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A Library of Hands-On Nanoscience Activities Appropriate for Grade 10 through 14 Students

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Abstract:

Nano-Link, the Regional Center for Nanotechnology Education, has created a library of over 20 activities developed to teach nanotechnology concepts to upper level students. The activities not only provide an inexpensive, tactile approach to understanding nanoscience concepts but also include aspects of practical applications, correlation to traditional science and engineering disciplines and avenues for critical thinking and problem based learning. Each topical activity has several versions that allow tailoring of the activity and content to the education level of the students. Many of these modules have been used for several years in high school and college classes with positive results and improvement in student understanding and interest in science.

Introduction:

The Advanced Technology Education (ATE) Program within the National Science Foundation places significant emphasis on the distribution of educational content within both high school and college level institutions. However, in many instances this is a challenging aspect of the successful implementation of an NSF ATE project. In 2009 the ATE started a project to study and improve the dissemination of created educational content. The project was named Synergy and Nano-Link along with eleven other ATE Centers participated in the Synergy project.

The project required each participating center to select one aspect of their dissemination activity with the intent of evaluating, dissecting, improving and measuring that particular dissemination activity. Nano-Link selected the dissemination of our nanoscience based educational content to high school educators as the focus topic.

The Process:

The logic diagram, which was one of the first steps in the evaluation and improvement process for the Synergy project effort, is shown in Figure 1. The logic diagram follows the progression of steps from input through long term results. Essentially, the goal of Nano-Link is to enthuse young (pre college) students about nanoscience in particular and science, technology, engineering and math (STEM) in general. In the early years of Nano-Link, dissemination efforts focused predominantly on the students, with classroom visits, summer camps and various activities used to reach students with information about nanoscience and STEM concepts and careers. This effort was moderately successful with hundreds of students reached and very positive and enthusiastic assessments. However, greater levels of outreach and greater impact were desired.

Professional development for educators was also a part of the Nano-Link outreach and dissemination. Again, although the efforts were successful in helping educators understand nanoscale concepts, the numbers were lower than desired and the number of educators that actually integrated nanoscience into classes was very small. Initial enthusiasm for integration was high, however when the time came for actual implementation the educators were hesitant.

As part of the Synergy effort, the Nano-Link team acknowledged the strength of the influence of educators on students' perception of science and science careers and therefore decided to focus the improvement efforts on the educators. This emphasis is shown in the logic diagram. One of the first activities undertaken in the Nano-Link Synergy effort was to survey educators (high school and college) to determine what they wanted in education content, which aspects of nanoscience was of greatest interest to them and what it would take for them to integrate new content into their classes. During a twelve month period over 250 educators were surveyed. The survey, results and implications are covered elsewhere, however the overwhelming response was that educators wanted hands-on, fun, activities that conveyed basic nanoscale concepts that would fit into one or a few class periods. Of lesser importance were lecture presentation materials, test questions, a great deal of technical rigor and stipends. Nano-Link also changed the approach toward professional development by shortening educator workshop duration, focusing on the activities, providing support for correlation with science concepts and providing all of the technical detail in on-line lectures (optional for educators).

