NanoTeach: Professional Development in Nanoscale Science

Final Report
McREL International
October, 2014
NSF Grant DRK-12 # *DRL-0822128*

Contents

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This report is based on the work supported by the National Science Foundation (NSF) under Grant # DRL-0822128. Any opinions, findings, or conclusions expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

The *NanoTeach* project's final activities are outlined below according to the five sections of the report.
Accomplishments
Products
Participants
Impacts
Changes/Problems
We also included appendices as reference throughout.

Accomplishments

What are the major goals of the projects?

Research Questions

This project will test the viability of professional development designed to support the integration of existing NS&T content and materials into high school science by researching the effects of participation and non-participation in *NanoTeach*. The guiding research questions are:

RQ #1 Does the *NanoTeach* facilitated professional development improve teachers' ability to integrate NS&T content into their classes in a manner that deepens student understanding?

RQ #2 To what extent is the approach utilized in the *NanoTeach* project a viable approach to the development of professional development materials and experiences that support integration of nanoscale science in high school science?

Project goal and teacher learning objectives

The primary goal of *NanoTeach* is to prepare teachers to use an instructional design framework to integrate NS&T content into their curriculum in significant ways. In order to achieve this goal, we will develop and test a professional development model that combines: (1) an **instructional design framework** (*Designing Effective Science Instruction*) a three part instructional design in which teachers will be able to integrate NS&T content, use instructional strategies that have a high correlation to student understanding, and create learning environments that help students conducting scientific inquiries, (2) **nanoscale science content** (from *NanoLeap*, *NanoSense*, and the NCLT), and (3) **multiple delivery methods** (face-to-face meetings, asynchronous online assignments, and synchronous sessions with new instructor controlled online video technology).

What was accomplished under these goals?

A. Major Activity: *NanoTeach* Resource Inventory

Overview:

The *NanoTeach* Development team conducted a review of existing Nanoscale Science and Technology (NS&T) educational resources and curriculum materials and evaluated the quality and usefulness of the materials for the *NanoTeach* Professional Development (PD) Workshop.

B. Major Activity: Viability of the Development Process

Overview:
The viability report summarizes the dynamic process used to develop the *NanoTeach* professional development (PD) project. The findings will be used to further inform ongoing curriculum development and professional development efforts to support nanoscience efforts. *NanoTeach* is a research and development (R&D) project that tests the viability of a PD model designed to support the integration of nanoscience and technology (NS&T) content into high school science. This R&D project utilizes an experimental design to evaluate the effectiveness of *NanoTeach*, a facilitated PD model to help high school teachers integrate nanoscience into their curriculum by increasing teachers' NS&T content knowledge and their repertoire of content-specific instructional strategies (Research Question #1). In addition, this project evaluates the viability of the process used to develop the intervention (Research Question #2). To assess the viability of the development approach utilized in the *NanoTeach* project, a variety of data collection activities are planned and will be reported on throughout the project. See Appendix A for the *NanoTeach* project logic model which clarifies the PD components and the data collection points. The final viability report is included in Appendix B.

C. Major Activity: Remote Access Experiences

Overview:
Stanford Nanofabrication Facility was tasked with developing remote access experiences to provide content knowledge and experiences for participants. Mike Deal developed outlines for the remote access experiences planned for both the pilot and field test experiences. One lab experience at SNF was a tour of the Carbon Nanotube lab where nanotubes will be grown in real time. Teachers will also look at images already prepared in the Scanning Electron Microscope (SEM) and Atomic Force Microscopes (AFM). Remote access activities were conducted with the field test teachers this summer. Activities included:

- A recorded webinar with professor Tom Kenney with follow-up questions from Mike Deal.
- Nanofabrication overview and cleanroom tour with researchers at the Stanford Nanofabrication facility.

YouTube videos of one session from each of these experiences are archived on the Google Site.

D. Major Activity: Pilot and Field Test

Pilot Teacher Participant
Many of the pilot teachers expressed an interest to stay engaged with the *NanoTeach* project in general and the field test teachers in particular. We planned on involving the pilot teachers as appropriate during the final year of the project. As we prepared for the winter debrief meetings and the Virtual Classroom sessions, we tested the Virtual Classroom lessons with our pilot

teachers who provided formative feedback on the platform as well as the content of the presentation and the video coding elements prior to the roll-out of the January 2013 sessions. We plan on having select pilot teachers share with field test teachers about the experiences they have had in sustaining the nanoscience and technology efforts post *NanoTeach* in a Google Hangout on June 14, 2013 during our face-to-face field test convocation. Finally, we are planning a short, two-question survey to determine the extent to which involvement in *NanoTeach* has contributed to STEM education efforts following participation in the program.

Field Test:
During the revision process between the pilot and field test, the project team used the feedback from the pilot and designed experiences that truly integrated the pedagogical strategies into content activities and lessons for each of the big ideas. While there were still sessions specific to improving teacher pedagogy, each session (activity, investigation, and content presentation) explicitly modeled at least one DESI strategy within the context of a new NS&T learning goal. Lessons also included formative assessment strategies and time for sensemaking. Furthermore, the entire two weeks was structured to scaffold the learning goals for each of the big ideas, which were sequenced to develop a coherent storyline.

As the project strived to improve over the course of the field test, we continued to incorporate changes based on participant feedback and realized success in our third site when the teachers indicated the workshop included the "ideal mix" of both nanoscience and pedagogy. Pedagogical content knowledge, together with the importance of creating a classroom environment conducive to teaching and learning are critical for high school classrooms and professional development experiences alike.

The summer professional development was conducted for three sites during June and July 2012. The professional development overview including links to all *NanoTeach* experiences for the field test are located on the Google site.

Participant manual
This manual was the main resource and for the professional development and was organized by 10 modules (one per day of the two week summer seminar). Each module provided an overview, agenda, and detailed guidance about the session. Sessions consisted of 1–3 lessons that were estimated to take between 1½– 4 hours to complete.

To adapt a lesson for the classroom, field test teachers were asked to follow the instructions in the lesson template; which served as a model of the end product, and enabled the participants to see how the development team adapted the lessons to meet the needs of the field test teachers. Additionally, these model lessons linked strategies from *Designing Effective Science Instruction* to the nanoscale science content.

When DESI was addressed explicitly, we included narrative text so participants could review it as they reflect on their practice. We also provided copies of all handouts needed during the professional development. Black-line masters of these handouts (templates) were available on the Google site.

