NanoSense: The Basic Sense behind Nanoscience

YEAR 1 ACTIVITIES

Activities conducted during the first 9 months of the NanoSense grant (September 2004 – June 2005) are described below, as well as plans for activities for the remaining 3 months of Year 1. We categorize the work in terms of 10 activities.

Activity 1: Teacher Meetings

In the first year of the NanoSense project, we held four meetings with our partner teachers. Primary objectives of the meetings included introducing the teachers to the project, gathering feedback on activities as they were being developed, and planning pilot use of materials with their students. Meetings lasted from 2 to 4 hours.

Project overview: November 20, 2004

Patricia Schank presented an overview of the NanoSense project, and Maureen Scharberg, San Jose State University, presented on the Understanding by Design approach to curriculum design (Wiggins & McTighe, 2001). Following these presentations and discussion, Tina Stanford and Anders Rosenquist presented an overview of some core concepts of nanoscale science and activity development ideas. Participants discussed our plan for activity development and teachers' impressions of topics and issues of most importance to them. We distributed folders with introductory readings on nanoscience and the Understanding by Design approach, instructions for using our internal project Wiki for group collaborations, instructions on how teachers should prepare and submit invoices for their time spent working with the project, the full NSF proposal and responses to reviewers' questions, and a CD with all of the folder materials and the ChemSense software. Materials presented were also posted to the group Wiki for future access. Contact information for all NanoSense team members and collaborators was also made available on the group Wiki.

Review early draft of Size Matters materials: March 5, 2005

In the second teacher meeting, the NanoSense team presented the initial materials for our first Size Matters unit for teacher review and feedback. The materials included the learning goals and road map for the unit, a science fiction story developed by our team illustrating how nanotechnology could affect our lives 40 years in the future, and PowerPoint slides for teachers to present the Unique Properties and Applications of Nanoscience lessons. We provided folders with these materials at the meeting and distributed the materials for review a week before the meeting on our internal group Wiki. At the meeting, we also presented the new NanoSense Web site and described the upcoming Advancing Nanoscience Education workshop. The teachers seemed quite engaged, asking many good questions and providing recommendations for changes to the materials, as well as ideas for additions such as worksheets and a more basic set of introductory slides. Two teachers, Geri Horsma and Carolina Sylvestri, volunteered to pilot-test our science fiction nano story with some of their students and faxed student feedback to the NanoSense team 2 weeks after the meeting. This feedback was used to revise the story.

Review first complete draft of Size Matters materials: April 25, 2005

In the third teacher meeting, we reviewed the first complete draft of the Size Matters unit, which has a week or more of activities (see Activity3: Instructional Materials Development). The teachers said that they were very impressed with how much progress we had made since the last meeting. Most of their recommendations focused on the Size and Scale lesson (e.g., there was much discussion around the card sort activity) and the Unique Properties lesson, which they felt still needed more elaboration to be understandable by the teachers and the students. Two teachers, Geri Horsma and Doris Mourad, also sent written comments on the activities (via a supplied FedEx mailer) 2 weeks after the meeting. During this meeting, we also gauged teacher interest in using one or more activities in the spring and fall, so that we could schedule pilot testing and a spring visit by our external evaluator, Ellen Mandinach from the Center for Children and Technology division of the Education Development Center (EDC) in New York. Teacher partners Irene Hahn and Britt Hammon committed to using this introductory unit with their students in mid May and early June, respectively. Other teachers expected to use some of the materials but indicated that the fall would be better for them. The NanoSense team spent the beginning of May implementing revisions to the materials based on teacher comments so that Ms. Hahn and Ms. Hammon would have the revised versions for use in their classrooms.

