problems. Anders handed out a draft of a new reading for the unit (to replace the Scientific American article) for comment, and presented two new Flash animations to accompany the unit. The teachers like the animations and gave detailed suggestions for improvements. We also discussed the June workshop at SJSU and distributed flyers.

April 24, 2007: Clear Sunscreen and Clean Energy updates, and Fine Filters pilot planning

Alyssa Wise presented a number of questions to our teachers regarding a few remaining suggested changes to Clear Sunscreen from our site visitor Larry Woolf (e.g., centering the slides more around charts and data; changing the organization, improving selected representations) and collected and summarized their feedback. Anders Rosenquist distributed a new version of the Clean Energy unit, revised based on the pilot study and with new material including a reading, lab procedures, and assessments and answer keys/rubrics, and reviewed the updated animations for feedback. Tina handed out updated Fine Filters materials and met Maria Powell after the session to plan a pilot test in her two classrooms for May.

May 30, 2007: Fine Filters pilot study update, summer workshop at SJSU

Tina Stanford distributed a full draft binder of the Fine Filters unit and reported on the pilot test of the Fine Filters materials with Maria’s classes. Anders Rosenquist reviewed analyses of the Clean Energy pilot findings. We distributed a proposed agenda for the June SJSU workshop and discussed possible roles that our partner teachers could play. (Three teachers have volunteered to teach sessions at the workshop.)

June 25-29, 2007: Teacher workshop at SJSU

We will hold a 1-week workshop for approximately 20 local high school teachers at SJSU in late June 2007. The workshop will cover all of the NanoSense units (Size Matters, Clear Sunscreen, Clean Energy, Fine Filters) and participating teachers will practice teaching, get feedback from peers and instructors, and collaboratively brainstorm ideas for integrating nanoscience into their curriculum. Participants will be given the option of receiving 2.0 semester credits from SJSU in chemistry, physical science, or integrated science and receive an stipend from a separate USDE Teacher Quality Enhancement. Since the workshop will take place after this report is due, a description of workshop activities and findings will be provided in next year’s report.

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, Indiana University
- Maureen Scharberg, San Jose State University

- Core Partner Teachers (attended 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
  - Kyle Cole, Stanford University, Palo Alto, CA

- Visiting Teachers (attended 1-3 meetings):
  - Resa Kelly, San Jose State University
  - Claudia Winkler, Gunn High School, Palo Alto, CA
  - Goarine Nersesian, Menlo Atherton High School
  - Robin McGlohn, Menlo School, Menlo Park, CA
  - Maria Powell, Gunn High School, Palo Alto, CA

IISME Summer Fellow

A San Francisco high school science teacher, Diana Theriault, will be joining the NanoSense team full-time over the summer (10 weeks) through the Industry Initiatives for Science and Math Education (IISME; iisme.org) Fellowship Program for Teachers. IISME is a nonprofit collaborative of San Francisco Bay Area corporations, universities, and local educators working to improve mathematics and science education. IISME Fellowships provide K-16 teachers with meaningful professional development by exposing them to industry and research environments, giving them direct experience with applications of science, inspiration to infuse their lessons with relevance, encouragement to stay in teaching (IISME teachers stay in teaching at more than twice the rate of their colleagues) and better understanding of career needs. The costs to the NanoSense project for this fellowship is minimal ($3000 for the entire summer), since half of the costs are covered by SRI human resources and another quarter is covered by a special IISME grant. Ms. Theriault has expertise in curriculum development, and created her own module on water treatment. She will help us refine and test the Fine Filters unit and map NanoSense activities to existing curriculum.

NanoTech 2006 Workshop at Boston Museum of Science

Co-PI Tina Stanford was an invited presenter at the Boston Museum of Science 2-day nanotechnology curriculum developers meeting on Nov. 6, 2006, and led two teacher workshops on the following day. The event was co-sponsored by the Center for High-rate Nanomanufacturing and the NISE-Net. Leaders from many nanoscience education projects presented and showcased their work in poster sessions. Bob Chang, PI of NCLT, presented a slide show reporting on the curriculum development efforts and professional development activities of his team. Tina Stanford, Bob Tinker from Concord Consortium, Aura Gimm from UW Madison MRSEC/IPSE and Nancy Healy, coordinator of NNIN educational outreach, reported on the progress of their nanoeducation efforts. The efforts spanned a wide range of materials, formats, and intended audiences. Several projects' work centered on the development of materials and programs set up by graduate students or teachers. The day ended with an hour-long Roundtable discussion with Bob Chang, Aura Gimm, Nancy Healy, and Tina Stanford.