Table 1: NanoTeach field test: Expectations for participation

<table>
<tr><th>Dates</th><th>Professional Development</th><th>Data Collected</th><th>Out-of-School-Time Commitment</th></tr>
<tr><td rowspan="4">Summer 2012</td><td colspan="3">Facilitated:</td></tr>
<tr><td>• Pre-reading and pre-assessment
• 2-week face-to-face professional development seminar</td><td>• Participant session evaluation
• Content pre-assessment</td><td>10 days/80 hours</td></tr>
<tr><td colspan="3">Team-study:</td></tr>
<tr><td>• Pre-reading and self-assessment
• 1-day face-to-face orientation to team-study resources and materials
• Self-paced study in peer groups and individually</td><td>• Participant session evaluation
• Content pre-assessment</td><td>80 hours</td></tr>
<tr><td rowspan="3">Fall 2012</td><td colspan="3">Fall Implementation: Facilitated and Team-study</td></tr>
<tr><td>• Peer review team sessions (scheduled by teams) for planning
• Implement size and scale initial lesson</td><td>• Size and scale lesson plan
• Fall implementation:
o Unit plan
o Lesson plan
• Reflection log</td><td>~ 6 hours</td></tr>
<tr><td>• Implement fall lesson (2–3 days) with students
• Teachers videotape Fall lesson for peer review process</td><td>• Teacher survey
• Student surveys
• Videotape of Fall lesson</td><td>~ 4 hours</td></tr>
<tr><td rowspan="4">Winter 2013</td><td colspan="3">Facilitated:</td></tr>
<tr><td>• Synchronous video coding via “Versatile Classroom” session (in groups of about eight teachers)</td><td>• Participant session evaluation</td><td>~ 4 hours</td></tr>
<tr><td colspan="3">Team-study:</td></tr>
<tr><td>• Webinar Q/A</td><td>• Participant session evaluation</td><td>~ 4 hours</td></tr>
</table>

Dates	Professional Development	Data Collected	Out-of-School-Time Commitment
Spring 2013	**Spring Implementation: Facilitated and Team-study**		
	• Peer review team sessions • For semester-long courses, implement introductory size and scale lesson • Implement spring lesson (2–3 days) with students • Teachers videotape lesson for final face-to-face session and project evaluation	• Spring implementation: o Unit plan o Lesson plan • Reflection logs • Teacher survey • Student survey • Videotape of lesson	~ 6 hours ~ 4 hours
Summer 2013	**Facilitated:**		
	• 2-day face-to-face debriefing session	• Complete post-assessment (prior to session) • Poster session materials • Participant session evaluation	2 days/16 hours
	Team-study:		
	• 1-day face-to-face debriefing session	• Complete post-assessment (prior to session) • Poster session materials • Participant session evaluation	1 day/8 hours
Stipend	**Facilitated:**		
	• $900 at the completion of Summer 2012 2-week face-to-face professional development seminar	• $900 on completion of all field test expectations, deliverables, and final debriefing sessions	**$1,800 stipend per teacher for 15 days (includes local travel)**
	Team-study:		
	• $900 at the submission of completed team-study modules log	• $900 on completion of all field test expectations, deliverables, and final debriefing sessions	**$1,800 stipend per teacher for 15 days (includes local travel)**

Table 2: Deliverables checklist

Participant Submission Items	Turn in to	Date Submitted
Spring 2012 Baseline on Sample of Participants		
+ Video of entire lesson	District Coordinator*	
+ Teacher survey w/consent form	District Coordinator	
+ Student surveys w/consent forms	District Coordinator	
Prior to Summer 2012 Workshop		
1. Content pre-assessment	Online	
2. Pre-reading activities	District Coordinator	
Portfolio: Fall 2012 Semester		
1. Size and scale lesson plan	Google Site	
2. Fall unit plan	Google Site	
3. Fall lesson plan (including student handouts)	Google Site	
4. Video of Fall lesson	District Coordinator	
5. Participation in peer review team discussions • 1 peer review team meeting per month • Meeting notes posted by peer review team scribe	Google Site	
6. Reflection Log entries related to • Size and scale lesson plan • Unit and lesson plan development • Video/Implementation • Peer review team discussions	District Coordinator	
Data Collection: Fall 2012 Semester		
✓ Fall teacher survey w/consent form	District Coordinator	
✓ Fall student surveys w/consent forms	District Coordinator	

Portfolio: Spring 2013 Semester		
1. Spring unit plan	Google Site	
2. Spring lesson plan (including student handouts)	Google Site	
3. Video of Spring lesson	District Coordinator	
4. Participation in peer review team discussions • 1 peer review team meeting per month. • Meeting notes posted by peer review team scribe	Google Site	
5. Reflection log entries related to • Unit and lesson plan development • Video / Implementation • Peer review team discussions	District Coordinator	
Data Collection: Spring 2013 Semester		
1. Spring teacher survey w/consent form	District Coordinator	
2. Spring student surveys w/consent forms	District Coordinator	
Summer Follow-up		
1. Content post-assessment	Online	
2. Portfolio: Poster session	McREL	

E. Major Activity: Building Teacher Content Capacity

Summative Assessment of Teacher Content Knowledge
The assessment of teacher knowledge focused on the Big Ideas of nanoscience and technology (NS&T) content being presented in the *NanoTeach* project: Size and Scale, Size Dependent Properties, Forces and Interactions, Tools and Instrumentation, and Nanoscience and Society. The assessment includes a total of 29 multiple choice (MC) questions of which 17 require recall of more factual knowledge (Level 2 questions) and 12 require higher-order thinking related to the NS&T content addressed in the *NanoTeach* project (Level 3). The assessment also includes 5 constructed response (CR) questions (Level 4). Findings from the pre/post knowledge assessment are found in Appendix B.

F. Major Activity: Virtual Classroom: Learning through Video Analysis (VC-LVA)

Overview:
The purpose of the VC-LVA (formerly Versatile Classroom) is for participants to view and code/share strategies shown on the video in real time for discussion. The facilitator controls video content, stop, start, and pause. The participants will need to view the video and complete coding (record evidence) prior to the synchronous session. During the sessions, participants watch video and discuss strategies related to building a content storyline.

Update

The VC-LVA process and findings were presented at the 11th International Conference on Education and Information Systems, Technologies, and Applications by Cyndi Long in July, 2013. A paper was accepted and appears in the conference proceedings: Long, C., & Ristvey, J. (2013, July). *Using virtual classrooms: Learning through video analysis to engage educators in meaningful facilitated, online distance learning.* Paper presented at The 11th International Conference on Education and Information Systems, Technologies and Applications, Orlando, FL.

Significant Results

Findings for the final report of the *NanoTeach* project are three-fold:

A. NanoTeach Field Test Report (RQ #1)
B. NanoTeach Case Study Report (RQ #1)
C. NanoTeach Field Test Viability Report (RQ #2)

Reported here are summaries and excerpts from the report prepared by lead researcher Dr. Elisabeth Palmer of Aspen Associates. Full texts of the reports (A and B) are found in the Appendices and instruments used are available upon request of the PI.