Review of pilot testing and summer development plans: June 16, 2005

In the fourth teacher meeting, findings from observing the use of NanoSense materials in Ms. Hahn's and Ms. Hammon's classes will be reviewed. We will also present our development progress and plans for the summer. In particular, learning goals and activity and assessment ideas will be presented for our Clear Sunscreen" unit, under development by Maureen Scharberg and SRI summer intern Alyssa Wise. Alyssa is a doctoral student at Indiana University at Bloomington, focusing on instructional design. She has an undergraduate degree in chemistry and has taught high school physics. Partner teachers Doris Mourad and Irene Hahn will each be working with the NanoSense team for 4 weeks during the summer to contribute to activity development and development of teacher support materials. At the meeting, they will discuss their plans for this summer work.

Meeting participants

Attendees of the meetings above included the following:

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

- Partner Teachers:
  - Doris Mourad, Castilleja School, Palo Alto, CA
  - Carolina Sylvestri, Gunn High School, Palo Alto, CA
  - Irene Hahn, Miramonte High School, Orinda, CA
  - Geri Horsma, Gunn High School, Palo Alto, CA
  - Britt Hammon, Antioch High School, Antioch, CA
  - Joan Carter, San Jose State University (Teacher in Residence)

Activity 2: Advancing Nanoscience Education Workshop

On March 28-30, 2005, NanoSense hosted a workshop at SRI International to discuss conceptual issues and needs related to incorporating the science and technology of the nanoscale in science education. NASA Ames Research Center, Foothill-De Anza Community College District (FHDA), and NanoSIG (http://nanosig.org) were cosponsors. Educational researchers and science educators (spanning high school, community college, and university levels), nanoscientists, science museum/informal-learning specialists, and workforce development staff came together at this workshop to identify and document core nanoscience concepts and how to bring them to students, and to uncover needs, gaps, and research questions for the field of nanoscience education. Additional information, including the list of workshop participants and all presentations, is available at http://nanosense.org/workshops.html.

The primary goals of the workshop were to plan for the integration of concepts of the nanoscale into science education and to move beyond the show-and-tell nature of many nanoscale education activities. In particular, we expected to:

- Identify representations of the core nanoscience concepts.
- Explore the role of hands-on and simulation-based experiences in the learning process.
- Discuss how to prepare teachers to teach in this new area.
- Identify and document industry needs, career paths, and pathways (both formal and informal) for introducing students to nanoscience.
- Recommend needs and directions for research related to nanoscience education.

Prior to the workshop, participants were asked to complete a 10-question online survey that was used to drive the focus of the small-group work at the meeting. At the workshop kickoff dinner, Larry Dubois from SRI International, Martha Kanter from FHDA, and Meyya Meyyappan from NASA Ames gave their perspectives on nanotechnology innovations in the industry in general and at SRI in particular, nanoscience education at FHDA, and NASA Ames's collaboration with FHDA to support development of a new nanoscience certificate program and internships for students participating in the program.

The following day, Robert Cormia kicked off the working meeting with a summary of FHDA's Atlas of Nanotechnology effort to build topic maps for the domain of nanoscience, including maps for the required scientific skills and concepts and a curriculum map of more than 500 courses taught in the San Francisco Bay Area. The Atlas was used to stimulate and organize the workshop discussions. Participants then gathered in working groups to address the workshop goals and prepare a summary of their recommendations for next steps. Examples of driving questions for each working group included:

- Concepts: What are the foundational concepts of nanoscience and key examples that illustrate them? Should more focus be placed on disciplinary or emergent concepts?
- Hands-On Experience: What is the role of lab experiences and simulation, what are good examples, and how can we best deliver them to students?
- Pathways/Careers: What are some possible career paths? Are there nanotech jobs or just "nanoskilled" workers? What are industry needs? What are ideal pathway(s) and timeline(s) by which students should be introduced to nanoscience education concepts in K-12, community college, university, and on-the-job training?

- Teacher Professional Development: How do we best train teachers? What are good models for teacher training?

See the Findings section for a summary of the workshop findings. A complete report of the workshop will be disseminated in summer 2005.