Audience questions ranged from how easy was it to implement nanoeducation materials in the classroom to how well our materials matched to standards and what impact we thought our projects would have on nanotechnology education.

The following day, Professor George Whiteside gave a well-received presentation on key features of nanotechnology, highlighting a few products enabled by new techniques. Teachers then proceeded to their chosen workshops. Forty teachers attended NanoSense workshops, half in the morning and half in the afternoon. In both sessions, the teachers represented a mixture of disciplines; all but one taught high school. Tina presented slides from the Size Matters unit, and then the teachers took part in lab activities around unique properties at the nanoscale. Upon finishing the labs, each lab pair reported on their findings and provided feedback on their experiences. Most comments on the workshop were positive. One exception involved the bubbles lab as evidence of self-aggregation, which did not work well for some teachers. Timing the boiling of water in 3 different sized beakers did not highlight differences as nicely as hoped; a bigger difference in the cylindrical area of the beakers may have resolved this issue. Participants each received a Size Matters booklet, CD of all NanoSense units, and materials used in the workshop (e.g., cards, UV beads, black boxes).

The two-day meeting provided a useful opportunity to share common concerns and solutions with other nanoscience curriculum materials developers. Based on her observations and discussions with participants, Tina Stanford felt that the NanoSense materials were the most thorough and teacher-friendly of all those presented at the meeting.

Activity 3: Evaluation

Evaluations were conducted for the Nanoscience Learning Goals workshop (see Activity 5) held at SRI International, and the NanoSense workshop for high school science teachers (see Activity 2), held at training facilities at San Jose State University. Agendas for these workshops are shown in Exhibits 5 and 6. Generally, the workshops were very well received. Analyses of workshop findings are available in the Findings section of this report.

We also conducted a pilot study of the Clean Energy unit and the Fine Filters unit. Data sources for these studies included pretests and posttests, lab worksheets, student notecards (where students wrote questions and “aha” moments), classroom observations, and debriefing sessions with the teacher. Pilot testing of the Clean Energy unit revealed promising trends in student learning and a number of possible improvements to the unit. A detailed summary of Clean Energy pilot study findings and resulting revisions is available in the Findings section of this report. Analyses of data from the Fine Filter pilot study are currently underway.

We also worked closely with our external evaluator, Ellen Mandinach, to provide detailed information about our project’s contributions for the NSEE Portfolio Evaluation project. Dr. Mandinach will also be conducting an external evaluation of our June 2007 teacher workshop (see Activity 2).

Activity 4: Dissemination and Outreach Activities

Local outreach

To enable greater dissemination of our materials and include a wider audience in our teacher workshops, we have recently identified mailing lists and other means to reach hundreds of local San Francisco Bay Area teachers. In particular, we have collected a list of over 50 local district and department science contacts, established public mailing list for teachers (nanosense-announce@ctl.sri.com), hosted “After School Online” sessions in the NanoSense group room of the Tapped In (tappedin.org) online teacher community to share ideas with other educators, and posted workshop announcements to local mailing lists, including: Bay Area California Regional Environmental Education Community, Santa Clara County Science Teachers Association, Contra Costa County Association of Science and Math Educators, California Association of Chemistry Teachers, Maureen Scharberg's high school teacher database, Jennifer Saltzman's Bay Area Teachers List, and Clarence Bakken's physics teachers lists.

NNIN outreach

In November 2006, Nancy Healy at Georgia Tech informed that NanoSense team she has been recommending NanoSense to individual teachers and to the nine university partners of NNIN who have educational outreach. She has also been burning CDs from the NanoSense web site and handing them out to educators. One of Dr. Healy's teachers gave us a copy of a lesson plan that she developed, which adopted our Size Matters unit. She commented that the students were able to learn from using these materials and greatly appreciated it being available to her.