A. NanoTeach Field Test Report

OVERVIEW

NanoTeach is a DRK-12 National Science Foundation (NSF) project[1] that developed and tested a model of professional development utilizing an instructional framework designed to support science teachers in integrating nanoscience and technology (NS&T) into their high school curricula. NanoTeach was a collaboration between Mid-continent Research for Education and Learning (McREL), the Stanford Nanofabrication Facility (SNF), the Georgia Institute of Technology, the National Nanotechnology Infrastructure Network (NNIN), and ASPEN Associates, an applied research and evaluation organization.

The year-long, professional development experience supported the integration of NS&T into existing science curriculum through ongoing reflective experiences using two different approaches:

1. FULLY FACILITATE MODEL: This model combined face-to-face and online training, peer groups, a participant manual and resources including Virtual Classroom: Learning Through Video Analysis synchronous online sessions following the first semester of implementation and prior to the second semester of implementation and ongoing support for participants.

2. TEAM STUDY MODEL: This model included a self-paced, team-study approach that guided teachers in peer groups through the *NanoTeach* process with a step-by-step manual and related resources.

[1] This work is supported by the National Science Foundation, Division of Elementary, Secondary and Informal Education award # DRL-0822128.

Both approaches were designed to promote inquiry-based teaching and learning and both involved implementation of lessons into high school curriculum during the fall and spring semesters of the field test. This report summarizes the findings from the *NanoTeach* field test.

THE *NANOTEACH MODELS*

The *NanoTeach* professional development models were specifically designed to enhance teachers' ability to integrate NS&T into high school science through the use of effective, inquiry-based instructional strategies. Using the *Designing Effective Science Instruction* (DESI) framework (Tweed, 2009), participating teachers learned how to integrate and implement NS&T concepts as represented by *The Big Ideas of Nanoscience and Technology* (Stevens, Sutherland, Krajcik, 2009) by creating and teaching two different lessons – one in the fall and one in the spring. Each lesson needed to address physical science topics within the specific discipline in which the lesson was being taught (e.g., chemistry, biology, physics or high school physical science). Each lesson was to be taught over a minimum of 2-3 days for a typical 45-minute class or a similar amount of time. Prior to teaching the lesson teachers were to teach a foundational lesson on the principles of Size and Scale related to NS&T to prepare students to understand the relative sizes of objects in the relevant subject area.

KEY FINDINGS

PARTICIPANTS

TEACHERS

Of the 45 public high school science teachers who completed the *NanoTeach* field test, 24 participated in the fully facilitated approach and 21 participated in the team study approach. Teachers in the fully facilitated and team study approaches were equivalent in their years of teaching experience with both new and veteran teachers in each group (see Table 3).

STUDENTS

A total of 1,637 students participated in the *NanoTeach* field test, 842 whose teachers participated in the fully facilitated approach and 789 whose teachers participated in the team study approach.

Students whose teachers participated in the *NanoTeach* facilitated approach were primarily enrolled in grades ten and eleven while students in the team study classrooms were primarily enrolled in grades nine and ten.

The participating students represented the National Science Foundation (NSF) target group of traditionally underserved populations of girls and students of color. Boys and girls were equally represented in both the facilitated and team study classrooms and students of color comprised about half of the sample with the team study classrooms being more diverse overall.

INQUIRY-BASED TEACHING AND LEARNING

To achieve the goal of supporting teachers in integrating NS&T through effective science instruction the *NanoTeach* project set out to develop models of professional development that promote inquiry-based teaching and learning (see pages 9-19 and Appendix A).

OUTCOME 1:	Teachers will be able to integrate NS&T content into their classes in an inquiry-based manner.

FINDING 1A: Teachers in the facilitated and team study approaches were equally prepared to teach the NS&T topics they had selected for their *NanoTeach* lesson and felt *most prepared to teach* Structure of Matter; Size and Scale; Size Dependent Properties; Models and Simulations; and Science, Technology and Society. Not surprisingly, teachers felt *least prepared* to teach Quantum Effects as it was not one of the 'big ideas' emphasized by the project and only briefly introduced.

FINDING 1B: Teachers in the facilitated and team study approaches were similar in that they were *most likely to report that they emphasized* learning basic science concepts, learning science investigation skills, and preparing students for further study in science as their key learning objectives.

FINDING 1C: Students and teachers in both the fully facilitated and team study groups reported engaging in a variety of inquiry-based practices during the implementation of the *NanoTeach* lesson. The most common inquiry-based practices suggested a greater emphasis on developing *student understanding* and promoting *student engagement* with less emphasis on formal scientific investigation.

STUDENT INTEREST / ENGAGEMENT

The *NanoTeach* project also set out to support teachers in developing lessons that promote student interest and engagement in science (see pages 20-22 and Appendix A).

OUTCOME 2:	Students in classrooms where teachers implement inquiry-based NS&T lessons will report high levels of interest and engagement.

FINDING 2: Teachers and students in both the facilitated and team study approaches reported high levels of engagement and interest in learning science and nanoscience.

TEACHER LEARNING

Another goal of the *NanoTeach* project was to develop teachers' NS&T content knowledge to support their integration of the content into their lessons.

OUTCOME 3:	Teachers knowledge of NS&T will increase over the course of the project.

FINDING 3: Teachers in both the facilitated and team study approaches demonstrated statistically significant *moderate to large gains* in their knowledge of NS&T from pretest to posttest.

SUMMARY

The results of this evaluation indicate that the *NanoTeach* project was successful in achieving both of its goals:

1. INQUIRY-BASED INTEGRATION OF NS&T: The *NanoTeach* professional development approaches support teachers' ability to integrate NS&T content into their classes in an inquiry-based manner.
2. VIABLE APPROACHES TO PROFESSIONAL DEVELOPMENT: The *NanoTeach* project did result in a viable approach to designing and implementing two different models of professional development experiences that support integration of NS&T in high school science. These findings will be summarized in a separate report.

The full report can be found in Appendix B of this final report.

B. NanoTeach Case Study Report

Overview

To more fully understand the impact of participation in *NanoTeach* on teachers' knowledge of nanoscale science and technology (NS&T) and their ability to implement classroom practices that support inquiry-based learning using the *Designing Effective Science Instruction* (DESI) framework (Tweed, 2009) case studies were conducted with four of the participating teachers.[2]

These case studies provide an opportunity to examine the ways in which the *NanoTeach* professional development model supports high school science teachers in learning a new and challenging content area, reflecting on their curriculum and where they might be able to integrate related skills and concepts, and, finally, selecting and applying appropriate instructional strategies to teach that content.

