AC 2011-321: DESIGNING AND IMPLEMENTING TEACHER PROFES-SIONAL DEVELOPMENT IN NANOSCALE SCIENCE AND ENGINEER-ING: WHAT MAKES FOR A SUCCESSFUL PROGRAM.

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Designing and Implementing Teacher Professional Development in Nanoscale Science and Engineering: What makes for a successful program.

Abstract

Nanoscale science and engineering is considered by many to be the next "industrial revolution." The NSF estimates that by 2015 nanoscale science and engineering will be a \$2.0 trillion industry with the U.S. needing approximately 1 million workers. The Georgia Institute of Technology's National Nanotechnology Infrastructure Network (NNIN) site has been developing and implementing a professional development program in nanoscale science and engineering education (NSEE) for secondary science teachers (grades 7 -12). It is our belief that we must provide teachers with the tools and resources needed to educate the future US workforce in nanoscale science and engineering. In addition, we have found that nanoscale concepts excite students about science and engineering. We have been refining our approach over the past several years and are now focusing our professional development on the Big Ideas in Nanoscale Science and Engineering: A Guidebook for Secondary Teachers¹. The primary focus of our program has been to help teachers understand how nanoscale science and engineering can fit into a standards-based science curriculum that is already taught in middle and high school classrooms (physical science, physics, chemistry, and biology). Additional components of the program include why students should learn about nanoscale science and engineering (workforce development) and how it is an interdisciplinary field which helps students understand the interconnections between the sciences and engineering.

Introduction

Nanoscale science and engineering (NSE) is viewed by many as the next great technical revolution. Evidence for this belief in the U.S. is the establishment of the National Nanotechnology Initiative (NNI) and the nearly quadrupling of its budget since its inception in 2001 from \$464 million to nearly \$1.8 billion in 2010². A substantial portion of the funding increase to several U.S. agencies has been due to the *American Competitiveness Initiative* signed into law in 2007.

The National Science Foundation (NSF) estimates that by the year 2015 there will be a need for two million workers worldwide in the fields of NSE³. An additional 5 million workers will be needed in support areas. Of these two million workers, it is estimated that the workforce needs will be 0.8-0.9 million for the U.S., 0.5-0.6 million for Japan, and 0.3-0.4 million for the E.U. The need for a skilled workforce to meet this challenge has been highlighted in two recent reports: *Innovate America*⁴ and *Engineering Research and America's Future: Meeting the Challenges of a Global Economy*⁵ which stress the critical importance of technological innovation in U.S. competitiveness, productivity, and economic growth. NSE is seen as one of these technologically important fields and as noted in *Innovate America*, "nanotechnology could impact the production of virtually every human-made object."

While the full economic impact of NSE has not yet been completely attained, it is rapidly expanding into many facets of our society from electronics to medicine. To meet the need of an educated populace that can work in NSE as well as support its safe development, it is critical that universities/colleges, governments, and industries support nano-education efforts at all levels of our society.

The National Nanotechnology Infrastructure Network (NNIN) is a National Science Foundation (NSF) funded program which supports nanoscience researchers by providing state-of-the-art NSE facilities, support, and resources. The NNIN is an integrated partnerships of fourteen universities distributed across the United States (<u>http://www.nnin.org</u>). NNIN's mission is to

support the NSE research and development needs of academic, industrial, and governmental users by providing tools, training, and process knowledge. In addition to researcher support, the NNIN has a large and integrated education and outreach program. The focus of the program is to develop a workforce ready for the demands of the rapidly developing field of NSE as well as develop a nano-literate public.



In terms of K-12 outreach, we have two

primary areas of focus: 1) develop and distribute activities to encourage K-12 students to enter science, technology, engineering, and mathematic (STEM) fields; and 2) develop programs and resources for K-12 teachers. The focus of this paper is on our efforts to encourage secondary science teachers to include NSE topics in their teaching.

Designing and Implementing NSE Professional Development

This paper presents the process used to develop teacher training workshops on NSE. The process included literature reviews, surveys, and discussions with teachers. Results from these guided the formation of the program. As the workshops developed, we asked two key questions: 1. what nano-concepts should be included and how are they related to K-12 science content and 2. do the approaches used lead to correct understanding of key concepts.

We developed our NSE professional development program based on the beliefs that NSE is an exciting topic which could help in developing student interest in STEM, that NSE should be taught in K-12 classrooms in order to meet the expected workforce needs, and that all citizens should be exposed to NSE topics in order to critically asses this new technology. While the field of NSE is widespread in academia and industry, little professional development opportunities have been made available for K-12 teachers. A variety of nano-instructional materials have been developed and made available online but there is a need for teacher professional development workshops to help teachers understand how to include nanoscience concepts in the science curriculum. Roco³ discussed the impact of NSE on the US education system and stressed the importance of educating at all levels to meet future workforce demands. He noted that the "key challenge" for NSE is education and training and this technology must be included now in education programs.