Activity 3: Instructional Materials Development

Overview

In the development of our nanoscience curriculum, we are applying the Understanding by Design approach (Wiggins & McTighe, 2001). Our initial efforts have been to address the challenge of identifying important big-picture ideas, or *enduring understandings* about nanoscience, for our high school students to take away with them. To achieve this goal, we consulted and brainstormed with nanotechnology scientists and science education experts. We also conducted an extensive review of the literature, Web sites, and other curricula to help us define our focus. We then aligned our goals with the National Science Education Standards. We established the *essential questions* to guide our unit development, followed by *key knowledge and skills* to be developed by students as a result of experiencing this unit.

Our next step in the process was to identify a set of assessments that would provide the teacher with enough information to evaluate students' understanding of these central ideas. Once this was accomplished, we developed a set of classroom activities to move students toward the goal of understanding. We met with teachers on multiple occasions to review these materials and refined them on the basis of their feedback. By May 2005, we had a complete draft of our introduction to nanoscience unit, Size Matters, consisting of multiple lessons and a week or more of activities. We piloted many of the activities with one teacher in two classes and will pilot a subset of the activities during the week of June 6 with another teacher.

On the basis of the insights of our evaluator, our own observations, and teacher and student feedback, we are currently revising this set of introductory materials and developing more in-depth teacher professional development materials to accompany the unit. The revised unit materials will be posted to the NanoSense Web site at http://nanosense.org/activities/sizematters/ in summer 2005. In fall 2005, we will test the refined introductory unit with additional teachers. We are also beginning development on two new units on the topics of clear sunscreen and water purification. The water purification unit will build on a ChemSense unit that focuses on solution chemistry. We plan to pilot-test these new units with teachers during fall 2005.

Determining a focus for our learning goals

Determining our learning goals was an iterative process that involved the NanoSense team members, partners, and advisors. Our first draft involved identifying seven enduring understandings that we wished students to achieve. In November 2004, we asked for comments on the accuracy and centrality of these goals from our nanoscientists at SRI, Markus Krummenacker, Marcy Berding, and Yigal Blum, as well as Maureen Scharberg and one of our advisors, Deb Newberry.

We held our first teacher meeting in November to share resource material and the initial draft of our learning goals. We brainstormed topics and the possible sequence of these to develop for the first few units. We met again in January with Deb Newberry. On the basis of comments from the teachers, partners, and advisors, we revised our initial set of goals to include a more refined and focused list of four enduring understandings, with complementary essential questions and key knowledge and skill*s*, as follows:

- What enduring understandings are desired?
  1. Nanoscience is an emerging science that 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. The nanoscale is 1-100 nanometers, and small macro- and even microscale objects (e.g., a grain of salt, bacteria) are still orders of magnitude larger than nanoscale objects.
  3. Nanosized particles of any given substance exhibit different properties than larger particles of the same substance.
  4. Nanotechnology focuses on manipulating matter at the nanoscale to create structures that have novel properties or functions.

- What essential questions will guide this unit and focus teaching and learning?
  1. How small is a nanometer, compared with a hair, a blood cell, a virus, or an atom? How do we see things that are very small?
  2. How do the properties of nanosized particles compare with those of larger particles or bulk materials?
  3. Occasionally, there are advances in science and technology that have important and long-lasting effects on science and society. What scientific and engineering principles will be exploited to enable nanotechnology to be the next big thing?

- What key knowledge and skills will students acquire as a result of this unit?
  1. Students will be able to distinguish between some commonly known objects (e.g., atom, cell, protein molecule, human hair strand) in terms of their relative size, using metric units appropriately.
  2. Students will be able to predict whether certain sizes of aggregations of matter will exhibit bulk properties or nanoscale properties.
  3. Students will be able to describe two or more applications (or potential applications) of nanoscience and their possible effects on society OR compare a current technology solution with a related nanotechnology-enabled solution for the same problem.

Developing assessments and content

We outlined assessment possibilities for each of the enduring understandings. After a careful review of candidate assessments, we chose a small subset to develop fully. Some assessments we embedded within student activities, and others we developed as formative and summative evaluation items. We developed one performance assessment, accompanied by a scoring rubric. Instructional activities for students were developed simultaneously.