The Emerging Field of Nanoscience and Technology

[2] See also the full evaluation report *The NanoTeach project evaluation report: 2012-2013 field test* (Palmer, November 2013).

Learning any new content can be challenging for students and teachers. When that content is also from an emerging field and one that crosses disciplines the challenge is even greater. Within NS&T, teachers are confronted with the unique properties of matter at the nanoscale. For some teachers, especially those who have been teaching for many years, the underlying principles and concepts of NS&T can leave them feeling as though much of what they understood about science up until now is wrong. New ideas and new understandings from an emerging field require significant opportunities to learn key content.

As such, the *NanoTeach* project focused on several of *The Big Ideas of Nanoscale Science and Engineering* (Stevens, Sutherland, & Krajcik, 2009)—core principals or concepts that "contribute to broader conceptual understanding by connecting the field to prior foundational ideas and establishing new foundations. They are critical because deeper understanding depends on these basic ideas as the building blocks for future science understanding" (Stevens, Sutherland, Schank, & Krajcik, 2007). Of the ten Big Ideas of NS&T, *NanoTeach* focused on six: Size and Scale, Size Dependent Properties, Forces and Interactions, Tools and Instrumentation, Self-assembly, and Nanoscience and Society.

DESI Instructional Framework

NanoTeach also modeled use of the DESI C-U-E instructional framework, which was designed to support teachers in selecting appropriate content (C), developing student understanding (U), and creating a learning environment (E) to facilitate inquiry-based learning.

In the DESI framework, the "C" represents the step of "Identifying Important Content." This is accomplished by "clarifying student learning goals, sequencing learning activities to achieve those goals, and aligning assessments with content. This necessitates thinking about ways to prune the curriculum and determine student prior knowledge and preconceptions" (Tweed, 2009, p. xvii).

The "U" represents the step of "Developing Student Understanding." This is accomplished by drawing upon research of how students learn to ensure that teachers "learn how to make lessons learner-centered, help student make meaning and build connections among science concepts, and develop each student's ability to learn." Specific "sense-making" strategies include addressing misconceptions, making student thinking visible through classroom discourse and encouraging formative assessment to identify student learning and provide feedback (Tweed, 2009, p. xvii).

Finally, the "E" in the DESI framework represents the step of "Creating a Learning Environment." This is accomplished through strategies that teach students to take responsibility for their thinking and learning and develop positive working relationships with others. In this area, "student engagement and motivation are critical components of collaborative classroom environments" (Tweed, 2009, p. xvii).

Methods

Sample

At the start of the *NanoTeach* project six teachers were selected for the case studies. Of these, four submitted a complete set of data on their lesson plans, classroom practices, and knowledge of NS&T prior to and after participating in the *NanoTeach* project. All four teachers were from the same southern state and taught at high schools in one of two neighboring school districts. Two of the teachers self-selected to participate in the fully Facilitated *NanoTeach* model; the other two selected the Team Study approach.

Measures and Analyses

Data for the case studies included qualitative and quantitative data regarding the change in teacher knowledge of NS&T and ability to teach this content in an inquiry-based manner using DESI strategies. Data sources and analyses for each were as follows:

Teacher Application to Participate in the *NanoTeach* Project. To participate in the *NanoTeach* project, teachers had to complete an application that included information about their years of teaching and open-ended questions regarding their self-assessed understanding of NS&T coming into the project and prior experience teaching in an inquiry-based manner, developing curriculum, and integrating NS&T into high school science courses. These data were used descriptively to provide a context for the case study teachers.

Assessment of Teacher Knowledge of NS&T.[3] Just prior to participating in *NanoTeach*, teachers completed a pre-test to assess their knowledge of NS&T coming into the project. At the end of the year-long project they completed a post-test using the same instrument. The assessment of teacher knowledge focused on the six Big Ideas of nanoscience and technology (NS&T) content being presented in the *NanoTeach* field test and included a total of 39 questions representing different cognitive levels, including 34 multiple choice (MC) questions and 5 constructed response. Of the 34 multiple choice, 20 required recall of more factual knowledge (Level 2 questions) and 14 required higher-order thinking related to the NS&T content addressed in the *NanoTeach* project (Level 3). All 5 constructed response (CR) questions required application of knowledge (Level 4). This assessment was developed and tested in the *NanoTeach* pilot project (2010-2011) and revised prior to use with the field test (2012-2013).

The final analysis of change from pre to post was conducted by weighting each of the 39 assessment items by the cognitive level. The 20 items requiring more factual knowledge (Level 2 questions) were weighted to comprise 51% of the total score; the 14 items requiring higher-order thinking related to the NS&T content addressed in the *NanoTeach* project (Level 3) were weighted to comprise 36% of the total score; and the 5 constructed response (CR) questions which required application and extension of knowledge (Level 4) were weighted to comprise 13% of the score. This weighting resulted in a total possible score of 100 points. In addition to growth over time, the percent of maximum score achieved was also examined to assess the level of content mastery.

[3] See "Appendix B: Assessment of Teacher NS&T Knowledge" in *The NanoTeach project evaluation report: 2012-2013 field test* (Palmer, November 2013) for further information about the C-U-E scale construction.

Student Survey of Classroom Practices.[4] A student survey was administered in spring 2012 (baseline) and at the end of the *NanoTeach* lesson implementation in fall 2012 (first lesson) and spring 2013 (second lesson) to elicit student perceptions of their teacher's classroom practices. Individual items for the *NanoTeach* student survey were obtained from existing evaluation instruments developed by CETP projects and from other sources including the surveys used by Horizon Research Inc. in their national curriculum and instruction surveys funded by the NSF (Weiss, Pasley, Smith, Banilower, & Heck, 2003).These data were analyzed within the DESI C-U-E framework of Content, Understanding, and Environment to examine the change in each scale from baseline to the end of the project in teacher's ability to utilize inquiry-based instructional practices. Changes in the level of Student Engagement were also analyzed. The percent of the maximum score achieved on all four scales was also examined to assess the level of pedagogical mastery.

Lesson Quality Assessment Tool (LQAT). Following the pilot test (2010-2011), the *NanoTeach* team developed and pilot tested the LQAT as a tool to examine classroom artifacts in order to assess the extent to which the planned and enacted instructional practices were likely to result in deep student understanding. "Planned instructional practices" refer to what the teacher plans to do (lesson plan, unit plan). "Enacted (implemented) instructional practices" refer to what the teacher actually does in the classroom (video, reflection log, student handouts). "Deep student understanding" was defined as having a focus on understanding NS&T concepts within the discipline through higher order thinking (HOT), rather than just rote memorization of factual information.