The primary focus of our professional development program has been to help middle and high school teachers understand how NSE can fit into a standards-based science curriculum that they are already teaching in classrooms (physical science, physics, chemistry, and biology). NSE requires that we take new approaches in our science education such as showing the interdisciplinary nature of science as well as understanding that properties of materials often change at the nanoscale. For example, a National Science Education Standard (content) for middle school physical science, "Properties and changes of properties in matter" indicates a "substance has characteristic properties, such as density, a boiling point, and solubility, all of which are independent of the amount of the sample." However, properties have been shown to change as they approach the nanoscale where melting points, optical properties etc. behave

differently. This requires that we incorporate this new information into our science education programs by introducing these topics to teachers and eventually to their students.

We began our program development by surveying teachers at the 2005 and 2006 National Science Teachers Association annual meetings to determine how much they knew about NSE, where they had received their information, and what they needed to include NSE in the classroom. This survey was initiated so that any professional development program we developed would meet the needs of practicing teachers. Not surprisingly, most of those surveyed new little about NSE which was a similar result to surveys conducted about the same time by other groups on the NSE knowledge of the general public.

Table 1 below summarizes the results of the surveys. For question 1, "a little" included – heard of it but did not really know what it means and "some" included – can explain it to others. The results show that approximately two-thirds of the survey participants (n = 90) knew very little about NSE and what it actually included. Questions 3 and 4 helped us in determining the types of support teachers needed in order to bring NSE into the classroom. In particular, they wanted short activities that were tied to scientific concepts they were required to teach. In terms of the type of workshops teachers wanted they included district (33%), national (21%), telecast (21%), college/university (17%), or any/all (8%). From these results, we concluded that we needed to develop a professional development program that would first introduce what NSE is and then show teachers how NSE fits into their courses. The format that we chose was direct face-to-face workshops.

Question	Choices and responses				
1. NSE	None	A little	Some	A lot	
Knowledge	15%	50%	31%	4%	
2. Source of	News media/	Colleagues	Internet	Workshop	Students/
NSE knowledge	publications				other
	49%	14%	7%	14%	16%
3. Type of	Add-on unit	Short activity	Special	Required	Other
materials needed	(enrichment)	tied to	topic linked	concept and	
		required	to NSE(2-3	NSE (2-3	
		concept (1	weeks)	weeks)	
		class)			
	15%	46%	12%	25%	2%
4. Support	Textbook/printed	On-line units	Videos	Workshops	Online
needed to	materials				assistance
include in	8%	30%	14%	30%	18%
classroom					

Table 1. Results of 2005-2006 teacher survey

A second source of information on teacher professional development needs came from the participants in the NNIN Research Experience for Teachers (RET) program. The program has supported over 100 teachers since 2005 to conduct NSE research and classroom materials development. Our work with the RETs also emphasized that there was no room in the science classroom for new topics but that NSE concepts tied very well with currently taught topics in secondary classrooms.

Over the past decade, educational researchers have determined what entails good professional development for teachers. An analysis of professional development performed by Mid Continent for Research in Education and Learning⁶ noted that teachers need strong content knowledge and the ability to change their pedagogy. Research in science education has demonstrated that teachers who participated in professional development programs with a strong content matter focus positively influenced the achievement of their students⁷⁻⁹. Other research has shown that strong content knowledge is necessary for the development of teacher pedagogical content knowledge¹⁰⁻¹². In terms of student interest and learning in science, achievement has been correlated to the use of relevance (to student lives) and real world examples¹³⁻¹⁴.Positive attitudes towards science have been linked to increased student achievement¹⁵ and appear to be related to a deeper level of learning because of increased interest¹⁶.

Research has now begun on what makes good professional development in nanoscale science as well as what topics in NSE are of interest to students. This research is important as NSF-funded centers begin to offer nano-focused professional development programs. One study¹⁷ noted that it is critical to demonstrate to teachers how to incorporate nanoscale science into existing curricula while incorporating strong content and pedagogy in the professional development. As more professional development programs in nanoscale science are offered, much of the focus is being driven by the "Big Ideas in Nanoscale Science and Engineering: A Guidebook for Secondary Science Teachers"¹. These big ideas include: structure of matter; size and scale; forces and interactions; size-dependent properties; quantum effects; self-assembly; tools & instrumentation; models and simulations; and science, technology and society. A recent study¹⁸on what interests 7-12th grade students in nanoscience topics generated the following areas: personal interests, relation to student's everyday life, and hands-on activities/ experimentation. The results indicate the importance to provide topics that are important to students' lives (real world) and have a hands-on inquiry approach. However, besides these few investigations there is still little published information on what makes good professional development in nanoscience and what approaches help teachers in learning key concepts. We use this information in developing our activities for teacher workshops.