During our first teacher meeting in November 2004, Maureen Scharberg introduced the Understanding by Design approach. As part of the iterative development process, at the second teacher meeting we presented our initial set of introductory slides and readings to the teachers for their critique. On the basis of their comments, we significantly revised and continued to fill out our content. A few teachers pilot-tested the science fiction nano story with their students. We received feedback from the students and revised the story on the basis of their comments.

We presented the first complete draft of our readings, slides, activities, and assessments to our partner teachers during a third teacher meeting in April 2005. We collected the teacher comments on each of our pieces other than the readings. They were to review the readings and send their written comments within the next 2 weeks. We continued to revise our materials on the basis of teacher feedback at the end of April and during the first few weeks of May.

Our first teacher pilot occurred in the two Advanced Placement chemistry classes of one of our partner teachers. She devoted a full week to the topic of nanotechnology. We observed each of her classes during this week with our evaluator. We also interviewed the teacher and some of the students. The observations and recommendations are summarized in Findings 2: Evaluation of Initial Implementation. In addition, Tina Stanford presented an overview of nanotechnology, using an amalgam of our curricular materials, to another AP chemistry class of a teacher who is not a NanoSense partner. Impressions of student reactions to this presentation are provided in Findings 3: Evaluation of Feedback on Outreach Presentation.

Another NanoSense teacher partner, Britt Hammon, plans to use the NanoSense curricular materials in her classroom the week of June 6. We plan to collect observations in her classrooms and interview the teacher and some of the students.

Size Matters curricular materials

Below is a brief outline of the introductory curricular materials in the Size Matters unit. The materials can be used individually or together as a unit.

- Introduction to Nanoscience (addresses enduring understandings 1 and 4)
    - Introductory science fiction short story, "The Personal Touch," involving nanotechnology applications in 2045, accompanied by a questions sheet developed to stimulate student discussion of the story. The novel applications of nanotechnology within the reading are paired with a column by the side of the story, providing more factually detailed information on the applications.
    - A reading that introduces students to the topic of nanoscience.
    - A PowerPoint slide presentation with accompanying teacher notes and a student worksheet. The worksheet is designed to help students highlight key points within the slide presentation.

- Size and Scale (addresses enduring understanding 2)
    - A student reading on visualizing the nanoscale, with examples involving powers of 10.
    - A diagram that compares dominant objects, forces, and laws at a various scales.
    - Two activities designed to help students develop a sense of scale from 10^1 meters to 10^{-10} meters. The first involves sorting cards with familiar pictures and pairing them with measurement units of decreasing value on a number line. The second activity, Cutting It Down, guides students in their ability to conceive objects at the nanoscale.
    - A quiz that allows students to pair objects with appropriate number units.

- Unique Properties at the Nanoscale (addresses enduring understanding 3)
    - PowerPoint slides that illustrate examples of unique properties at the nanoscale, with accompanying teacher notes.
    - A general reading on unique properties at the nanoscale and three specific readings on electrical, mechanical, and optical properties.

    - Lab station activities designed to demonstrate central concepts about properties, with accompanying teacher directions and student lab sheet.
    - A quiz on unique properties of nanoscale objects.

- Nanofabrication Techniques (addresses enduring understanding 4)
    - A reading on nanofabrication techniques and tools of the nanosciences.
    - A quiz on the reading.
    - Optional extension activities using model atomic force microscopes, ChemSense software, and Molecular Workbench software.

- Applications of Nanoscience (addresses enduring understandings 1 and 4)
    - PowerPoint slides illustrating approximately a dozen examples of applications, with accompanying teacher notes.
    - A performance activity in which students research a current or possible application of nanotechnology and prepare a poster or presentation. The activity includes student instructions, a list of topics and references, and a scoring rubric.

Summer development plans

Our student intern, Alyssa Wise, joined the team in mid-May 2005. She reviewed our existing materials, and has begun to develop a unit on the topic of clear sunscreen. Two partner teachers, Irene Hahn and Doris Mourad, will work with the NanoSense team for 4 weeks during the summer to help with development of new units and support materials. In particular, Ms. Hahn has expressed interest in working on teacher materials and a unit on quantum dots or tools of the nanosciences. Ms. Mourad may help with the development of our water purification unit. The team is also completing revisions to the Size Matters unit, including professional development materials to help teachers understand nanotechnology in general and specific support materials to help teachers work with the curricular materials we have developed.

