NanoSense: The Basic Sense behind Nanoscience

First Year Report
May 2005
NSF IMD Grant ISE-#0426319

Contents:

Project Activities and Project Findings attached as separate documents.

Contact Information:

Dr. Patricia Schank, Senior Research Scientist
Center for Technology in Learning
SRI International
333 Ravenswood Ave
Menlo Park, CA 94025
Phone: (650) 859-3934
Fax: (650_859-3673
Email: patricia.schank@sri.com
Web: http://nanosense.org

SECTION 1: PARTICIPANTS

Participant Individuals

Patricia Schank (PI), Tina Stanford (Co-PI), Anders Rosenquist, Vera Michalchik, Reina Fujii, Nora Sabelli—SRI International
Maureen Scharberg—San Jose State University
Ellen Mandinach—Educational Development Center
Alyssa Wise—Indiana University, Bloomington, IN
Jennifer Chiu—University of California, Berkeley, Berkeley, CA
Doris Mourad—Teacher, Castilleja School, Palo Alto, CA
Britt Hammon—Teacher, Antioch High School, Antioch, CA
Irene Hahn—Teacher, Miramonte High School, Orinda, CA
Carolina Sylvestri—Teacher, Gunn High School, Palo Alto, CA
Geri Horsma—Teacher, Gunn High School, Palo Alto, CA
Joan Carter—Teacher in Residence, San Jose State University, San Jose, CA
Nancy Day—Teacher, Menlo-Atherton High School, Menlo Park, CA

Robert Cormia—Faculty member, Foothill College
Brian Coppola—University of Michigan

Partner Organizations

Research and Development Partners

<u>Chemistry Department, San Jose State University, San Jose, CA</u>**.** We are working closely with Dr. Maureen Scharberg and a student assistant in the Chemistry Department at SJSU to develop relevant and standards-based nanotechnology curriculum for high school science classrooms. Dr. Scharberg provides expertise in curriculum design and teacher training, and will lead the development of 1-2 curriculum units and host teacher training workshops at SJSU. Dr. Scharberg is also working with SRI and our external evaluator to help coordinate testing and revision of units. She and her student assistant are developing a database of high school science teachers that will be used for NanoSense workshops and for updating teachers on the project.

<u>Center for Children and Technology, Educational Development Center, New York, NY</u>**.** Dr. Ellen Mandinach at EDC is leading the evaluation efforts for the project. Dr. Mandinach provides expertise in basic, applied, and formative research to investigate how technology and curriculum can make a difference in the classroom. Acting as a critical partner, EDC will help our team shape our strategies for developing our materials and analyze their usefulness in real classrooms with our teacher partners. EDC uses a multimethod approach to collect and analyze indicators of the usefulness and value of the curriculum units. EDC's efforts are be both formative and summative, providing ongoing and iterative feedback to NanoSense developers in order to appropriately shape the development effort and describe the degree to we meet our goals.

NanoSIG, La Honda, CA. NanoSIG is an international special interest group for people both committed to nanotechnology and those interested in the business of nanotechnology. NanoSIG provides a variety of services to those interested in nanotechnology through business and technology oriented forums, news, jobs/career center, and other programs. Adolfo Nemirovsky and Bo Varga at NanoSIG collaborated with the NanoSense team to organize NanoSIG meetings on programs, ideas, and projects on nanoscience education for high school students and meetings with high school teachers to map nanoscience concepts to California high school standards. NanoSIG also helped organize the March 2005 Advancing Nanoscience Education workshop.

Foothill-De Anza Community College District (FHDA), Los Altos, CA. FHDA is one of the largest community college districts in the United States, providing credit classes for about 44,000 students per quarter. Faculty member Robert Cormia helped the NanoSense team organize the March 2005 Advancing Nanoscience Education workshop. Faculty member Dr. Singh collaborated with the NanoSense team to develop and submit a National Science Foundation Advanced Technological Education (ATE) proposal, “Nanotechnology Program Curriculum Articulation (PCA)”.