We are part of a five year NSF-funded study, NanoTeach, which is examining best practices (pedagogy and content) for helping teachers to include NSE in physical science concepts. The program is funded to Mid-continent Research in Education and Learning (McREL), Stanford, Georgia Tech, and Aspen Associates. Results from this study will begin to be available within a year and will add additional results to help inform professional development programs in NSE.

The NNIN NSE teacher professional development program is part of the agenda of the NNIN site at Georgia Institute of Technology. The other 13 NNIN sites do not offer professional development programs for teachers. This site is also the primary coordinating site for all NNIN education programs and activities. We have been very active over the last few years in providing workshops to teachers at local, regional, and national events. These workshops range in duration from two hours to one week. Figure 1A illustrates states where we have reached at least one teacher in a workshop and Figure 1B illustrates Georgia counties where we have reached at least one teacher. For both figures, it typically is for more than one teacher per shaded area. These results are for years 2006 through 2010.



Figure 1. Shaded areas indicate state (A) or Georgia county (B) where teacher workshop participants reside.

We began our workshop development by exploring the numerous educational materials currently available on the Internet typically from NSEC, MRSEC, and the NNIN websites. Each lesson was analyzed in terms of how it could possibly fit into current science topics. We also used secondary science textbooks to align the lesson with current curriculum. From examining approximately 40-50 NSE classroom lessons, we narrowed the list down to approximately six that we felt could address broad science concepts important to NSE and we designed our initial workshops around these lessons. An additional consideration was that the lesson did not require expensive equipment, could be done with simple materials, and were short in duration. Concepts that we wanted teachers to understand included size and scale, self-assembly, hydrophilic and hydrophobic properties, and current applications of NSE in consumer products (focused on workforce development issues). Each workshop begins with a PowerPoint that introduces NSE in terms of what defines it, what area of STEM it includes, and workforce and education issues.

For each workshop we use a pre and post survey instrument. Appendix 1 provides examples of surveys. The surveys are intentionally short as most of the workshops are offered at science teacher conferences and there is little time for in-depth surveys. The purpose of the surveys has been twofold – to determine if teachers gain knowledge of concepts highlighted in the workshops and if our approach is helping teachers gain understanding (i.e., did the instructional methods improve understanding). Appendix 1 provides examples of surveys which vary with workshop depending on the lessons presented which also may vary by audience. Results presented in this paper are for questions that have been in numerous workshops.

We learned early on that most teachers were able to define what a nanometer is (Table 2) but had difficulty with important aspects of size and scale as related to macro, micro, and nano-scales (Table 2). Understanding what comprises the nanoscale is an important concept for a field that is defined by scale (1-100nm). We start each workshop with a size sorting activity^{19,20} in which most participants are able to correctly sort items in the macro and micro range but as they transition from the micro into the nanoscale difficulties typically arise. This activity leads to good discussions on the importance of understanding scale and what reference points individuals use in sorting the items. Recent work²¹ has shown that it is difficult for teachers and students to conceptualize scale and that the most common reference point for relative scale is a person's own size.

Size of a nanometer (1x10 ⁻⁹)	Pre-survey	Post-survey
Correct	89%	99%
Incorrect	11%	1%
Sorting of nano &		
microscale objects		
Correct	64%	69%
Incorrect	36%	31%

Table 2. Survey results for questions dealing with size and scale

The "Big Ideas" provide a foundation to align curriculum and instruction and professional development programs. Each of the ideas has a set of learning goals which provide a guide for what content should be learned within the broad big idea framework. With the development of the "Big Ideas", we further refined our workshop to provide materials to teachers that are connected to each idea and the associated learning goals. Our current workbook contains two lessons for each big idea. These lessons come from a variety of resources but include connection to current science concepts, hands-on activities, and inexpensive materials. We have revised our pre-post surveys around the big ideas and will be utilizing these in Spring/Summer 2011 workshops to see if the new approaches lead to improved concept knowledge.