The focus of the LQAT analysis was on instruction and not student performance. As such, the LQAT had three parts that aligned with the DESI framework of Content, Understanding and Environment. Each part had multiple sub-sections. For example, Part 1: Content has two subsections, Section 1: Learning Objectives and Section 2: Presence of Nano Science Big Ideas. Within each section individual DESI strategies were assessed.

Each set of artifacts was reviewed and rated by two raters, external consultants trained in DESI and science teaching, who then discussed their ratings to arrive at consensus for a final rating.[5] The quality ratings were outlined as follows for DESI content:

- High degree: Very likely to result in deep student understanding (e.g., primary emphasis on NS&T concepts/HOT and little emphasis on factual/memorization).
- Moderate degree: Somewhat likely to result in deep student understanding (e.g., some emphasis on NS&T concepts/HOT and some emphasis on factual/memorization).
- Low degree: Not likely to result in deep student understanding (e.g., little or no emphasis on NS&T concepts/HOT and primary emphasis on factual/memorization)

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[4] See "Appendix A: *NanoTeach* Field Test Summary of DESI Instructional Practices (C-U-E) and Student Engagement" in *The NanoTeach project evaluation report: 2012-2013 field test* (Palmer, November 2013) for further information about the C-U-E scale construction.

[5] See Appendix C1: Lesson Quality Assessment Tool (LQAT): Training Guide.

A similar rubric of high, moderate, and low was used for the DESI Understanding and Environment. While the case study included lesson plans and videos of lesson implementation from spring 2012 (baseline, prior to any interaction with *NanoTeach* project PD) and the fall 2012 and spring 2013 implementation of the *NanoTeach* lessons, often the baseline artifacts did not lend themselves to ratings using the LQAT. In these instances a rating of “NE” for “no evidence” was given. The resulting LQAT ratings were examined for trends in the quality of the lessons planned and implemented from baseline to the end of the project.

The case studies can be found in Appendix C of this final report.

C. NanoTeach Field Test Viability Report

Introduction

The *NanoTeach* field test includes two approaches to professional development, both of which are designed to improve teachers’ ability to incorporate nanoscience and technology (NS&T) content into existing curricula and implement research-based classroom practices that support student’s conceptual understanding. The field test began summer 2012 and concluded summer 2013.

This report summarizes data gathered over the course of the *NanoTeach* field test regarding the viability of the approach used to develop and implement both the facilitated and team study models of professional development. Data sources included informal observations of the summer professional development sessions, and participant satisfaction surveys and focus groups conducted by the external evaluator. Formal debriefings with the *NanoTeach* team members responsible for development and implementation were also conducted and notes from monthly development team meetings reviewed.

The *NanoTeach* Model

The *NanoTeach* year-long, professional development experience was designed to support the integration of nanoscience and technology into existing curriculum through ongoing reflective experiences using two different approaches:

- a fully-facilitated model that combined face-to-face and online training, peer groups, a participant manual and resources including Virtual Classroom: Learning Through Video Analysis synchronous online sessions following the first semester of implementation and prior to the second semester of implementation and ongoing support for participants.
- a self-paced, team-study approach that guided teachers in peer groups through the *NanoTeach* process with a step-by-step manual and related resources.

Using the *Designing Effective Science Instruction*[6] (DESI) framework, participants learned how to integrate and implement NS&T concepts as represented by *The Big Ideas of Nanoscience and Technology*[7] by creating two different lessons (each lesson a minimum of 2-3 days of 45-minute classes per day or a similar amount of block time). These lessons were to address the three

[6] Tweed, A. (2009). *Designing effective science instruction: What works in science classrooms*. Arlington, VA: NSTA Press.
[7] Stevens, S., Sutherland, L., & Krajcik, J. (2009). The big ideas of nanoscience. Arlington, VA: NSTA press.

elements of DESI – content, understanding, and environment – using nanoscience content related to topics in physical science.

The *NanoTeach* model delivers professional development through five (5) core elements.

The *NanoTeach* Field Test

1. Summer Professional Development:
    a. Facilitated: 2-Week Seminar (Summer 2012). Face-to-face Seminar (80 hours) in which participants explored NS&T using the DESI framework with the goal of integrating NS&T into existing curricula that include physical science concepts. Participants began working with Peer Review Teams to develop their first lesson in preparation for fall implementation.
    b. Team-Study: 8-Week Team-Study (Summer 2012). Team-study participants began with a 1-day orientation to the *NanoTeach* model, materials and resources. Then participants worked individually and within their Peer Review Teams to explore NS&T using the DESI framework at their own pace and on their own schedule with the goal of integrating NS&T into existing curricula that include physical science concepts (80 hours). Participants worked with their Peer Review Teams to develop their first lesson in preparation for fall implementation. Peer review teams were provided the opportunity to connect with developers through regularly scheduled office hours and email communication.
2. Lesson Implementation I (Fall 2012).[8] All participants taught an introductory lesson on size and scale prior to implementing their revised lesson with support from their Peer Review Team[9]. Teachers were required to have at least one portion of the lesson videotaped for use in the project evaluation. Participants completed a unit plan, lesson plan and self-reflection logs.
3. Mid-Year Support:
    a. Facilitated: Video Coding (Winter 2013). In January, teachers in the facilitated group participated in a synchronous online group video session (Virtual Classroom: Learning through Video Analysis)[10]. This session served as a means of peer- and self-reflection and another opportunity to participate in revision of an NS&T sample lesson.

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[8] Due to scheduling conflicts, a few teachers implemented both of their lessons in the spring rather than the fall.
[9] Peer Review Teams (PRT): During the initial summer workshop, teachers are placed into peer review teams that include three to five teachers and a facilitator from *NanoTeach* project. The PRTs are charged with providing collegial feedback to one another throughout the lesson development and implementation.
[10] Virtual Classroom: Learning through Video Analysis: This session provided teachers the opportunity to practice analyzing video of nanoscience and technology lessons with an eye toward identifying elements of a content storyline through evidence. Long, C., & Ristvey, J. (2013, July). *Using virtual classrooms: Learning through video analysis to engage educators in meaningful facilitated, online distance learning.* Paper presented at The 11th International Conference on Education and Information Systems, Technologies and Applications, Orlando, FL.

b. Team-Study: Webinar (Winter 2013). In January and February, teachers in the team-study group participated in a question-and-answer webinar to prepare them for implementation of their spring lesson.

4. Lesson Implementation II (Spring 2013). All teachers again taught an introductory lesson on size and scale[11] prior to implementing their second revised lesson with support from their Peer Review Team. Participants were again required to videotape the lesson for use in the project evaluation and at the final seminar. Participants completed a unit plan, lesson plan and self-reflection logs.
5. Summer Debriefing (2013). All participants attended a face-to-face seminar to debrief on the year-long, *NanoTeach* professional development process. Using a share-a-thon format, teachers presented their lessons to the other teams within their approach (facilitated or team-study) and discussed lessons learned (2-day facilitated seminar; 1-day team-study).