NASA Ames Research Center, Moffitt Field, CA. NASA Ames has created partnerships with leading universities and high-technology industry leaders, bringing the scientific and corporate communities together in efforts to advance human knowledge and explore the unknown. NASA staff Dr. Meyya Meyyappan and Ms. Valerie Sermon are working with Foothill College to develop a new nanoscience certificate program and offer internships for students to participate in the program and to high school students. NASA also helped the NanoSense team organize the March 2005 Advancing Nanoscience Education workshop, in which Dr. Meyyappan was a featured speaker.

School Partnerships

Six high school teachers are working with the NanoSense team to advise the development of our activities, pilot-test them in their classrooms, and provide feedback on their use. These schools represent a range of low- to high-performing students from culturally diverse populations.

Antioch High School, Antioch, CA. Antioch’s student population is approximately 28% Hispanic, 9% African American, 3% Asian, and 2% Filipino; the highest parent education level is 29% college degree and 7% graduate school; and 31% of the student body qualifies for free or reduced-price lunches. The school’s 2001 API score was 589 out of 1000, and its API rank is 2 out of 10.

Britt Hammon, a veteran chemistry teacher at Antioch High School, attended our initial NanoSense teacher meetings, and plans to use activities from the NanoSense introductory unit with her chemistry students for one week starting June 6, 2005. Ms. Hammon has also served as the school's assessment coordinator, and has developed an integrated science curriculum that combines earth science, physics, and biology. Ms. Hammon was also a partner teacher on the ChemSense project, developing several curriculum activities and testing them in her classroom.

Gunn High School, Palo Alto, CA. Gunn's student population is 26% Asian, 5% Hispanic, and 2% African-American; the highest parent education level is 16% college degree and 75% graduate school; and 4% of the student body qualify for free or reduced-price lunches. The school's 2002 API score was 883 out of 1,000.

Carolina Sylvestri, chemistry and physics teacher, and Geri Horsma, biology teacher, attended our initial NanoSense teacher meetings and provided feedback on our early materials. They also pilot tested our science fiction nanostory with a few of their students. Both Ms. Sylvestri and Ms. Horsma plan to use NanoSense activities with their students in fall 2005.

Castilleja School, Palo Alto, CA. Castilleja is a nonsectarian, all-female private school; approximately one third of the student population are ethnic minorities, and virtually all graduates go on to four-year colleges.

Doris Mourad, chemistry teacher, attended the initial NanoSense teacher meetings and provided feedback on our early materials. Ms. Mourad also attended the March 2005 Advancing Nanoscience Education workshop, and will be working closely with the NanoSense team over the summer to help us develop activities and assessments for our units that focus on optical properties at the nanoscale (e.g., quantum dots and clear sunscreen).

Menlo-Atherton High school, Menlo Park, CA. Menlo-Atherton's student population is approximately 40% Hispanic, 9% African-American, 4% Asian, and 5% Pacific Islander; the highest parent education parents is 23% college degree and 32% graduate school; and 16% of the student body qualify for free or reduced-price lunches. The school's 2002 API score was 696 out of 1,000.

Nancy Day, chemistry teacher at Menlo-Atherton, attended our March 2005 Advancing Nanoscience Education workshop, and plans to use some NanoSense activities with her students in fall 2005.

Miramonte High School, Orinda, CA. Miramonte's student population is 16% Asian, 3% Hispanic, and 1% African-American; the highest parent education level is 35% college degree and 57% graduate school; and fewer than 1% of the student body qualify for free or reduced-price lunches. The school's 2002 API score was 871 out of 1,000.

Irene Hahn, chemistry teacher, attended our initial teacher meetings and used the NanoSense introductory unit with two classes of chemistry students over the course of two weeks in late May, 2005. Ms. Hahn was also a partner teacher on the ChemSense project, developing several curriculum activities and testing them in her classroom.

Other Collaborators or Contacts

Advisory Panel

An advisory committee of recognized experts in chemistry, nanoscience, and science education guides and monitors the quality, relevance, and application of our work. Panel members include:

Dr. Larry Dubois—Nanoscientist and vice president of the Physical Sciences Division at SRI International.