An example of a lesson used in a workshop would be the NNIN unit "Ferrofluids: What does nanotechnology have to do with magnetism?" (<u>http://www.nnin.org/nnin_k12teachers.html</u>). As we searched for a lesson for the Big Idea - Forces and Interaction, we noted that there were several lessons available on the Internet that focused on ferrofluids. However, we discovered (through our RETs and exhibit booth as NSTA) that teachers were not interested in ferrofluids because they could not see a connection to the magnetism taught in physical science or physics classes. We developed our own lesson that connected NSE (via ferrofluids) to magnetism. The activity includes the following essential questions:

- 1. What does magnetism have to do with Nanotechnology?
- 2. Can liquids be magnetic? Have you ever seen a liquid that is magnetic?

3. How could you keep a liquid in place in outer space where there is no gravity?

In terms of objectives, by the end of the activity the participant should be able to: 1. Review magnetic characteristics.

- Discuss the difference in the behavior of liquids that have different size magnetic particles.
- 3. Discuss what ferrofluid is and some of its uses.

The lesson includes an introduction to the topic, exploration of the activity, group work, group discussion, and wrap up. Teachers are provided a hard copy of the student version of the lesson so that they explore it during the workshop as a student would. Thy receive the teacher and student versions of each lesson in a workbook on a CD. For this lesson:

- Teachers review what they know about magnetism, liquids, and solids.
- They explore magnetic interactions.
- Teachers are given vials of iron fillings and iron fillings in water. They make observations including the interaction of the materials with magnets.
- They see the interaction of a ferrofluid and a penny (within the solution) with a magnet. They write their observations but no explanation is provided as to what is occurring.
- Teachers take their vial of ferrofluid and are directed to explore the material with a magnet. They compare to the other vials with iron fillings and answer questions

including: "Is a ferrofluid a solid or a liquid?"; "Does the solid in the ferrofluid behave the same as the iron fillings in the vial of water?"; "How was the penny able to float?"; "What is considered to be nano about ferrofluid?"

Group discussion follows on how teachers would develop student understanding and how this lesson is tied to NSES. Teachers are provided space in the workbook to enter what they consider are the curriculum connections. If time permits (depending upon the length of the workshop), discussion of these curriculum connections occurs including what modifications teachers would make to use the activity with their students.

Lessons learned

We analyzed the pre and post survey data from teacher workshops that occurred between 2007 and mid 2009. As noted above, the good news was that teachers were able to define a nanometer to be 1×10^{-9} meter (Table 2) and could reasonably sort items in the micro- and nano-scales. However, there was little improvement in the scaling ability between the pre and post surveys indicating that even with the sorting activity teachers were still somewhat confused about size and scale. This is an important finding because teachers must understand these concepts which are key to nanoscale science. The results have been used to modify the presentation to include emphasis of nanoscale objects.

More worrisome were the results for other questions. We asked if materials at the nanoscale would have to self assemble in order to be built. This was connected with a lesson on self assembly²³. The lesson is used to help participants understand the hierarchal development of materials through forces and interactions and that this leads to new materials and devices. Included in this is a discussion of top-down fabrication used to indicate that there are others methods of fabrication. Table 3 shows the results for 2007-2009 workshops which indicate there is an increase in incorrect responses i.e., that the participants believe that self assembly is the only way to fabricate nanoscale materials. Upon reviewing these results, we revised the lesson in mid-2009 to include a hands-on activity which demonstrates top down fabrication. Table 3 shows that the participants were able to understand that there is more than one method of fabrication. We have interpreted these results to indicate that when presenting NSE topics it is critical to be extremely clear about the materials and concepts used in the lesson. By altering the lesson to include a hands-on activity that demonstrates an additional form of nanofabrication the participants did not "latch-on" to the idea that self-assembly is the only means of nanofabrication.

Pre-survey	Post-
	survey
37%	33%
63%	67%
54%	70%
46%	30%
	Pre-survey 37% 63% 54% 46%

Table 3. Pre & post survey results of a subset of questions (Appendix 1)

Correct	20%	10%
Incorrect	80%	90%
AFMs see nanoscale objects (2009-		
2010)		
Correct	76%	86%
Incorrect	24%	14%
Nanoscale objects below range of		
visible light & cannot be seen by		
optical scopes		
Correct	72%	86%
Incorrect	28%	14%
Ferrofluids -what is attracted to a		
magnet		
Correct	43%	53%
Incorrect	57%	47%
Colloids have particles that are in		
the range of (list of choices)		
Correct	31%	69%
Incorrect	69%	31%