Activity 4: Evaluation Planning

Planning for the formative evaluation of our materials began in February and March 2005 with teleconferences with our external evaluator, Ellen Mandinach. Members of our development team, Patricia Schank and Anders Rosenquist, also met with Dr. Mandinach at AERA in Montreal on April 13, 2005. During these meetings, we discussed our expectations and framework for the evaluation. It was decided that we would ask one or two of our teachers to commit to implementing some or all of our introduction to nanoscience unit, Size Matters, in May or June, and Dr. Mandinach would conduct an initial formative evaluation of one or both teachers' implementation. We also scheduled several phone conversations to further discuss objectives and to jointly draft initial instruments, including student questionnaires, observation protocols, and interview frameworks. We also agreed on several overarching issues for the evaluation. Telephone conversations with Ellen in April and May helped us refine our approach and plan the logistics of the evaluation. The core issues for evaluation include:

- *Implementation variables*. Is the unit difficult to implement? Are the kids engaged? Are they doing what was intended? Were activities omitted that we thought should be included? Why did the teacher omit or adapt specific activities? Did the teacher use the teacher notes?

- *Curriculum alignment*. How well do our activities match the learning goals? Where do they fall short? Are some goals over- or underrepresented? Are activities related to certain goals skipped by some teachers? How well do our assessments (formative and summative) measure students' understanding related to all learning goals? How might the activities/assessments be changed to align better with the learning goals?

- *Learning outcomes*. What kinds of evidence are we seeing for key learning outcomes? What assessment strategies will work best for gathering evidence regarding student learning outcomes?

Schedule of implementation

Two of our participating teachers, Irene Hahn (Miramonte High School) and Britt Hammon (Antioch High School), volunteered to implement the NanoSense Size Matters unit in their classrooms at the end of the 2004-05 school year. Together, these classes represent a diverse range of students with respect to demographics and overall levels of academic achievement.

Activity 5: Evaluation of Initial Implementation—Miramonte High School

Ellen Mandinach spent Monday through Friday, May 16-20, 2005, observing the initial implementation of Size Matters in two of Irene Hahn's AP Chemistry classes at Miramonte High School. Ms. Hahn's class met every day of the week for approximately 50 minutes. The following outlines her schedule for the unit:

- *Friday, May 13*. She assigned the NanoSense science fiction story and accompanying worksheet.

- *Monday, May 16*. She presented the NanoSense Introduction to Nanoscience PowerPoint slides, had students do the NanoSense card sort activity, and assigned the NanoSense introductory reading on nanoscience. She collected the story worksheet but did not go over it in detail, other than to discuss which elements of the story seemed most and least realistic to the students.

- *Tuesday, May 17*. She presented her own, custom-developed introduction to tools of the nanosciences—in particular, atomic force microscopes and scanning tunneling microscopes.

- *Wednesday, May 18*. She presented the NanoSense slides on unique properties at the nanoscale and attempted to supplement them with some lecture material spontaneously developed in response to student questions. An interesting, though unresolved debate ensued regarding how light is emitted from solid objects.

- *Thursday, May 19*. The students completed an MRSEC nanogold lab activity instead of implementing the NanoSense Unique Properties lab stations.

- *Friday, May 20*. She handed out the NanoSense Nanofabrication Techniques reading but did not formally assign it or discuss it. She also handed out a compilation of student responses to the science fiction story that summarized what applications the students found most/least believable, and a list of the questions they wrote on their worksheets. Next, she presented the NanoSense slides on applications of nanoscience. After the presentation, she assigned the NanoSense performance assessment, which had students research and prepare a presentation comparing a current technology with a related, new nanotechnology application. She handed out the NanoSense list of possible topics, which also included topic summaries and links for more information. Students self-selected into small groups (three or four per group) and selected topics for their presentations.