Michael Ranney—Professor, Graduate School of Education, University of California, Berkeley. Dr. Ranney's expertise is in science education and scientific reasoning.

Deb Newberry—Former nuclear physicist and current industry consultant and nanoscience technology instructor at Dakota County Technical College Nanoscience Technology Program, and coauthor of the popular nanotechnology book *The Next Big Thing Is Really Small.*

Christine Peterson— Cofounder (with Eric Drexler) and president of Foresight Institute, a nonprofit that educates the public, technical community, and policy-makers on nanotechnology and its long-term effects.

Robert Tinker— Physicist and President of the Concord Consortium. Dr. Tinker directs the Molecular Workbench project, which offers simulations of self-assembly and other nanoscience phenomena.

Other collaborators include:

Dr. Brian Coppola—Professor of Chemistry at the University of Michigan. Dr. Coppola was Co-PI of the ChemSense project, and collaborates on a variety of chemistry education projects around the country. He is also co-authoring a new high school textbook that brings a more holistic and investigate approach to science learning. Dr. Coppola consults with the NanoSense project to help ensure the accuracy of the content and appropriateness of the curriculum activities.

Joan Carter—Teacher in Residence Science Education Program, San José State University. Ms. Carter collaborated with our SJSU partner, Dr. Scharberg, to develop an Introduction to Nanogeoscience curriculum unit using the Understanding by Design approach. She has also attended our initial NanoSense teacher workshops and provided feedback on our early materials.

Robert Cormia—Faculty member at Foothill-De Anza College (FHDA). Mr. Cormia teaches courses in Internet projects, XML, informatics, bioinformatics, and starting in fall 2005, a new nanotechnology survey course. We have consulted with Mr. Cormia on his "Atlas for Nanoscience" effort to build a topic map for the domain of nanoscience, as well as maps for required skills and concepts and a curriculum map of courses taught in the San Francisco Bay Area.

Valerie Sermon, NASA Ames— Director, NASA Ames Research Center & Private Sector Internship Program. Ms. Sermon leads NASA Ames' collaboration with FHDA to support development of a new nanoscience certificate program and offer internships for students to participate in the program. She also helps organize nanoscience internships for high school students at the Ames Research Center. Dr. Sermon collaborated with NanoSense on the organization and structure of the March 2005 Advancing Nanoscience Education workshop.

Adolfo Nemirovsky—Chair of the NanoSIG nanoEducation and Training Forum (nETF). nETF promotes nanotechnology education and workforce development. Mr. Nemirovsky collaborated with the NanoSense team on the organization and structure of the March 2005 Advancing Nanoscience Education workshop.

Sukhjit Singh—Faculty, De Anza College. Dr. Singh collaborated with NanoSense staff and Mr. Cormia to develop and submit a National Science Foundation Advanced Technological Education (ATE) proposal entitled "Nanotechnology Program Curriculum Articulation (PCA)" in October, 2004. This project proposed to define, create, test, refine and disseminate a nanotechnology *curriculum articulation model*, a set of modules and an infrastructure to facilitate a coherent, modular set of nanotechnology courses to be offered by Community Colleges and Universities. The proposal was not funded, and is currently under revision for a future submission.

Alyssa Wise—Graduate student, Indiana University. Ms. Wise is a PhD student in Learning Sciences at the School of Education, with a Masters in Instructional Systems Technology. Ms. Wise attended the March 2005 Advancing Nanoscience Education workshop and is working with the NanoSense team over the summer to develop a curriculum unit around optical properties at the nanoscale (clear sunscreen).

SECTION 2: ACTIVITIES AND FINDINGS

(See attached files)

Opportunities for Training and Development

The NanoSense team has a strong commitment to the training of students, researchers and teachers in the area of nanoscience education. This training is accomplished by working closely with researchers at SRI, faculty and students at San Jose State University, and teachers in local high schools. NanoSense staff Patricia Schank and Tina Stanford have also attended several professional development seminars and workshops on nanoscale science at Stanford University.