A similar result was found with our activity to demonstrate the importance of new tools to explore the nanoscale. We use a "black box" lesson to help teachers understand how an Atomic Force Microscope works. The pre and post question was: AFMs see objects that are nanoscale in size. Results from workshops occurring in 2007-2009 show that teachers thought that the AFM could see nanoscale objects and that this incorrect knowledge increased after completion of the lesson (Table 3). We revised the lesson to include additional information on why optical microscopes are not used for nanoscale objects and stressed that the images received with an AFM are graphical representations of the forces between the surface and the probe tip. We also altered the survey question and developed two questions to determine the level of understanding of the roles of AFMs and optical microscopes (Appendix 1): AFMs only represent objects at the nanoscale it does not see them and Nanoscale objects are in the size below the range of visible light and cannot be seen by optical microscopes. With the changes in the workshop presentation and the survey questions there were improvements in teacher understanding (Table 3).

In summer 2009, we offered a one week teacher workshop followed by summer high school camps where the teachers would be able to enact the lessons they learned and thereby reinforce their understanding of the materials and be better prepared to include the materials in their classrooms. Appendix 2 contains the pre and post content surveys that were used by the external evaluator and developed by the co-authors. As can be seen from these surveys, more content-specific questions were used to assess content knowledge which was possible during a week long workshop.

Table 4 presents summarized results for some of the items used to evaluate content knowledge of the participants. As can be seen, in most cases there is a marked improvement in content knowledge which we attribute to greater time on task, i.e., each topic was covered in greater detail during a week long workshop. However, not all items show a gain in knowledge which we interpret to be areas where the concepts are confusing to teachers. For example, the question on ferrofluids showed no improvement even though participants spent sufficient time with the materials and had a clear explanation that ferrofluids are colloids of magnetic nanoparticles and

that the particles move when in a magnetic field and that the fluid moves in relation to the magnetic nanoparticles. We will be exploring this issue further during our week long summer workshops in 2011. However, this points to the issue that some concepts are difficult for teachers and that we must learn what they are and how we can improve our presentation of materials to enhance teacher learning.

Table 4.	Exampl	es of pre	& post	survey	results	from	a one
week we	orkshop	(Append	ix 2)				

week workshop (rippendix 2)				
Question	Pre-survey	Post-		
		survey		
Size of a nanometer				
Correct	71%	100%		
Incorrect	29%	0%		
Property of matter stays constant be	tween macro	and		
nanoscale				
Correct	50%	100%		
Incorrect	50%	0%		
Which has the largest surface area to	o volume rati	0		
Correct	86%	100%		
Incorrect	14%	0%		
Which explains the role of gravitational forces between				
macro and nanoscale				
Correct	43%	71%		
Incorrect	57%	29%		
Ferrofluid is a (list of choices)				
Correct	43%	43%		
Incorrect	57%	57%		
What are the common elements used in fuel cell reactions				
Correct	29%	67%		
Incorrect	71%	33%		
Catalysts are used in chemical reactions to (list of choices)				
Correct	86%	100%		
Incorrect	14%	0%		
A piezoelectric material is one that (list of choices)				
Correct	86%	86%		
Incorrect	14%	14%		

The results of the external evaluation indicated that the participants:

- Increased their knowledge of:
 - the potential to address standards through nanotechnology topics; they were able to connect nanotechnology topics to a wide range of Georgia Performance Standards
 - materials and resources appropriate to introducing nanotechnology in their teaching
- Expressed strong:
 - intention to use nanotechnology topics to address process and content standards (Georgia standards)
 - o desire to learn more about nanotechnology
- Endorsed the workshop as a professional learning experience likely to increase student achievement

In terms of the student participants, the evaluation determined that students:

- Were engaged in the learning activities at the summer camps
- Were interested in learning more about nanotechnology
- Understood the importance and impacts of nanotechnology
- Developed new science knowledge but remained unsure about the nanometer scale.

The external evaluation summary of the pre/post content for the students (same instrument as used with the teachers) shows gains in content understanding:

Domain	No.	Mean score		Change	%
	Items	Pre	Post	(Post-Pre)	Actual/Potential
Nanometer scale	12	39.5	62.0	22.5	37.2
Science content	13	37.9	84.4	46.4	74.8
All	25	38.7	73.6	34.9	57.0

Table 5. Summary of student learning from NSE camps

Follow-up surveys of the teachers indicated that they did use the materials in their classrooms in a variety of subject areas. The teachers were from rural Georgia where they are often the only or one of only a couple of science teachers in the high school and thus teach multiple subjects. The teachers overwhelming indicated that the workshop provided them with content knowledge to successfully implement the camp.