- *Monday-Wednesday, June 6-8*. The students presented and explained their chosen applications of nanoscience.

Dr. Mandinach attended all class sessions from May 16 through 20. She took extensive field notes, conducted interviews with the teacher and students, and collected student worksheets. NanoSense team members also observed the classes each day except May 19.

Activity 6: Evaluative Activities for Outreach Presentation—Acalanes High School

NanoSense team member Tina Stanford presented an introduction to nanoscience to AP chemistry students at Acalanes High School on May 19, 2005 (see also Activity 10: Dissemination and Outreach Activities). On the basis of discussions with the teacher and feedback from students after her presentation, Ms. Stanford documented student interests and understandings regarding nanoscience, presented in Findings 3: Evaluation of Feedback on Outreach Presentation

The style of presenting was a combination of lecture and class discussion. The presentation materials were selected from among those developed for the longer NanoSense Size Matters unit. The presentation began with a definition of nanotechnology, followed by the first few PowerPoint slides from the unit. The NanoSense scale diagram was given to students to help guide their thinking about the relationship between matter, tools and dominant forces at different scales. The NanoSense unique properties slides were used as an organizer for comparing the optical, mechanical, and electrical properties of bulk materials with those of nanoscale materials of the same substance. Samples of red and blue nanogold were passed among the students to focus the discussion of optical properties. The NanoSense applications of nanoscience slides were shown last. Students were asked questions throughout the presentationand in turn asked several questions regarding the applications of nanotechnology.

Activity 7: Evaluation of Second Implementation—Antioch High School

Britt Hammon used several activities from the NanoSense Size Matters unit in her chemistry class at Antioch High School on June 2 and during the week of June 6-10. Ms. Hammon's class meets every other day for approximately two hours each day (the school is on a block schedule). The following outlines her schedule for the unit:

- *Thursday, June 2*. She discussed nanoscience as an aggregate of chemistry, physics, and electronics, and had students read the NanoSense Introduction to Nanoscience.

- *Monday, June 6*. She presented the NanoSense Introduction to Nanoscience slides and had students complete the accompanying worksheet. Students then completed the Cutting it Down activity. Students also read the NanoSense science fiction story and completed the accompanying worksheet, working in pairs. Finally, she assigned the Unique Properties reading.

- *Wednesday, June 8*: She presented the NanoSense slides on Unique Properties at the Nanoscale, and students completed the Unique Properties lab stations.

- *Friday June 10*: She presented the PowerPoint slides on Applications of Nanoscience and assigned the NanoSense performance assessment to prepare a poster comparing a current technology with a related, new nanotechnology application.

Members of the NanoSense team observed the classes on June 6 and June 8, taking field notes and conducting brief interviews with teacher and students.

Activity 8: Synergistic Activities

Gordon Research Conference on Visualization in Science and Education

Patricia Schank was invited to give a presentation on ChemSense and NanoSense at the 2005 Gordon Science Education & Policy Conference on Seeing and Understanding: Guiding Research for Visualization in Science and Education in Oxford, England, in July 2005. Dr. Schank's talk will focus on how student-created drawings and animations can support nanoscale science learning, discourse, and assessment. Anders Rosenquist will also present a poster on the NanoSense project (see Activity 10: Dissemination and Outreach Activities) that will highlight NanoSense activities and their use of visualization.

Scaling and sustainability of large-scale science education innovations

In March 2005, we submitted a joint IERI proposal with the Concord Consortium to adapt ChemSense to run under Pedagogica, a scripting and data acquisition/analysis tool that will allow ChemSense to support structured problem-solving activities and collect student performance data, and use this framework to collect data in multiple school settings. If funded, we will develop activities using ChemSense and Molecular Workbench together to help students learn nanoscale science and will place these interactive curriculum and assessment materials in as many schools as choose to download our software and register their students with us. These schools will receive real-time reports analyzing what their students are doing with the software. The reports will assess the students' inquiry and modeling skills in science, as well as their content knowledge. The activities themselves will provide formative feedback to students, and we will study the effect of this feature on their learning. We will also study how the teachers use the reports, in order to gauge the effect of cognitive feedback on teachers' practice. Finally, we will select as case studies a group of schools that have been successful in implementing our innovation, as well as others that have failed to do so. This work will enable us to identify the critical factors that affect success in the adoption and/or adaptation of a technological innovation by schools that have no other contact with the creators of the innovation.

