McREL NIMD Project Description

I. General Information

Institution: McREL - Mid-continent Research for Education and Learning
PI: John Ristvey
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Title: A NanoLeap Into New Science
Proposal # 0426401
Program Officer: Carole Stearns

II. Project Description

Project summary: Mid-continent Research for Education and Learning (McREL) has partnered with the Stanford Nanofabrication Facility (SNF) and ASPEN Associates to develop and evaluate two proof of concept modules that integrates real-world nanoscale science and engineering research and where they best fit into a standards-based science, technology, engineering, and mathematics (STEM) curriculum. Two modules (NanoLeap Chemistry and NanoLeap Physical Science) will be developed that will include student activities, experiments, and assessments, to promote student learning of the interdisciplinary nanoscale core concepts of force (physics) as it relates to properties of matter (chemistry), scale (mathematics), scientific instrumentation (technology), and processes (inquiry). The standards-based proof of concept modules will serve as application and replacement units respectively with materials that can be used in one block or be inserted into the curriculum at appropriate times. Teacher guides and an online professional development will address the varied needs of the science education community and ensure effective classroom implementation. A formative evaluation, including pilot and field tests, will provide project staff with data to inform the development and implementation processes. The summative evaluation will assess the effectiveness of the project in achieving its articulated goals and impact on student achievement and teacher practice.

Project goals: Combining educational expertise with emerging science, the project will develop two high school curriculum modules entitled *NanoLeap Chemistry* and *NanoLeap Physical Science* that will address nanoscale science, technology, engineering, and mathematics (STEM) standards. The modules will have accompanying resources and professional development for educators to facilitate implementation of the modules.

1. To explore where nanoscale science, technology, engineering, and mathematics concepts can fit into high school physical science and chemistry classes in a manner that supports students in learning core science concepts.
2. To determine a viable approach for instructional materials development in the areas of nanoscale science, technology, engineering, and mathematics.

Target audience:
High School Teachers and Students
Physical Science (Grade 9), Chemistry (Grades 10-12)

III. Pre-college Education Activities

Description of activities: NanoLeap Professional Development

The main goal of the professional development is to assist teachers in successfully implementing the NanoLeap Series within the context of their local settings and to accomplish the goals for teachers set forth in the proposal:

- To increase teacher understanding of nanoscale science and engineering content, awareness of the essential interdisciplinary nature of nanoscience, and recognition of the value the field brings to a standards-based science curriculum.
- To strengthen teacher capacity for implementing inquiry activities using research-based instructional strategies.

Three major strands will organize the professional development:
1) nanoscale science content, 2) nanoscale technology and applications, and 3) pedagogical strategies.

We will hold a three-day, intensive professional development session for teachers in November 2005 and summer 2006. We plan to have A Team teachers prepared to begin pilot testing the NanoLeap Series by mid- to late-November in 2006 and field testing with B Team in 2007. From December 2005 through June 2006, we will hold telephone conferences every other month with A team teachers to supplement the electronic communications. These subsequent, monthly sessions will have the teachers responding with their reflections to specific assignments. The summer 2006 sessions with A team teachers will be conducted at sites in the A team home states. These sessions will be designed to review module modifications reflect what we learned from the 2006 sessions, promote the fidelity of implementation. Although one measure of teacher understanding of the content will be student scores on assessments, as part of the evaluation, we will incorporate multiple mechanisms for determining teachers' understanding of the NanoLeap content and pedagogy. During Cohort A's module implementation in late 2006 – 2007, each of the 16 teachers will be observed during one class period when they are teaching a NanoLeap lesson. During the summative evaluation in late 2007 – 2008, observations will be conducted in 24 – 26 teachers' classrooms (12 – 13 each in chemistry and physical science).

Program staff and expertise

John Ristvey serves as the Principal Investigator for the project and lead the instructional materials development team. He has longstanding expertise in the management of large instructional materials development projects with clients such as UCLA (NASA's Dawn mission http://dawn.jpl.nasa.gov).