Conclusion

We have provided a number of teacher professional development workshops to assist teachers in understanding the interdisciplinary nature of nanoscale science and engineering and how this topic can be included in standards-based science teaching. We were quite dismayed to learn that the teachers did not improve their understanding of particular concepts during the 2007- mid-2009 workshops. Many of the misunderstandings we attribute to the often short time of the workshops (typically 2-4 hours) and that the teachers tended to grasp on to a new topic and incorporate that into their knowledge base and understanding. For example, the teachers saw AFM images and therefore internalized that the AFM could "see" the nanoscale even though we explained that the images were graphic representations. In terms of fabrication, the lesson on self assembly became "the method" for fabrication. These results taught us that providers of NSE teacher professional development must be extremely clear on introducing NSE topics so that teachers understand the full scope of each. The changes in our presentations beginning in mid-2009 indicate that there is improved participant understanding of the nanoscale topics. We continue to refine our presentations around the big ideas to ensure the understanding of the content. The week long workshop showed improvement in content knowledge which we attribute to longer time with each topic. While we advocate for longer workshops, this is not always possible when providing outreach at science teacher conferences or in-service days. Our recommendation for shorter duration workshops would be to limit the number of concepts taught so that the topic can be covered with reasonable depth.

A weakness of our professional development program is with sustained follow-up. Because many of our workshops have been at regional and national meetings it is difficult if not impossible to provide sustained support. The participants in our one week workshop in Georgia indicated that they did not want additional support except for email interaction. We do provide this type of support for participants in all of our workshops and send a quarterly newsletter to all which includes links to new resources and materials. We are now in the process of gathering data from a short questionnaire to determine how many of our workshop participants have included NSE in their classrooms and if additional support is wanted and in what form. This request has been emailed to all who have participated in an NNIN professional development workshop to do an online survey. While the survey is new (initiated at the time of the writing of this article) we do have 30 responses which can indicate the initial results:

Like to learn if you used the resources from the workshop				
Used a lesson from the workshop	46.7%			
Used more than one lesson from the workshop	40.0%			
Used a lesson from another source	0%			
Did not use any nano lessons	13.3%			
How did you use the resources from the workshop				
As part of a state-standard based lesson – short	63.3%			
activity & required concept				
Special nano topic – short activity not required	26.7%			
concept				
Special topic – longer activity	13.3%			
Did not use	10.0%			
What type of materials would help you to include NSE				
Add-on unit as special topic - enrichment	58.6%			
Short activity tied to required concept but	82.8%			
related to NSE				
2-3 week unit as a special NSE topic	10.3%			
2-3 week unit based on required topic & NSE	20.7%			
related				

Table 6. Preliminary results from follow-up survey questionnaire of workshop participants

These initial results (while a small number to date) confirm that teachers are willing to include NSE topics in their teaching but that they must be tied to currently taught science concepts and not require considerable time to teach. This has been our approach to providing professional development to secondary science teachers and we will continue to do so but with greater emphasis on each topic to ensure content understanding. The results of the various surveys presented here indicate that providers of NSE professional development should offer teachers content based lessons with a nano theme and not nano-based lessons. These materials should be short enough that they can fit into current teaching. In addition, it is important to clearly state nano-based concepts and provide sufficient time for learning these concepts during a workshop.

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Appendix 1 Examples of surveys used in NSE teacher workshops

Addressing Science Standards through Nanotechnology Teacher Pre-Survey (2007-2009)

- 1. Which of the following is equal to a nanometer:
 - O $1 \times 10^3 \text{ m}$
 - O 1 x 10⁻⁶ m
 - O 1 x 10⁻³ m
 - O 1 x 10⁻⁹ m

2. Which of the following objects is the smallest:

- O diameter of a ribosome
- O diameter of a carbon nanotube
- O width of a proteinase enzyme
- O length of a human muscle

3. Cosmetics, sports equipment, medicines and clothing have all been influenced by nanotechnology.

- O True
- O False

4. Water slides off of an object with nano fibers which is called Lotus Effect.

- O True
- O False

5. Fill in the circle of the leave(s) that display the lotus effect:

- O Lotus
- O Mustard
- O Ivy
- O Beech
- O Magnolia
- O Cabbage
- O Maple
- O Elephant Ear

- 6. Materials at the nano size will have to self assemble to be built.
 - O True
 - O False

7. Atomic Force Microscopes see objects that are nano in size.

- O True
- O False
- 8. A magnet can be a liquid.
 - O True
 - O False
- 9. Hydrophobic objects love water and Hydrophilic objects fear water.
 - O True
 - O False
- 10. Do you currently teach your students a unit which includes nanotechnology?
 - O Yes
 - O No