Lessons Learned: Teacher Recruitment

The *NanoTeach* project began formal nationwide recruitment of teachers for the 2012-2013 field test in fall 2011 with the intent of recruiting enough teachers by February 2012 to ensure that at least 50 would complete all aspects of the year-long professional development. To participate in the *NanoTeach* project, teachers had to complete an online application that included a detailed summary of the project including expectations for participation. The application also asked for background on teacher preparation coming into the project, such as years of teaching and open-ended questions regarding teachers' self-assessed understanding of NS&T coming into the project and prior experience teaching in an inquiry-based manner, developing curriculum, and integrating NS&T into high school science courses. Teachers who completed all components of the project would receive a stipend of $1,800 (15 days at $120/day) for the out-of-classroom time required for participation.

Two-Stage Recruitment

The *NanoTeach* project began recruitment with a two-stage strategy of first approaching school districts to obtain buy-in regarding the value of the project to the district and to garner support from district leaders in reaching out to individual teachers. Districts were asked to sign a Memorandum of Agreement stating the expectations of district and school leaders, participating teachers, and the *NanoTeach* partners. Lessons learned included the importance of conducting formal presentations to districts—both in person and via webinars—to better understand the local context and implications for rolling out the project, discuss how *NanoTeach* specifically aligned with district priorities, and address any related concerns or special circumstances.

In the course of recruitment, two particular challenges were also encountered. One challenge related to change in district personnel, which typically meant that one or more people who were "championing" the project were no longer available to advocate for the project and encourage participation. This suggests a need to have multiple "champions" at all leadership levels in order

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[11] Teachers who are implementing their spring lesson in a year-long course, i.e., with the same students, are not required to re-teach the size and scale lesson, but could choose to review some of the key concepts prior to their second lesson.

to support the project in moving forward. A second related challenge was teachers' responses to this top-down (district-level) approach to recruitment. In some instances, teachers' felt that participation in the project was more of a mandate than an opportunity. A way to address this in the future would be to ensure that when the project team requests meetings with a district that it is a requirement that the meeting(s) include all constituent groups at one point or another to share the same information, hear all concerns, and ensure that all parties have agreed to participate. While this has not been common practice in the past, it is more and more how education is moving in terms of supporting change not only at the classroom level, but at the institution level as well.[12]

***NanoTeach* Group Assignment**

Two lessons learned regarding successful recruitment of teachers came early in the process. It quickly became clear that the initial plan to r*andomly assign teachers to either the facilitated or team study model was a barrier* as most teachers wanted to select their group and could not participate in the study if they would have been assigned to a particular group because of summer commitments. Another barrier was *confusion about the team study approach*, which was initially called "self-study"; teachers interpreted this as a self-paced approach that they could do on their own rather than within the required peer review team. Consequently, the self-paced approach was renamed as "team study" and the expectations more clearly stated while the requirement of random assignment was dropped to allow teachers to self-select whether they wanted to participate in the facilitated or team study approach. If allowing self-selection into the *NanoTeach* groups is allowed in the future, it is worth *providing some guidelines about who is likely be successful in each model.*

Flexibility in Assignment by Location

Another lesson learned was the importance of starting early in reaching out to teachers through professional networks and district leadership. The *NanoTeach* project intentionally worked through existing relationships and professional associations in promoting the project in an effort to recruit teachers for sites in three geographic locations. The rationale for having three distinct locations, preferably a school district, was to reduce the variability in results that could arise from differences in state and local education policies and practices. Another consideration for the project was to have one local site (i.e., within Colorado), to save on travel costs, and one in each of two states to which the project team could travel. In the end, one site ended up being an "all-states" team that included teachers from a variety of states, including teachers from a variety of locations within the state and other teachers who lived one of the other states, but who had a conflict with the dates of the summer session.

Implications

Although 74 teachers began the field test (41 facilitated and 33 team-study) as noted by their attendance in the initial summer 2012 professional development activities, only 45 completed all of the requirements regarding participation and data collection (24 facilitated and 21 team-study). The remainder of this report discusses some of the reasons why some teachers may have chosen to continue while others did not.

Lessons Learned: Facilitated Model

[12] See NSF Improving Undergraduate STEM Education (IUSE) at www.nsf.gov.

During summer 2012, three different 2-week workshops were held in Texas, Colorado, and Louisiana. As might be imagined, each of the participant groups differed in their preparedness with regard to effective science pedagogy and knowledge of nanoscience content. While each group included individuals with a range of experiences within the group, the groups themselves also exhibited notable differences, often related to their local context.
To assist the *NanoTeach* team in reflecting on their practice, an external evaluator gathered feedback and reported the findings to the team after each workshop.[13] The *NanoTeach* team met with the external evaluator after each two week workshop to review preliminary findings and discuss how to incorporate the feedback into subsequent workshops and how to finalize professional development resources. As such, the evaluation indicated that the final workshop in Louisiana was the most representative of the intended *NanoTeach* model as indicated by participant feedback.

Participant Perceptions of Quality and Utility
Overall, participants had a very positive view of the *NanoTeach* facilitated workshop.[14] They had positive views of the hands-on activities, inquiry-oriented activities, NS&T learning experiences, and pedagogical instruction on DESI. They were particularly impressed with the lessons that integrated NS&T with DESI.

When the workshop was presented to the first two groups, participants felt the focus was more heavily weighted towards the DESI pedagogy and wanted more NS&T content. The second group also wanted greater depth of NS&T content as might be gleaned from scientists in the field. By the time the workshop was presented to third group, these concerns about the balance of NS&T with pedagogy and the depth of presentation seemed to be resolved. The perceptions of each group reflected local mandates and preparedness of teachers in each group with regard to pedagogy and knowledge of science and NS&T, the mix of *NanoTeach* facilitators working with each group, and the change over time in the delivery of *NanoTeach* as the team reviewed feedback and reflected on the balance of pedagogy to NS&T content.

Modeling Integration
A key set of lessons learned revolved around how to effectively model the integration of nanoscience and pedagogy for participants. From the beginning, the *NanoTeach* approach clearly emphasized hands-on activities, sense-making and other effective instructional strategies for secondary science. What was learned upon reflection along the way was the importance of keeping the *emphasis at the level of the lesson* each day and across the 2-weeks to better meet the *needs of adult learners* who would be taking what they learned back to their classrooms. It also became clear that an essential strategy for modeling integration was to *explicitly address learning goals by continually referring back to the goals* both within a session and in subsequent sessions of the professional development.