Nanotechnology in Schools research and development institute

With separate funding, the NanoSense team is working with the University of California, San Jose State University, and Foothill De Anza Community College District to hold a professional development workshop on nanoscience for local community college students and their faculty mentors in the summer of 2007. To help motivate them to consider science and math teaching careers, the community college students will also be provided with nanoscience education outreach opportunities to middle and high school science classrooms. Finally, a Nanotech Summer Institute will be held in summer 2008 to provide middle school and high school teachers with a basic understanding and knowledge of nanoscience and nanotechnology. NanoSense and other materials will be used in the workshops and outreach efforts. San Jose State University will cover costs material and kit production, and for participant stipends.

CNSI outreach

In February 2007, we met with Sarah Tolbert's group at UCLA to discuss our mutual outreach efforts and possible collaborations. Dr. Tolbert works with the California Nanosystems Institute (CNSI), a state-funded initiative that is working with the UCLA school district and hosting workshops for dozens of local teachers about 6 times per year. CNSI has lab activities but no curriculum; we expressed interest in adapting some of their lab activities, and they expressed interest in using some of our materials. In particular, CNSI is considering offering our Size Matters unit to their teachers in their next (fall 2007) series of workshops, using our Clean Energy curriculum to accompany their nano solar-cell lab, and using our sunscreen lab for one of their workshops. Dr. Tolbert felt that getting their materials more broadly disseminated was one of their biggest challenges, particularly because of the extensive time, labor, and cost required to assemble kits for their workshops and teachers. They currently employ a full-time undergraduate just for making kits for their workshops. They would like to find a way to outsource the creation of the kits, but they have no money for that. This raised a question of whether national centers like NNIN or NCLT might be able to help their (and other) projects identify ways to outsource and fund the making of kits for laboratory activities.

In a separate meeting during our visit, we discussed nanofiltration applications and technology with Eric Hoek, a professor of materials science at UCLA. Eric also agreed to be interviewed as a featured scientist for our Fine Filters unit.

Stanford CPN outreach

We are collaborating closely with Kyle Cole, Associate Director of the NSF-funded Stanford Center for Probing the Nanoscale (CNI), to extend both NanoSense and CPN outreach efforts. Kyle has attended our NanoSense teacher meetings and workshops, and demonstrated some of CPN's materials to our participating teachers. At his invitation, we presented our project and materials at the American Association of Physics Teachers meeting at Stanford in May, and will lead teachers in hands-on NanoSense activities at CPN's Summer Institute for Middle School teachers in late June 2007.

Nanotechnology 101 Book

John Mongillo, a science writer in Rhode Island, contacted us to request permission to feature NanoSense materials in his forthcoming book, *Nanotechnology 101*, a reference book for middle school and high school students to be published by Greenwood Publishing Group. We developed a section called "Common Student Nanoscience Questions with Scientist Answers" for the book, and the Clear Sunscreen unit (with worksheet excerpts) was also highlighted in chapter on nanoscience applications. The final manuscript was sent to us for our review in May, and the book is expected to go to press in early January 2008.

NanoEd Portal

In January 2007, our NanoSense curriculum units were added to NCLT's NanoEd Resource Portal, a repository for the collection and dissemination of information for the NSEE community. See http://www.nanoed.org/courses/nanosense.html

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 units are also distributed at conferences and teacher workshops.

Other outreach options

During his site visit in August 2006, Dr. Larry Woolf recommended that due to the time constraints in regular classrooms, we consider alternate uses of NanoSense materials. For example we might (a) create an roadmap showing where specific activities in our units are tied to key science topics to enable teacher to easily choose very short activities, (b) use the modules for special high-school or community college courses on technology/engineering or current topics in science, (c) use the units for enrichment courses or after school programs, (d) expand to middle school, which is less topic-driven, (e) focus on AP science classrooms. Dr. Woolf also suggested making kits of materials available in conjunction with the units, a recommendation echoed by CNSI and by teachers in our professional development workshops. We have considered and are pursuing several of these avenues, as described above and elsewhere in this report (e.g., use in local community college workshops through the Nanotechnology in Schools initiative, use with local middle school teachers through CPN).