Addressing Science Standards through Nanotechnology Teacher Post-Survey (2007-2009)

- 1. Which of the following is equal to a nanometer:
 - O $1 \times 10^3 \text{ m}$
 - O 1 x 10⁻⁶ m
 - O 1 x 10⁻³ m
 - O $1 \times 10^{-9} \text{ m}$
- 2. Which of the following objects is the smallest:
 - O diameter of a ribosome
 - O diameter of a carbon nanotube
 - O width of a proteinase enzyme
 - O length of a human muscle

3. Cosmetics, sports equipment, medicines and clothing have all been influenced by nanotechnology.

- O True
- O False
- 4. Water slides off of an object with nano fibers which is called Lotus Effect.
 - O True
 - O False

5. Fill in the circle of the leave(s) that display the lotus effect:

- O Lotus
- O Mustard
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- O Magnolia
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 - O True
 - O False
- 8. A magnet can be a liquid.
 - O True
 - O False
- 9. Hydrophobic objects love water and Hydrophilic objects fear water.
 - O True
 - O False

10. Do you think it is important to include nanotechnology in science curriculum?

- O Yes
- O No

11. Do you plan on adding "something" about nanotechnology in your teaching in the next academic year?

- O Yes
- O No

12. What type of education materials would help you include nanotechnology in your classroom?

- O Text materials
- O add-on unit as a special topic, i.e. enrichment
- O short activity tied to the teaching of a required scientific concept
- O 2-3 week unit as a special topic that is linked to nanotechnology
- O 2-3 week unit that is based on a required scientific concept and also related to nanotechnology
- O on-line unites for downloading
- O newsletter regarding teaching resources, materials and workshops
- O district level workshops
- O national, state, or regional conferences
- O school level workshops
- O telecast/ webcast
- O on-line assistance
- O other, please specify_





Addressing Science Standards through Nanotechnology Teacher Pre-Survey (2009-2010)

- 1. Which of the following is equal to a nanometer:
 - O $1 \times 10^3 \text{ m}$
 - O 1 x 10⁻⁶ m
 - O 1 x 10⁻³ m
 - O 1 x 10⁻⁹ m
 - O No Idea
- 2. Which of the following objects is the smallest:
 - O diameter of a ribosome
 - O diameter of a carbon nanotube
 - O width of a proteinase enzyme
 - O length of a human muscle
 - O No Idea
- 3. Cosmetics, sports equipment, medicines and clothing have all been influenced by nanotechnology.
 - O True
 - O False
 - O No Idea

4. One of the medical applications of nanotechnology is the encapsulation of medicines to fight cancer.

- O True
- O False
- O No Idea
- 5. Colloids have particles that are in the range of :
 - O 1-100 mm
 - O over 100 μm
 - O 1-100 μm
 - O 1-100 nm
 - O over 100 nm
 - O less than 1 nm
 - O No Idea

- 6. To create nano size materials, researchers must use the following (select all that apply)
 - O self assembly
 - O top down fabrication
 - O bottom up fabrication
 - O all of the above
 - O No Idea
- 7. Atomic Force Microscopes only represents objects at the nanoscale it does not see them.
 - O True
 - O False
 - O No Idea
- 8. When a ferrofluid is exposed to a magnetic field, what is attracted to the magnet?.
- 0

the colloidal mixture

- O the magnetic particles
- O the material the magnetic particles are suspended in
- O none of the above
- O No Idea

9. Nanoscale objects are in the size below the range of visible light and cannot be seen by optical microscopes.

- O True
- O False
- O No Idea

10. Do you currently teach your students a unit which includes nanotechnology?

- O Yes
- O No





Teacher Post-Survey (2009-2010)

- 1. Which of the following is equal to a nanometer:
 - O $1 \times 10^3 \text{ m}$
 - O 1 x 10⁻⁶ m
 - O $1 \times 10^{-3} \text{ m}$
 - O $1 \times 10^{-9} \text{ m}$
 - O No Idea
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 - O 1 100 μm
 - O 1 100 nm
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 - O the magnetic particles
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- O district level workshops
- O national, state, or regional conferences
- O school level workshops
- O telecast/ webcast
- O on-line assistance
- O other, please specify_____



Appendix 2. Pre/Post content survey for NSE one week teacher workshop



Exploring Nanotechnology Questionnaire

Answer Selection: Correct = \bullet Incorrect = \emptyset \bigstar

- 1. Which of the following is equal to a nanometer?
 - O $1 \times 10^{3} m$
 - O $1 \times 10^{-3} m$
 - O 1 x 10⁻⁶m
 - O 1 x 10⁻⁹m
 - O $1x10^{-12}m$

2. Which of the following would you use a nanometer to measure? Remember, the nanoscale measures objects between 1 and 100 nanometers. Fill in the circle for all correct answers.