Another key learning regarding modeling integration was to *allow adequate time for sense-making based on the needs of the group.* It was clear there is no formula for how much time to allow for reflecting and talking about what was being learned. Rather, it was essential that the presenters *be aware of the needs of each group as "learners of new content" who are preparing*

[13] Huffman, D. (2012). *NanoTeach* Summer Workshop Evaluation Report. External evaluation report.
[14] Ibid.

to apply this new knowledge in their own environment. Because *NanoTeach* involves learning new content *and* pedagogy, it became important to allow enough time for sense-making with regard to both the new nanoscience concepts and their application in the classroom through appropriate instructional strategies. It was also important to be *explicit about the transition from learning content to learning pedagogy.* Another strategy that was modeled in support of sense-making was being intentional about *consolidating participant learning at the end of the day* through a formal wrap-up with participants.

Being Flexible in Assessing and Attending to Needs

To understand the specific needs of each group the *NanoTeach* team relied on the applications teachers submitted when applying to participate the project. These applications included background on teachers' preparedness coming in with regard to NS&T and inquiry-based pedagogy. The team very quickly learned, however, that it also needed to *be intentional about assessing participants' needs during the session as needs differed by individual, by school and by district*. As an example, upon working with the participants it became clear that some were working within specific district mandated constraints for lesson planning, such as teaching a common lesson within professional learning communities. This had immediate ramifications for teachers working with others not participating in the study. This also reduced the number of lessons developed that would be integrated into curricula.

One strategy for identifying participants' needs also served to *maintain consistency of delivery across the 2-weeks.* The strategy involved *assigning* a *small, core team*[15] *of presenters who were in attendance at all times*. In this manner, other members of the team could be present to observe participants and how the sessions were progressing to more effectively build upon one another. Each day a team member was assigned "watch" for DESI and another to "watch" for NS&T content and keep notes regarding any issues and concerns to be raised during a discussion at the end of the day. A consistent presence of presenters during the workshop also *allowed participants to develop trusting, collaborative relationships with the presenters*.
In reviewing the events of the day and the needs that emerged, the team also learned a key lesson: *be flexible.* Being flexible came to include *having a menu of approaches and activities to keep diverse groups of participants engaged*, rather than a set agenda. For example, having a variety of wrap-up activities available to select based on the needs of the participants that day. Similarly, it became clear that it was necessary for presenters to be *prepared with a depth of knowledge* to answer some of the more common higher-level NS&T questions from participants at the time, rather than waiting for a response from the external content experts. In the end, the lesson for both the presenters and participating teachers was to stay mindful that this was about "*teaching students, not just teaching the curriculum."*

Attention to the Environment

In modeling the DESI strategy of environment with three different participant groups, the *NanoTeach* team saw evidence of the need to be intentional about the physical layout of the

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[15] An ideal "core team" might consist of three presenters: a DESI lead, a nanoscience/activity lead, and a logistical lead responsible for materials, set up, transportation, technology issues, Google site, etc. To capture additional lessons learned during the *NanoTeach* field test the core team included an archivist who took notes on implementation of the planned activities and issues that arose. This fourth person would not be necessary for scale-up.

summer workshop and the opportunities for presenters and participants interact in creating a supportive learning environment. At the second of the workshops the layout was such that the presenters were separated from the participants – presenters up front with participants in a horseshoe. This physical separation seemed to create a separation on an emotional level between the presenters and participants and among participants. It became clear that the *physical space needs to support collegial interactions during group work and between presenters and participants*. Within the space limitations, the *NanoTeach* team began to *build the essential trust and mutual respect by being intentional about assessing and attending to participant needs,* as noted above. This involved listening to the concerns of participants and meeting them where they were in terms of their specific needs.

Just as the *NanoTeach* team needed to remain flexible in their interactions and presentations, it was important to have a physical space that was also flexible. Like many hands-on science workshops it is helpful to have a facility that provides enough individual work space to accommodate the use of a laptop, books and other hardcopy materials while also providing space for hands on science experiments. Access to technology was also examined well ahead of selecting a location to ensure adequate access to the Internet, Google websites, and other websites that might normally be blocked in a school setting, including Skype. A lesson learned specifically from the *NanoTeach* workshop reinforced the importance of having a layout to the room that allows the facilitators to mingle with the participants.

Guiding and Facilitating

In reflecting on the nature of the facilitation or guidance needed for the face-to-face group, the *NanoTeach* team identified several lessons learned. A key lesson was to *balance participant-centered with facilitator-centered* approaches each day. This meant there was time for modeling how to integrate NS&T content with pedagogy to scaffold teacher learning when they worked on their own or with each other. Focusing on "facilitation," rather than teaching, led to *"just in time opportunities" (flexible programming)*. In this manner, participants had *opportunities to interact with the content (both NS&T and pedagogy), with the facilitators, and with each other*. Although some participants were initially resistant to activities that required they organize into different groups to "talk with someone hadn't talked to," in the end they came to appreciate both the learning and the personal interactions with more of their colleagues.

This format also allowed for *"just in time support" or guidance tailored to individual participants, which was particularly important during work time for unit and lesson planning*. A "red, yellow, or green" flag from each participant ensured that the right type of support was provided in a timely manner. Participants most often needed guidance on what was expected in the *NanoTeach* lesson plan, including examples. They also needed assistance thinking through the process of integration from clarifying the meaning of their state or district science standards as it related to the NS&T content to considering when it best fit into the curriculum sequence. The success of this balanced approach may be attributed, in part, to the wide-ranging expertise of the team. Creating this breadth and depth of expertise was intentional in the initial selection of *NanoTeach* team members and in the ongoing cultivation of expertise through professional learning opportunities, including the development of lessons that integrate NS&T and DESI pedagogy. Essential areas of expertise included: various disciplinary content in science, NS&T

content knowledge, development of integrated lessons, science standards, storyline development, and DESI pedagogy.

Resources to Support the Storyline

Many lessons were learned from the *NanoTeach* pilot test. When it became clear to the team early on that creating a coherent "storyline" with regard to content and pedagogy was, in fact, the overarching challenge in developing a viable professional development model they organized a large amount of their efforts around accomplishing just this. As a result, *NanoTeach* facilitators were intentional about actively modeling for teachers how to improve the storyline in their lessons throughout the two-week summer professional development session and added the "video coding" of lessons as a culminating activity on the tenth and final day. These lessons learned were then carried forward to the field test in terms of impressing on all participants the importance of creating a coherent storyline. For the field test facilitated group, the *NanoTeach* team continued the active modeling of this process and provided teachers an opportunity to participate video coding.