Papers and presentations

NanoSense activity development progress and current findings were presented at the Workshop on K-12 & Informal Nanoscale Science and Engineering Education and at the annual

IMD meeting. NanoSense PI Patricia Schank also authored an article, with Joe Krajcik, for a book of nanoethics essays (published by Wiley) and an article, with Alyssa Wise, for the APS newsletter.

Publication citations

- Schank, P. & Krajcik, J. (in press). Can Nanoscience Be a Catalyst for Education Reform? In P. Lin (Ed.), *Anthology of nanoethics essays*. Wiley Publishing.

- Schank, P., & Wise, A. (2006). Introducing High School Students to Nanoscale Science. Forum on Education of The American Physical Society Summer 2006 Newsletter. http://www.aps.org/units/fed/newsletters/spring2006/index.html

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Presentation citations

- Schank, P., & Stanford, T. (2007, May). Overview of the NanoSense project. Poster presented at the *Spring 1007 Meeting of the American Association of Physics Teachers*, Stanford, CA.

- 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. (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

Activity 5: Synergistic Activities

A workshop to identify and clarify nanoscience learning goals (June 14-16, 2006)

Teaching nanoscience without a foundation of learning goals is a challenge for practitioners and teachers. This working meeting, funded by NSF and organized by NCLT and the NanoSense team at SRI, brought together 43 invited experts and practitioners in nanoscience, learning science and science education to explore and debate the major concepts and learning goals for nanoscience. Our major goals were to obtain an informed decision on the major concepts of nanoscience, clarify the meaning 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 are documented in a separate report to NSF and were presented at the 2007 Workshop on K-12 & Informal Nanoscale Science and Engineering Education. Highlights of the workshop results are summarized in the Findings section of this report.

Evaluation of auto-constructed nanotechnology education system

Taxonomize, Inc. and the NanoSense team submitted an NSF STTR Phase 1 proposal, which was awarded funding for fiscal year 2007. Taxonomize proposes to produce, field test, and evaluate an online educational resource system that will provide automatically constructed courseware. The “self-assembled” courseware will focus on education in nanotechnology, with the ability to extend into all subject areas. The key results of the “Courseware Self-Assembly” system (CSA) will be: (1) an analytical resource- mapping software product that will mine diverse repositories of learning content and auto-categorize them to produce (2) a Web-based, graphical interface for effective instructional use of a multi-dimensional set of learning content resources for nanotechnology, with foundations to extend to other subject areas for distance/distributed education. We are conducting a formative evaluation of the CSA system to determine the key factors the system needs to master in order to automatically generate high-quality, pedagogically-appropriate courseware.

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 (significantly revised from last year).

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

Teacher Materials

- Introduction to Sun Protection: 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

- Summary 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
- Sunscreen Ingredients Activity: Teacher Instructions & Answer Key
- All About Sunscreens: PowerPoint with Teacher Notes
- Reflecting on the Guiding Questions: Teacher Instructions

Student Materials

- Light Scattering by Three Sunscreens: Student Handout
- Sunscreen Ingredients Activity: Student Instructions & Worksheet
- Summary of FDA Approved Sunscreen Ingredients: Student Handout
- Reflecting on the Guiding Questions: Student Worksheet

Lesson 3: How Sunscreens Block: Absorption

Teacher Materials

- How Sunscreens Block: Absorption: Teacher Lesson Plan
- How Sunscreens Block: The Absorption Mechanism: 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: How Sunscreens Appear: Scattering

Teacher Materials

- How Sunscreens Appear: Scattering: Teacher Lesson Plan
- How Sunscreens Appear: The Scattering Mechanism: PowerPoint with Teacher Notes

- Ad Campaign Project (ChemSense Activity): Teacher Instructions & Rubric
- Sunscreens & Sunlight Animations: Teacher Instructions & Answer Key
- Reflecting on the Guiding Questions: Teacher Instructions

Student Materials

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

Lesson 5: Culminating Activities

Teacher Materials

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

Student Materials

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

Exhibit 3. Clean Energy unit materials (revised based upon pilot study).