NanoSense funding supports a graduate student from Indiana University at Bloomington who is interning with the project to help develop curriculum activities, and a student assistant at San Jose State University (SJSU). We are also working closely with a graduate student at the University of California at Berkeley who is working to integrate ChemSense and the Molecular Workbench using Pedagogica, with funding from the TELS Center for Learning and Teaching. The aim of this work is to create a nanoscience activity that uses Molecular Workbench to simulate a nanoscience concept and ChemSense to gather student assessment data. By partnering with SJSU and Berkeley/TELS, we are supervising and supporting graduate students who will become the teachers, designers, researchers and educational policy makers of tomorrow.

Additionally, we have worked closely with six high school chemistry teachers who have provided useful and frequent feedback on the Nanosense activities and are using some or all activities in their classrooms. Two of these teachers are interning with the project during the summer months, in addition to attending our general meetings and workshops. By working closely with teachers, we are providing teacher professional development opportunities and creating a teacher-researcher model that scaffolds procedures and activities necessary to co-design research in schools.

Outreach

The NanoSense web site was developed in spring 2005 to provide public access to NanoSense activities, information about our workshops, presentations and publications, research findings, and project contact information.

We presented the NanoSense project at the Advancing Nanoscience Education workshop (Menlo Park, March 2005). Materials from the workshop were also posted on the NanoSense web site. NanoSense was also presented at the international Gordon Research Conference on Visualization in Science Education (Oxford, July 2005). Dr. Schank was an invited speaker at the GRC conference.

Tina Stanford presented an invited guest lecture on nanoscience to a chemistry class at Acalanes High School in Lafayette, CA on May 19, 2005.

The ChemSense software—a constructivist representational environment that will be paired with some NanoSense activities—was released to the public on our Web Site in January 2005. We have also submitted the software to the Journal of Chemical Education (JCE) Digital Library upon request from JCE staff.

SECTION 3: PUBLICATIONS AND PRODUCTS

Publications

Technical Reports

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.

Conference Presentations and Workshops

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.

Web sites

http://nanosense.org

The NanoSense Web site provides access to NanoSense activities, information about our workshops, presentations and publications, research findings, and project contact information.

Other Products

Curriculum Modules

The NanoSense team has developed and pilot-tested one full curriculum unit, and is currently developing two other units that will be tested in fall 2005.

All activities will be made available to the public on the NanoSense Web site at http://nanosense.org and distributed at teacher workshops at national conferences and at training facilities at San Jose State University.

1. *Size Matters* (6 lessons/sections, plus suggested extensions). This unit introduces students to the field of nanoscale science through readings, presentations, discussions, and lab activities around the size and scale of various objects, unusual properties of the

nanoscale, and example applications.

2. *Clear Sunscreen* (under development, draft expected August 2005). This unit explores issues related to size and scale, specifically the effect of the size of nanopowders on the interactions of energy and matter (e.g., the absorption of light, addressing the electromagnetic spectrum and associated wavelengths). For example, old sunscreens use "large" zinc oxide particles, which block ultraviolet light but scatter visible light, giving the cream a white color. If nanopowders of zinc oxide are used instead, the cream is transparent, because the diameter of each nanoparticle is smaller than the wavelength of visible light.

3. *Quantum Dots* (under development, draft expected August 2005). This unit explores issues related to size and aggregation, specifically, how the size and aggregation of nanocrystals can effect physical properties (e.g., reflect different colors of light). Nanogold, for example, can appear orange, red, or green depending on the size and spacing of the gold atom aggregates. Quantum dots can be used as fluorescent labels in biological imaging and drug discovery research.

Software

The ChemSense software supports the sharing, viewing, and editing of a variety of chemistry representations, including text, images, drawings, and animations of nanoscopic processes.

ChemSense has been made freely available for download on the ChemSense web site at http://chemsense.or/download as of January, 2005, and is also being made available through the Journal of Chemical Education (JCE) Digital Library.