Christine Morrow serves as Co-Investigator and manages the project, coordinating communication and collaboration among the teams. As Director of Education and Outreach for the NSF-sponsored Ferroelectric Liquid Crystal Materials Research Center at CU-Boulder, Ms. Morrow has expertise developing and coordinating curriculum projects in partnership with university-based STEM researchers, K-12 educators and staff developers.

Dr. Yoshio Nishi, Director of the Stanford Nanofabrication Facility, serves as a Co-Investigator and oversees the project tasks at SNF. Dr. Nishi is also the Research Director for the Center of Integrated Systems and a Professor of Electrical Engineering.

Dr. Marni Goldman, Education Director for the Stanford Nanofabrication Facility, serves as the liaison between the researchers at SNF and personnel at McREL, and provides technical assistance in materials development.

Dr. Mike Deal, Senior Research Scientist in the Electrical Engineering Department of Stanford as well as a senior staff member at SNF, provides technical assistance and coordinates remote access to SNF instrumentation.

Dr. Mary Tang, senior staff member at SNF, provides technical assistance to the project

Dr. Donna Bogner provides technical assistance in materials development. Dr. Bogner has 35 years experience teaching chemistry and computer science from middle school to university levels. She has authored, reviewed, edited, and published science education materials in the areas of chemistry and energy, including a chemistry methods book, student study guides, teacher guides for using computer programs, and environmental and physical science curriculum.

Dr. Elisabeth Palmer, Director of Research and Development, ASPEN Associates, will lead the design and implementation of the evaluation with the assistance of two outside consultants: **Dr. Frances Lawrenz**, Professor of Science Education, U. of Minnesota; and **Dr. Doug Huffman,** Assistant Professor, Science Education, U. of Kansas.

Dr. B. J. McCormick provides technical assistance for materials development. A physical-inorganic chemist, he has 40 years experience teaching introductory and graduate level chemistry.

Earl Legleiter leads the professional development for Cohorts A and B. At McREL he provides technical assistance for science education, emphasizing intensive professional development and collaboration with researchers in science and mathematics education.

Beth Sockman, a consultant to McREL, assists with the development of modules assessments. Sockman is an instructor at Pennsylvania State University in the Department of Learning and Performance Systems and a doctoral candidate.

Ms. Jacinta Behne, serves as the Web and communications expert for the project. Ms. Behne is the website manager for two JPL/NASA websites (Genesis, Dawn). She was the project manager for PBS TeacherLine online teaching reading and writing courses.

Project objectives

Process Objectives

To achieve the project's goals, the NanoLeap project will specifically:

1. Develop two, 2-3 week standards- and inquiry-based curriculum modules (one in physical science and one in chemistry) that embed nanoscale STEM concepts in a manner that supports student understanding of core science concepts on both the macroscale and nanoscale.
2. Develop teachers guides for each of the curriculum modules that support teachers in delivering standards- and inquiry-based instruction and assessing students' understanding of core science concepts on both the macroscale and nanoscale.
3. Train teachers to implement the standards- and inquiry-based curriculum modules (Professional Development).
4. Test and refine the curriculum modules and teachers guides with master science teachers in high school teachers in physical science and chemistry.
5. Test and refine the curriculum modules and teachers guides with a broad base of high school teachers in physical science and chemistry.
6. Evaluate the effectiveness of the design process utilized in developing the NanoLeap curriculum modules and teachers guides.

Outcome Objectives

As a result of these activities, NanoLeap project expects to achieve the following:

1. Teachers who participate in training on the NanoLeap materials will be able to implement the curriculum in a manner that supports inquiry-based learning.

2. Students in classrooms where teachers fully implement the NanoLeap materials (treatment group) will demonstrate a level of understanding of core science concepts that is at least equal to, if not greater than, that of students in classrooms where the NanoLeap materials are not implemented (control group).
3. Students in classrooms where teachers fully implement the NanoLeap materials (treatment group) will demonstrate greater levels of interest and engagement in learning science than students in classrooms where the NanoLeap materials are not implemented (control group).
4. Students in classrooms where teachers fully implement the NanoLeap materials (treatment group) will demonstrate an increased understanding of nanoscale science, technology, engineering, and mathematics concepts, applications, and careers.