Collaboration with TELS and UC Berkeley graduate student

In April 2005, we began discussions with members of the TELS Center for Learning and Teaching—in particular, with Marcia Linn and her graduate student Jennifer Chui at UC Berkeley—about creating chemistry-learning activities that integrate Molecular Workbench simulations and ChemSense within Pedagogica. This work would build on the different strengths (e.g., simulation versus assessment) of these very different tools. Jennifer has developed initial sketches of several possible interactive activities and will be designing one or more activities as part of a graduate project. This work would integrate nicely with the proposed IERI work (above) to support more structured problem-solving activities and automated logging of student performance data.

Women in Engineering speaker event

On June 1 2005, the NanoSense project and the IEEE SF Bay Area Nanotechnology Council cosponsored a talk by Robert Cormia, from Foothill College, titled "Angstromology: A Tour of the Universe at the Nanoscale Level and Beyond" (see http://ewh.ieee.org/r6/scv/wie/upcoming-events/20050525-angstromology.html). This talk was free and open to the public, with about 40 participants attending. This talk provided a tour of the universe at the quantum scale, shedding some light on what is, isn't, or might be nanotechnology.

Center for Articulation project

In October 2004, the NanoSense team collaborated with Robert Cormia (Foothill College) and Sukhjit Singh (De Anza College) to develop an NSF Advanced Technological Education (ATE) proposal for a Nanotechnology Program Curriculum Articulation (NPCA) project. The goals of this project are to develop a "Center for Articulation" to train faculty in developing a rigorous practice of defining and declaring learning outcomes in terms of knowledge and skills and, more importantly, to document the method by which a student learning outcome is produced. Funding for this proposal was not awarded, but we plan to submit a revised proposal, addressing reviewer contents, in a future ATE round.

Engineering education

We are also beginning discussions around a project to improve student understanding in undergraduate and graduate engineering education under the NSF Engineering Education Program (EEP). This work would involve the development of software to help students visualize and manipulate processes of nanoscale science on six different, but related, levels—atomic, molecular, nano, micro, and macro—and application of this software to the study of student understanding of size, scale, and nanoscale science. This work would be partly modeled after the the GenScope project (Horwitz, Neumann & Schwartz, 1996), which gives students a way to investigate scientific and mathematical concepts in genetics through direct manipulation and experimentation at multiple levels (DNA, chromosome, cell, organism, pedigree, and population).

Activity 9: Advisory Activities

Several of the NanoSense advisory board members have met with our research team during the past year. Deb Newberry visited SRI in January 2005 and brainstormed with the NanoSense team around activity development. She suggested that we reduce the scope of our learning goals for the first unit, and highlighted the importance of the interface (i.e., surface-to-surface) level of material interactions. Dr. Newberry also visited SRI in March to review our current set of nanoscience activities; she gave valuable comments on our introductory slides and readings and provided ideas for assessment.

Another advisory board member, Michael Ranney, visited SRI in February 2005 to discuss our introductory story, which he was able to pilot-test with his high-school-age daughter. He provided detailed comments and suggestions for improvement. In April, Dr. Ranney visited SRI again to help us refine and focus our properties slides and readings.

Maureen Scharberg and advisors Marcy Berding and Brian Coppola were solicited to give their input on our learning goals and the accuracy of the science concepts and ideas. They each gave timely feedback, which was incorporated into our next iteration of the activities. Robert Cormia also gave feedback, focusing on key concepts of nanoscience based on thinking at Foothill College on development of the Atlas of Nanotechnology.