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
- Clean Energy Pretest/Posttest: Teacher Instructions & Grading Rubric

Student Materials

- Clean Energy: Pretest
- Clean Energy: Posttest

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
- Hybrid Cars, Solar Cells, and Nanoscience: Teacher Key

Student Materials

- Clean Energy Initial Ideas: Student Worksheet
- Hybrid Cars, Solar Cells, and Nanoscience: Student Reading and Worksheet
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Lesson 2: Solar Energy and Nanoscience

Teacher Materials

- Solar Energy and Nanoscience: Teacher Lesson Plan
- Clean Solar Energy–The Impact of Nanoscale Science on Solar Energy Production: PowerPoint with Teacher Notes
- Nanocrystalline Solar Cell Lab Activity: Teacher Instructions & Answer Key
- Reflecting on the Guiding Questions: Teacher Instructions

Student Materials

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

Exhibit 4. Fine Filters unit materials (revised from Year 2 draft).

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
- The Water Crisis: 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: The Science Behind Water and Filtration
Teacher Materials
- The Science of Water: Teacher Lesson Plan
- The Science of Water: PowerPoint Slides and Teacher Notes
- The Science of Water Lab Activities: Teacher Instructions & Rubric
- Reflecting on the Guiding Questions: Teacher Instructions

Student Materials
- Animating Filtration Methods (ChemSense Activity): Student Instructions
- The Science of Water Lab Activities: Student Instructions and Worksheet
- Reflecting on the Guiding Questions: Student Worksheet

Lesson 3: Solutions and Filtration
Teacher Materials
- 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.

Nanoscience Workshop for High School Teachers
Saturday, December 2, 2006

Sponsored by the NSF-funded NanoSense project at SRI International and San Jose State University

AGENDA	
8:30 am	**ARRIVAL, CHECK-IN AND CONTINENTAL BREAKFAST** Arrive, pick up materials, and make a name badge. Enjoy muffins and juice while you check out the nanoscience demonstrations.
9:00 am	**WELCOME & INTRODUCTIONS** *Patti Schank, Tina Stanford & Maureen Scharberg* Meet us and your fellow workshop participants. We'll then share our goals for the workshop and lay out the plan for the day.
9:15 am	**INTRODUCTION TO NANOSCIENCE & ITS APPLICATIONS** *Tina Stanford* An introduction to what nanoscience is, using presentation, demonstrations and discussion.
10:00 am	**NANOSENSE DEMONSTRATION STATIONS** **Station 1: Size Matters** *Patti Schank, Geri Horsma & Carolina Sylvestri* We'll explore activities for understanding size and scale, how properties change at the nanoscale, and how we "see" at the nanoscale. **Station 2: Clear Sunscreen** *Maureen Scharberg & Miriam Motoyama* We'll do an experiment that uses UV beads to test sunscreen protection, and look at animations for helping students understand the underlying science. **Station 3: Latest Developments** *Tina Stanford & Doris Mourad* We'll do an activity from each of our two newest units: Clean Energy and Fine Filters.
11:30 am	**EVALUATION & REFLECTION** *Tina Stanford & Maureen Scharberg* We'll complete a short evaluation of the workshop and then discuss our experiences of the day. We'll conclude by talking about next steps and ways for us to keep in touch and work with you in bringing nanoscience into your classroom.
12:00 pm	**LUNCH (PROVIDED)** We'll have sandwiches, chips and drinks. Yum.

Exhibit 6. Agenda for nanoscience learning goals workshop.

Nanoscience Learning Goals Workshop
AGENDA
SRI International, International (I) Building

Wednesday, June 14, 2006: Nanoscience — What are the Fundamental Big Ideas?