Instruments

At this early stage of development, the outside evaluator for NanoSense is observing classroom implementation of the curriculum units, collecting detailed questionnaires regarding students' response to elements of the units, and conducting semi-structured interviews with teachers and students about their experiences with the activities. As the units undergo revisions and are implemented in additional settings, the evaluator will co-develop with the NanoSense team assessments of student learning and rubrics to analyze conceptual elaboration in classroom discourse.

SECTION 4: CONTRIBUTIONS

Nanoscience and Related Disciplines

Our work on NanoSense is generating a number of outcomes of value to nanoscale science learning. These include:

- Tools and curricular activities that help students and teachers understand and build models of nanoscale phenomena.
- A framework for developing nanoscale science curriculum that links to educational standards and introduces nanoscale science at appropriate places in traditional high school curricula.
- Support for science teachers to develop science understandings in unfamiliar science fields through teacher professional development materials.
- New knowledge about the relationships between students' use of representations and their understanding of nanoscale science.
- New knowledge about the forms of teacher practice in relation to student use of nanoscale representations, discussions, and collaborative inquiry.

Contributions to Other Disciplines

- A different lens through which students can revisit core concepts from physics, chemistry, and biology, as well as related areas such as materials science and engineering to support student understanding and (eventually) move these fields forward through interdisciplinary research.
- An improved understanding of the importance that constructivist representational environments can add to science learning—especially for students who have been less-well served by traditional approaches to science education.
- An improved understanding of how teachers model and assess representational and collaborative practice to support student representation, discourse, and understanding, and what types of tools and activities support teacher practice.
- A general software environment for representation building and sharing animations that can be used in domains other than chemistry. For example, for nanoscience learning, students could animate concepts such as hydrogen filtration by carbon nanotubes, representing details such as hydrogen and tritium gas, the introduction of nanotubes, and tritium becoming trapped in the nanotubes over time. If adapted for physics learning, students could animate concepts such as Newton's 2nd Law of Motion (F=ma), representing details such as velocity and acceleration at a macroscopic level. If adapted for biology learning, students could animate concepts such as mitotic cell division,

representing details such as chromosome replication and movement to each pole of the cell.

Human Resources

We are developing and disseminating new educational materials that expose teachers and students to the emerging field of nanoscience and provide compelling, real-world examples of science in action that aim to improve student interest (and hopefully retention) in science. We are also contributed to the training of several new researchers—two graduate students and one undergraduate—and are working closely with six high school chemistry teachers. In doing so, we are supervising and supporting graduate students who will become the teachers, designers, researchers and educational policy makers of tomorrow, and are scaffolding procedures and activities that are necessary to co-design research in schools.

Research and Education

Our work on NanoSense is generating a number of outcomes of value to the endeavors of researchers and educators both in and outside of the scientific disciplines. These include:

- The creation of classroom-tested activities to give students direct experience with the methods and processes of science more generally and nanoscale science in particular, in keeping with emerging science standards (National Research Council, 1997; AAAS, 1993).

- Interdisciplinary activities to help tie together the disjoint high school curriculum, support understanding of the interconnections between the traditional scientific domains, and provide compelling, real-world examples of science in action.

- Professional development materials for teachers to increase their understanding of the fundamental scientific disciplines (e.g., chemistry, biology, physics) that contribute to nanoscale science.

- The application of a generalized software framework (ChemSense) that could be used to support collaboration and representation construction in other domains, and to gather student data for research in these domains.

- An improved understanding of the representational environments that can add to science learning

- An improved understanding of how teachers model and assess representational and collaborative practice to support student representation, discourse, and understanding

Public Welfare

We believe that nanoscale science curriculum paired with constructivist representational environments can improve science learning and lead to a populace better educated and able to make informed decisions on issues and technologies that affect many aspects our lives. We also hope that students who are introduced to nanoscience through compelling, real-world examples of science in action will be more motivated to continue studying science than has been the case in the past—and provide the knowledge and skills needed to innovate and solve challenges that we face now and in the future.