Nano S&E content focus:
Identified Big Ideas in Nanoscale Science

- Properties of matter and the way in which they affect how structures interact with surfaces
- Measurement, including concepts of scale and instrumentation
- Forces and bonding
- The relationship between nanoscience, technology, and engineering, as well as the technological, economic, and social implications of nanoscale science and engineering

V. Education Materials and Programs

Essential Understandings

- Nanoscience is the study of structures with at least one dimension roughly between 1 and 100 nanometers
- At the nanoscale level, a large fraction of an object's atoms or molecules are exposed at its surface; therefore, the objects properties are dominated by surface interactions.
- Scientific instruments can be used to characterize and measure properties of objects, their structure and surfaces, even if the objects cannot be seen.
- Magnetic and electric forces, such as van der Waals forces can be measured experimentally at the nanoscale level.
- Nanoscience includes the scientific concepts involved in biology, chemistry, and physics.
- A sound understanding of nanoscience can help to inform public policy.

NanoLeap: Chemistry The NanoLeap chemistry module will be designed as a three week unit that can serve as a **culminating unit** to a high school chemistry course. The module will ask students to *apply knowledge and skills* learned in traditional curriculum topics throughout the year and will serve as an extension of those concepts that are of particular importance in nanoscale science. The central question that students will consider throughout the module is, "**How and why do the chemical and physical properties of nanosamples differ from those of macrosamples of the same substance?"**

Student Assessment

Student will pick an application or nano product and make a presentation to the class as if he/she were presenting a "poster session" at a scientific meeting. The student is asked to act like a scientist working in the nano world researching the question: **How and why do the chemical and physical properties of nanosamples differ from those of macrosamples of the same substance?**

Standards Addressed (NSES) Grades 9-12

- Science as Inquiry: Abilities to do scientific inquiry; Understandings about scientific inquiry
- Physical Science: Structure and properties of matter;
- Science and Technology: Understandings about science and technology
- Science in Personal/Social Perspectives: Science and technology in local, national, and global challenges

Nanoleap: Physical Science The NanoLeap physical science module will be designed as a two to three week unit that can serve as a replacement unit for a high school physical science class. This module will extend concepts of properties of surfaces, measurement of force interactions, and apply these concepts at the nanoscale level. The module will also serve as a means for students to develop skills in experimental design. The central question that students will consider throughout the module is, "**What factors affect contact force measurements between interacting surfaces?**" This NanoLeap physical science module will fit into the existing physical science curriculum as a replacement unit for the introduction of forces and the study of static forces (contact forces and action-at-a-distance forces including frictional forces, adhesive forces and combinations therein, and measurements of forces). It should be assumed that students have learned about experimental design, metric system, and properties of matter, prior to beginning this module, though activities in this module could replace the first two of these topics. Following this module, students would most likely engage in a study of the forces involved in the laws of motion.

Student Assessment:
Students will read about one potential synthetic application (i.e., space tape, improved "ouchless" bandages, internal surgical bandages, moving microchips or fibers without scratching them, self cleaning adhesive that works anywhere, climbing athletic shoes) of surface interactions or the measurements of tiny forces in the field of biology (i.e., antibody-antigen binding, cellular adhesion, actin-myosin mechanical behavior, protein folding, or insect biomechanics) and research the question: **What factors affect contact force measurements between interacting surfaces?** Students will report the findings of their research by using a format of a research summary or abstract.

Standards Addressed (NSES) 9-12

- Science as Inquiry: Abilities to do scientific inquiry; Understandings about scientific inquiry.
- Life Science**:** Structure, function, matter, energy, and organization in living systems
- Physical Science: Structure and properties of matter; Motion and forces
- Science and Technology: Understandings about science and technology
- Science in Personal/Social Perspectives: Science and technology in local, national, and global challenges

Principles and Standards for School Mathematics (PSSM) 9-12

- Numbers and Operations (9-12): Understand numbers, ways of representing numbers, relationships among numbers, and number systems; Develop a deeper understanding of very large and very small numbers and of various representations of them.
- Measurement (9-12): Understand measurable attributes of objects and the units, systems, and processes of measurement; Make decisions about units and scales that are appropriate for problem situations involving measurements.