8:30 am	**CONTINENTAL BREAKFAST AT SRI**
9:00 am	**WELCOME AND OVERVIEW** Welcome, participant introductions, workshop overview. *Moderator: Patricia Schank*
9:45 am	**BIG IDEAS DISCUSSION** What big ideas should every 12th grader who graduates from high school understand about basic science at the nanoscale? Participants (beginning with the scientists) present big ideas to the group. Ideas are posted, clustered, and tallied as they are presented. *Moderator: Joe Krajcik*
10:30 am	**BREAK**
10:45 am	**BIG IDEAS DISCUSSION (CONT.)** Continue submitting, posting, clustering, and tallying of big ideas.
11:45 am	**SELECTING THE BIG IDEAS FOR AFTERNOON WORK** Participants prioritize the big ideas for our afternoon work by writing their names on colored dots for 1st, 2nd, and 3rd choice and placing the dots by posted big ideas. *Moderator: Anders Rosenquist*
12:00 noon	**LUNCH** Workshop staff identify the top 4-6 big ideas.
1:00 pm	**SMALL WORKING GROUPS** Participants are assigned to small groups, one for each top big idea. Each group identifies one note taker and one facilitator. Each group explicates why their idea is a big idea, the core science behind the idea (how it works), at least two examples of phenomena that illustrate the idea. *Moderator: Tina Stanford*
2:30 pm	**BREAK**
2:45 pm	**SMALL WORKING GROUPS (CONT.)** Continue explicating the why, how, and examples of the big idea.
4:00 pm	**GROUPS REPORT OUT (15 MINUTES EACH)** Each group reports their results. *Moderator: Joe Krajcik*
5:30 pm	**ADJOURN**
6:30 pm	**DINNER AT MANDARIN GOURMET, PALO ALTO**

Advancing Nanoscience Education Workshop
AGENDA
SRI International, International (I) Building

Thursday, June 15, 2006: Education — What Should Students Know and When?

8:30 am	**CONTINENTAL BREAKFAST AT SRI**
9:00 am	**LEARNING GOALS, PREREQUISITE KNOWLEDGE, AND SEQUENCING DISCUSSION** Introduce the objectives for today: for each big idea from yesterday, identify associated learning goals, what things students need to know before they can understand the ideas, and how to sequence the ideas. Examples from other science domains will be provided and discussed. *Moderator: Joe Krajcik*
10:00 am	**BREAK**
10:15 am	**SMALL WORKING GROUPS** Small groups reassemble to identify learning goals associated with their big idea, what prerequisite things students need to know, and how to sequence the ideas. *Moderator: Tina Stanford*
12:00 pm	**WORKING LUNCH** Small group work continues over lunch.
1:30 pm	**SMALL GROUPS REPORT ON PROGRESS, PROBLEMS, NEEDS (10 MINUTES EACH)** Small groups report out on progress, and major problems or needs (e.g., missing information) in writing learning goals, prerequisite ideas, and sequencing, and get help from full group. *Moderator: Anders Rosenquist*
2:30 pm	**BREAK**
2:45 pm	**SMALL WORKING GROUPS (CONT.)** Continue refining learning goals, sequencing, and prerequisite knowledge.
4:00 pm	**GROUPS REPORT OUT** Each group reports their list of learning goals, prerequisite knowledge, and sequencing of ideas. *Moderator: Joe Krajcik*
5:30 pm	**ADJOURN** Dinner on your own; recommendations will be provided.

Advancing Nanoscience Education Workshop
AGENDA
SRI International, International (I) Building

Friday, June 16, 2006: Alignment — How Do the Learning Goals Link to Standards?

8:30 am	**CONTINENTAL BREAKFAST AT SRI**
9:00 am	**LINKING LEARNING GOALS TO EXISTING STANDARDS** Introduce the objectives for today: to link the learning goals identified yesterday to the National Science Education Standards (NSES) and AAAS Benchmarks. Examples from other science domains will be provided and discussed. *Moderator: Jo Ellen Roseman*
9:30 am	**SMALL WORKING GROUPS** Small groups reassemble to link their learning goals to the NSES and AAAS Benchmarks and identify where alignment cannot be made. Lists of NSES and AAAS Standards will be provided.
11:00 am	**SMALL GROUPS REPORT OUT (10 MINUTES EACH)** Each group reports their alignments with the standards. *Moderator: Tina Stanford*
12:00 noon	**REFLECTION AND NEXT STEPS** *Moderator: Joe Krajcik*
12:30 pm	**LUNCH AND WORKSHOP EVALUATION** Complete the short workshop evaluation.
1:30 pm	**REPORT OUTLINING AND WRITING** For workshop staff.