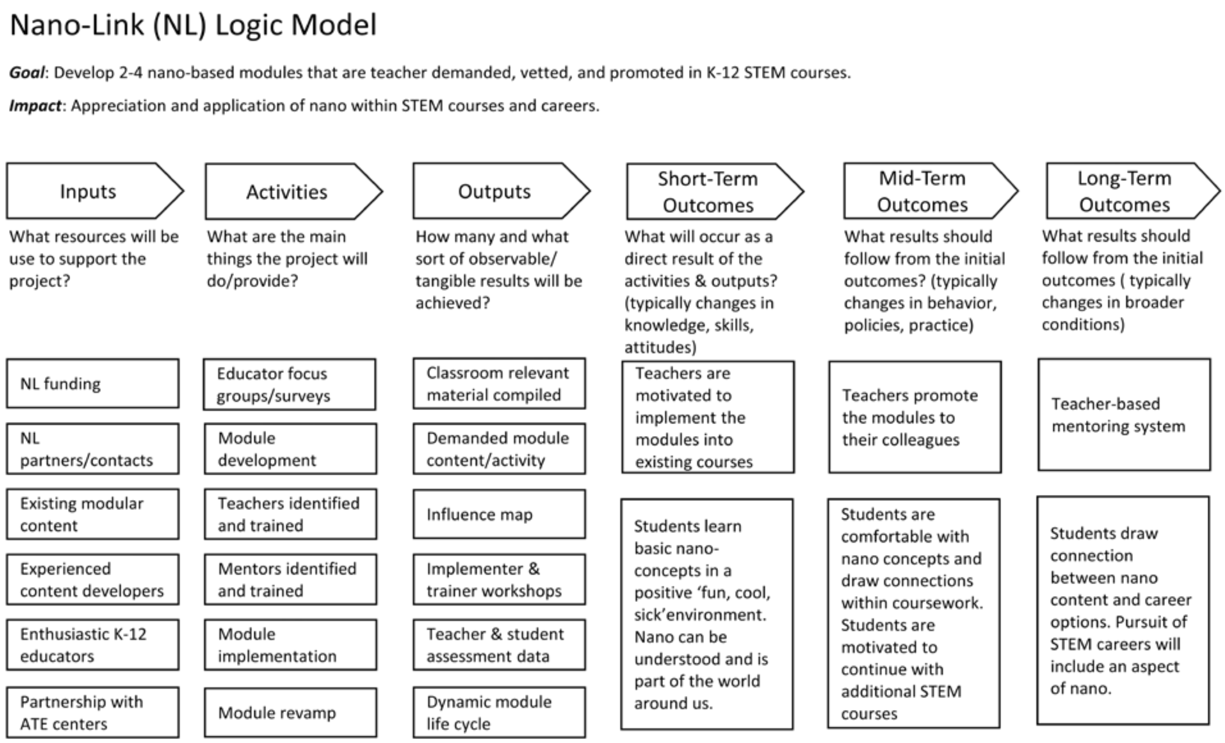

Figure 1: Synergy Project logic model.

The Modules:

Based on the surveys as well as several educator focus groups and one on one interviews, the modular concept for the educational content was created, where a module is a topically based education unit which includes a student activity as a focal point that can be completed in one to four class periods. The table of contents for a module is shown in Figure 2. The emphasis for the modules is in the hands-on activities, which are a critical element for the educators and students. Twenty modules have been developed or are in process. These modules are shown in Table 1. For the eight modules that are complete and have been in use in classrooms Nano-Link is continuing to assess the critical elements for a module and the table of contents may be modified. For example, the supplementary videos on the Nano-Link website are used by 85% of the educators and/or students, but the detailed technical resources are used much less often (20%). Items are also being added, based on educator, student and industry input. These items include problem based learning units, critical thinking problems or experiments and team based activities. Table 1 includes the traditional science and nanoscale concepts covered in the module, the potential applications and careers (as part of the module discussion) and the current status of each module.