Dissemination format
The A Team will be involved closely with the development of materials. The A Team is comprised of two groups of eight teachers each. This approach allowed us to recruit teachers across grades 9 – 12 from both chemistry and physical science classrooms and still allow a high level of involvement throughout the development process. A Team master teachers were primarily recruited from the Denver metropolitan area, from the Minneapolis/St. Paul area, and the San Francisco Bay area. McREL, SNF, and ASPEN Associates will recruit B Team teachers representative of the chemistry and physical sciences disciplines, grades 9 – 12, and a range of preparedness levels. In addition, the project teams will recruit teachers that represent diverse populations and serve students from diverse populations. We will recruit 50 teachers for B Team from Denver, Minneapolis/St. Paul, and at least two other states—probably Texas and California—to include a broad sample of teachers and students.

Describe a recent successful project activity related to your education materials

Over the last few months we have secured an exceptional team of master teachers that comprise our NanoLeap A team. We expect next month's professional development team meeting to be rewarding for the A team as well as the project team.

VI. Research

Describe the research on learning and teaching that is underway or planned

Between the months of November, 2004 and March, 2005, the NanoLeap team developed and conducted an online survey. The stated purposes of the survey were to find out: (1) the relative importance of the underpinning concepts that might support the teaching of nanoscale science concepts in the high school curriculum; (2) where potential nanoscience concepts can be taught in high school; and (3) how likely teachers are to use nanoscience instructional materials. The survey consisted of 34 questions, which could be broken down into four categories: demographics, the importance placed on given scientific concepts, placement of nanotechnology topics within given courses, and interest in teaching a nanoscale science unit. Nineteen of the 305 teachers who took the survey provided their course syllabus for the NanoLeap project team's consideration in developing materials.

VII. Evaluation

Summarize evaluation plan

The evaluation of *NanoLeap* will utilize multiple methods to gather quantitative and qualitative data from participants throughout all phases of the project. The evaluation approach, particularly the formative evaluation, is informed by the Design-Based Research model which emphasizes the importance of understanding the "real-world demands placed on designs and adopters of designs," providing a rich account of the ways in which the curriculum modules are implemented in different settings, and contributing to the knowledge of effective design strategies in these settings (The Design-Based Research Collaborative, 2003). Findings from data collection will be reviewed with project staff on an ongoing basis. A report of key findings will also be prepared for the formative evaluation and the summative evaluation.The formative evaluation will provide project staff with data on an ongoing basis to inform the development and implementation processes. In keeping with the design-based approach the formative evaluation will examine the manner in which teachers implement the curriculum, how students respond to the activities, and the extent to which these activities result in intended and unintended impacts on students and teachers. The summative evaluation will utilize treatment/matched comparison groups and pre/post data collection to answer questions about the effectiveness of the NanoLeap curriculum modules in supporting teaching and learning. All data collection protocols for the summative evaluation will be developed and piloted with the A Team during the Spring Semester Series 2006 and revised, as needed, for use in the summative evaluation during the B Team Spring Semester Series 2007.

VIII. Lessons Learned

List 2-3 lessons learned to share with other engaged in pre-college nano education

Describe what you might do differently in the future

The site visit conducted on April 21 through 22 of 2005 afforded us the opportunity to receive feedback and mid-year correction recommendations from our reviewers and each other. As a result of the meetings, two key recommended changes were articulated:

1. Examine the content topics to be addressed and the placement of content.
2. Examine the insertion point structure for initial development and replace it with a module approach. This change in development was based on the project members' opinions and was validated by our external peer reviewers. Once the materials have been developed and pilot tested in modular form, then individual teachers will have the ability to use an insertion point approach for implementation.