- O A hydrogen atom
- O A molecule
- O The width of DNA
- O The hair on the elbow of an ant
- O Viruses
- O Cells
- O An iPod nano
- O A protein Strand

3. What products use nanotechnology today. Fill in the circle for all correct answers.

- O Tennis rackets
- O Pants
- O Glass
- O Golf clubs
- O Car wax
- O Shampoo
- O Wrinkle cream
- O Batteries

- O Sunscreen
- O Makeup
- O Glue
- O Lasers
- O iPods
- O Bottles

4. Which of the following would not be a property of matter.

- O Starts with letter a
- O Volume
- O Reacts with oxygen
- O Density

5. Properties of matter remain constant between the macro and nanoscale.

- O True
- O False

6. Which of the following would have the largest surface to volume ratio?



7. How does increased surface area effect reaction rates?

- O Increases the reaction rate.
- O Decreases the reaction rate.
- O Does not effect the reaction rate.

8. Which of these explain the role of gravitational forces between the macro and nanoscale.

- O Gravitational forces become negligible as you move into the nanoscale.
- O Gravitational forces as a function of mass and distances are less important at the nanoscale.
- O Gravitational forces are the dominate force of the macroscale.
- O All of the above.

9. Which of these explain the role of electromagnetic forces between the macro and nanoscale.

- O Electromagnetic forces dominate at the nanoscale.
- O Electromagnetic forces are a function of charge and distance.
- O Electromagnetic forces are not a function of mass.
- O All of the above.

10. Which combination of magnetic fields and poles shows two magnets repelling each other?



11. Permanently charged magnets have domains that

- O Are randomly aligned
- O Are aligned and point in the same direction
- O Have electrons which only align when an electric current is applied
- O Have atoms that are spinning

12.A ferrofluid is a

- O Solid
- O Solution
- O Colloid
- O Suspension

13.Can a substance like nitinol have more that one solid phase?

- O Yes
- O No

14. Catalysts are used in chemical reactions to

- O Change the mass of a reaction
- O Speed up a reaction
- O Be incorporated into a reaction to change the end product

O Increase the temperature of a reaction

15. An electrolyte is

- O A solution with a large number of anions
- O A metal alloy that conducts electricity
- O An aqueous ionic compound that conducts an electric current
- O A suspension of metals

16.Fuel cell technology has/is generating many different types of fuel cells

- O True
- O False

17. What are the common elements used in a fuel cell reaction?

- $O \quad H \text{ and } O$
- $O \quad H_2O \text{ and } C$
- $O \quad C \text{ and } H$
- O None of the above

18. Heat moving up a metal spoon in a boiling pot of water is an example of

- O Conduction
- O Radiation
- O Convection

19. Thermal energy is

- O A measure of how fast an object will heat up
- O A measure of the sun's energy as it reaches the earth's atmosphere
- O The sum of the kinetic and potential energy of all the particles in an object
- O The amount of heat that can be absorbed by an object.

20. A piezoelectric material is one that

- O Responds to stress by generating an electric potential difference, or voltage.
- O Responds to temperature changes by changing its reflectance properties\
- O Responds to light by developing a diffraction gradient.

21. The electric magnetic spectrum is made up of which of the following?

- O Gamma rays
- O TV waves
- O Visible light
- O Microwave

22. Can we see objects at the nanoscale?

- O Yes
- O No

23. Can we see anything at the nanoscale using an optical microscope?

- O Yes
- O No

24. Which statements below are unique properties of the nanoscale. Fill in the circle for any correct answers

- O Surface area-to-volume ratio increases as an object's size decreases
- O Changing the size of an object does not affect how it behaves.
- O Electrical forces play an important role at the nanoscale
- O Atoms are the foundational "building blocks" for matter
- O We can see the nanoscale with a powerful optical microscope
- O Properties of matter can change with size
- O Gravity plays a foundational role in the behavior of nanoscale items.
- O A material's properties are not influenced by atomic forces.

25. How is nanotechnology used today? Fill in the circle for any correct answers.

- O To treat cancer
- O To detect bomb materials
- O To make solar cells
- O To make stain-resistant clothes
- O To make wind turbines
- O To make more powerful nuclear weapons
- O To make computers faster

- O To see atoms
- O To make nanorobots that enter the blood stream
- O To rapidly deliver drugs to the body
- O To make clean water
- O To make sources of renewable energy
- O To make energy
- O To make cells easier to see