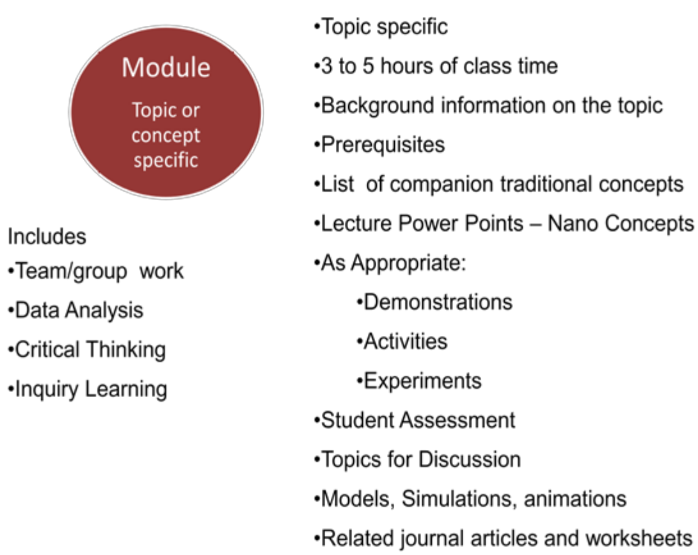

Figure 2: Typical module table of contents

Module	Focus	Traditional Sciences	Nano Concept	Application Correlation	Status
Effervescent Tablets	Surface area to volume ratio	Algebra and graphing	Reactivity and surface area	Batteries, catalytic converters	Complete and distributed
Magic Sand	Superhydrophobicity	Chemistry Physics	Priorities of Forces and Interactions	Water purification	Complete and distributed
Crystals Part 1	Self Assembly	Physics Chemistry	Material structure	Critical thinking	Complete and distributed
Crystals Part 2	Unit Cells	Material Science	Material structure	Material structure	In process (3/13)
Cross-Link Polymer	Fluid and polymer interactions	Chemistry Biology	Priorities of Forces and Interactions	Drug delivery	Complete and distributed
Ring-Polymer	Fluid and polymer interactions	Chemistry	Priorities of Forces and Interactions	Absorbent material	Complete and distributed
Magic Fish	Scientific Method	General	General	Design of experiments	Complete and distributed
Sunscreen	Nano particles and light interaction	Physics	Size dependent interactions	Sunscreen	In beta test
Thin Films	Interaction with light	Physics	Size dependent interactions	Decorative products	Complete and distributed
Memory Metals	Crystalline structure of metals	Physics Material Science	Nanoscale properties	Springs	Distributed
Light Emitting Diodes Part 1	Energy band structure Energy and wavelength	Physics	Quantum at the nanoscale	Energy efficient lighting	In beta test (2/13)
Light Emitting Diodes Part 2	Device operation	Physics	Quantum at the nanoscale	Solid state	In process (3/13)
What's wrong with this picture?	Atomic Structure	Physics	Atomic structure	Geckos and Jumping spiders	In beta test (2/13)
Water and Salt	Dissolving process Temperature dependence	Chemistry	Sense of Scale	Supersaturated solutions	In beta test (2/13)
Micelles: Biology and Soap	Non uniform charge distribution Non	Biology	Hydrophobic and hydrophilic	Detergent	In process (3/13)
Protein Folding	Non uniform charge distribution	Biology	Molecular structure	Drug interactions	In process (3/13)
Micro Fluidics	Mixing fluids (turbulent and lamiar plow)	Physics Material science	Phenomena at the nanoscale	Lab on a Chip	In beta test (2/13)
Carbon Nanotubes Part 1	Material Properties - Strength	Material Science	Molecular structures	Automobiles	In process (3/13)
Diffraction Gratings	Optics as sensors	Physics	Size dependent interactions	Sensors	In process (5/13)
Nanoparticles in Solution	Diffusion	Chemistry	Molecular interactions	Targeted systems	In process (5/13)

Table 1. Current modules

Modification:

The educational content is designed to be adaptable to multiple ages and educational levels. The chart in Figure 3 depicts some of the variations that are possible for the cross linked and ring polymer modules. For the lowest grade levels the activities can be used to show the relationship between atomic structure and physical properties. For example, the cross linked polymer, when dry, is course and room temperature. When water is added to the polymer, it expands, feels very soft and cool to the touch. By adding the water to the polymer the atomic structure is changed and the physical properties are {obviously} changed. For more advanced students, variations in temperature and use of different fluids can lead to an investigation of molecular structure, chemical bonds, bond strength and temperature dependence. The variations in the matrix serve as a starting point for educators which can lead to multiple course and class specific variations.

Category	Middle School	High School	College
Materials	Cross-Linked polymer powder Water Petri Dishes Transfer pipettes or small flexible plastic cups Food coloring (optional)	+ Different liquids (oil, salt water, soap, glycerin, alcohol etc.) Access to hot and cold water	+ Stopwatches Video camera Beakers, scales Raman Spectrometer SEM
Concept(s)	By adding water to the XL polymer the arrangement of atoms is changed therefore changing the material properties	+ Interaction is dependent upon the type of liquid and also the temperature of the liquid	+ Use liquid and temperature variations to define inequality equations for the various forces and interactions (cohesive, adhesive, vibrational etc**.**
Variations	None	+ Molecular structure and attributes of the liquid Temperature dependency	+ Time of interaction, amount of dry and liquid materials Different concentrations of liquids i.e. salt and water, water and soap
Questions	Can you think of other examples where adding one material to another changes the properties? Can you think of possible applications for a material such as the cross-linked polymer?	+ What are the forces and interactions between the atoms/mers in the polymer and the molecules of the liquid? Does the molecular structure of the liquid impact the reaction? If so, how?	+ Using the Raman, which chemical bonds were broken with different liquids Define relative strengths of the different bonds Define the charge distribution of the liquid molecules and the influence on the interaction with the cross linked polymers

Figure 3. Variations for cross linked and ring polymer modules.

Results:

The modular approach employed by Nano-Link as a result of the work performed during the Synergy project has resulted in 20 modularized topics. To date, 8 of the modules have been widely disseminated to over 50 high school and college educators in 15 states. These educators have used the modules in classes with over 5000 students. This is a significant improvement over the previous efforts of Nano-Link and was realized by working with the educators and intended audience. Complete, topically based educational modules were created that met their needs and student expectations.