At our Advancing Nanoscience Education workshop in March 2005, advisory board member Larry Dubois gave the opening presentation at the workshop's kickoff dinner. Dr. Dubois gave an insightful overview of nanoscience, current developments, and educational challenges moving forward. One advisory board member, Christine Peterson from the Foresight Nanotech Institute, was unable to attend the workshop, but Scott Mize, President of the Foresight Nanotech Institute, attended in her absence. Advisor Robert Tinker attended the workshop via phone and discussed the use of Concord Consortium's Molecular Workbench for teaching nanoscience and possible collaborations with Concord Consortium to integrate ChemSense and Molecular Workbench through Pedagogica (see Activity 8: Synergistic Activities). Robert Cormia presented the Atlas of Nanotechnology at the workshop and led a discussion on the development of the tool and its application to nanoscience program articulation.

Activity 10: Dissemination and Outreach Activities

Papers and presentations

NanoSense activity development progress and current findings were presented at two conferences this year, the Gordon Science Education & Policy Conference in Oxford, England, and the Instructional Materials Development Conference at NSF. The Gordon conference work, presented in both a discussion session (Patti Schank) and in a poster session (Anders Rosenquist), highlighted the overall goals of the project and our findings to date. At the IMD conference, Patti Schank and Tina Stanford highlighted the conceptual challenges of developing nanoscience learning activities, presented the NanoSense goals and research questions, gave an overview of the ChemSense environment, summarized candidate nanoscience activities, and discussed our implementation approach.

In May 2005 we also presented our NanoSense work at an internal Center for Technology in Learning (CTL) meeting to discuss NanoSense progress, findings, and challenges, and to gather recommendations and ideas from other content developers in CTL. We also presented our NanoSense work to SRI senior staff to obtain internal funding to support workshop report writing. This funding was used to write the technical report for the Advancing Nanoscience Education workshop that was held at SRI in March.

Publication citations

- Schank, P., Sabelli, N., Cormia, R., Stanford, T., Hurst, K., & Rosenquist, A. (in preparation). *Report of a workshop on science and technology education at the nanoscale*. Menlo Park, CA: SRI International.

Presentation citations

- Schank, P. (2005, February). NanoSense: *Developing activities to teach high school students about nanoscience principles, applications, and implications*. Presented at the

Instructional Materials Development Conference, Washington, DC.

- Schank, P. (2005, July). That's what happens: *Students explain chemistry through drawing and animation*. Presented at the Gordon Science Education & Policy Conference on Visualization in Science & Education, Queen's College, Oxford, UK.

- Rosenquist, A. (2005, July). *NanoSense: The basic sense behind nanoscience*. Poster presented at the Gordon Science Education & Policy Conference on Visualization in Science & Education, Queen's College, Oxford, UK.

Outreach presentation at Acalanes High School

NanoSense team member Tina Stanford presented an introduction to nanoscience to AP chemistry students at Acalanes High School on May 19, 2005. The goal of the presentation was to introduce the students and the teacher to nanotechnology and to those aspects of the science that make it unique compared with the study of larger scale materials. The materials used were selected from among those developed for the longer NanoSense Size Matters unit. On the basis of discussions with the teacher and feedback from students after her presentation, Ms. Stanford documented student interests and understandings regarding nanoscience. See Findings 3: Evaluation of Feedback on Outreach Presentation for more information on the evaluative activities and findings related to this presentation.

NanoSense Web site

The NanoSense web site (http://nanosense.org) was established in spring 2005. We worked with an interaction designer to address branding, color treatment, text layout, icon development, and logo treatment to help establish a sense of identity for NanoSense. The site provides an overview of our project activities and links to more detailed information about the goals of the project, NanoSense activities, past workshop materials and planned workshops, papers and presentations, and project contact information. Sample screenshots of the NanoSense web site are provided in the Findings section of this report.

Activities developed by the NanoSense team will be made available to the public on the NanoSense Web site as they are pilot-tested and vetted by our partner teachers. In the final 2 years of the project, activities will also be distributed at teacher workshops at national conferences and at training facilities at San Jose State University.

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