As a result of these efforts to present a coherent storyline, in the field test, the *NanoTeach* team felt that the resources that accompanied the professional development activities were more seamless integrated than they were in the pilot test. Key resources were: a participant manual in hardcopy and online; a Google website with a variety of resources, including sample lesson plans and related multimedia; and other hardcopy reference books related to science standards, effective science pedagogy, and NS&T. With all of these available resources, presenters were intentional about providing time and activities that allowed participants to *explore the NanoTeach manual and other resources* related to DESI, the Big Ideas, NS&T, education standards, etc.

The participant manual, though not necessarily aligned with the daily schedule, was organized in a manner that clearly supported its use as a *common orienting document* both during the workshop and when teachers returned to their classrooms. It also became clear that the manual played an important role in allowing presenters to readily *refer participants back to learning goals and related resources* throughout the workshop. Ultimately, a key lesson learned was the need to *build in redundancy by continually referring back to the learning goals, storyline, and manual* throughout the workshop.

Resources for Lesson Development

Based on the need for more examples of model lesson identified in the pilot test, the participant manual included model lessons using the DESI lesson planning format. This also provided robust information for the team study teachers to have a sense of all of the important components of the lesson as they worked through the experiences with their peers. Therefore, a key lesson regarding resources was the need to *provide sample lessons in the format required* by *NanoTeach*. Participants *needed a clear model of the expectations embedded in the NanoTeach lesson plan* to know what they were to develop. Being relatively new to NS&T, many teachers were also a bit hesitant to dive into the many NS&T lessons available in the online *NanoTeach* resource inventory until they had considered what content might fit in their curriculum. Finding places to integrate NS&T in the fall curriculum seemed to be particularly challenging for many teachers, especially in physics; spring seemed to offer more opportunities.

An emerging lesson was the importance of having the *NanoTeach team available to work individually with participants to flesh out their interests and ideas, consider content knowledge needed and curriculum fit.* In the end, many participants selected a lesson that was modeled from the summer and modified it to meet their needs – at least for the fall lesson – rather than creating one on their own. Thus it appears that the sequence of learning for participants, at least at this stage, involves *developing a size and scale lesson based on their experiences in the workshop and then adapting or adopting an existing lesson for their classroom*. By the end of the project, the team would like to see participants prepared to use all of the available resources in a dynamic way. Whereas the first summer session was "putting a toe in the water," by the end of the project the following summer it's "time to get your head wet!" *NanoTeach* facilitators also provided explicit access and experiences with previously developed and vetted lessons that were made available in the *Resource Inventory*. For the most part, these resources were not utilized unless they were part of what was modeled during the summer.

Remote Access / Webinars

An important component of the workshop was the various opportunities to connect with scientists working on a range of topics within the field of NS&T. These opportunities were made available to the facilitated group in the face-to-face sessions via in-person visits from scientists and video conferencing, all of which was videotaped and archived for access by the team study participants. The project utilized formal partnership with Stanford Nanofabrication Facility, and the NNIN network through coordinating efforts from partners at Georgia Tech. Although all of the presentations addressed topics related to the Big Ideas presented in the workshop, the most useful presentations were the ones participants could immediately apply to the work at hand; *presentations that were too abstract did not translate into application* as easily.
Similarly, the mode of delivery and presentation style/pedagogical style influenced the extent to which participants were able to engage with the material. In some instances, presenters were pre-recorded while others participated live via Skype or telephone. A lesson learned was to ensure that all *presentations include time for sense-making either during or after the session*. At one workshop, one of the scientists was able to come on-site the first week, which provided an *extended opportunity for participants to make a personal connection through informal interactions* prior to the remote access in the second week. This was particularly useful as this scientist was able to answer the more technical questions from participants on the spot and even to say "I don't know." *Hearing a scientist in the field acknowledge that we are all still learning about this emerging field* supported the notion that teachers also do not need to know everything about NS&T in order to venture into the field.[16]

In the end, a key lesson learned was the importance of ensuring that both the method of delivery, pedagogy, and content support teachers in connecting with the material in meaningful ways: *presentations by external sources that lend themselves to direct application of current knowledge and trends and include more personal contact with scientists and opportunities for sense-making are more likely to support learning.*

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[16] The *NanoTeach* team also made use of O-T2-O-T6 from the following NanoSense document to support this conversation: http://nanosense.org/activities/sizematters/overview/SM_OverviewTeacher.pdf.

Ongoing Access to Resources

As mentioned above, participants had access to many resources including hardcopy and electronic copies during the workshop. At times, having a printed copy of the participant manual and/or other reference materials was important; at other times, the amount of printed materials was too much given the somewhat limited desk space available to participants. The primary means of distributing resources, however, was the *NanoTeach* Google site. The participant manual and sample lessons were available on the website from the beginning with new resources being added on an ongoing basis, including multimedia and presentations by the *NanoTeach* team and scientists. *Using a Google site to store and share resources was clearly effective* for participants, particularly during work time on unit and lesson planning. Having a single site for participants to access resources was a lesson learned from the *NanoTeach* pilot test, which utilized both Google and Ning sites.

Lessons Learned: Team Study

In considering the viability of the team study approach it is important to recognize that this is the first time this model has been implemented; as such, it was considered a "pilot test."

Team Study Orientation

As mentioned earlier, during recruitment this non-facilitated, self-paced approach to *NanoTeach* was referred to as "self-study" in all of the recruitment materials and presentations. Many participants applied to the team study approach because they preferred a more flexible schedule for completing the 80 hours of professional development over the intensive, facilitated 2-week professional development session. The change to the idea of team study rather than self-study was made necessary because the development team wanted teachers to talk with each other and support one another in their learning. Another logistical reason was to ensure that lab materials were distributed, shared and used in a more authentic way.

Despite extensive descriptions of what was expected of participants in the "self-study" group, many participants were not clear that this approach required working with a peer group and was not solely "independent study" or work to be done all on their own. Consequently, many of the participants in this group were disgruntled at the initial team study orientation meeting, which was designed to provide the background and scheduling they needed to work with their peer groups on this "non-facilitated" professional development. Over time, other "team study" participants dropped out of the project.

The intent of the 1-day orientation was to assist teachers in setting up their Peer Review Teams, clarify expectations regarding deliverables, engage them in some initial activities to expose them to the DESI framework and NS&T, and review the available resources. In debriefing both participants and the *NanoTeach* team members who led the orientation sessions, some lessons learned emerged.

Participant Early Perceptions of Quality and Utility

When asked in fall 2012 for feedback on their early experiences by the external evaluator, the results from the team study participants was mixed.[17] Most reported mixed or negative experiences with the team study approach as currently designed. The primary concerns were the

[17] Huffman, D. (2012). *NanoTeach* Self-Study/Team-Study Evaluation Report. External evaluation report.

overwhelming amount of material in the large, written teacher manual, which they found confusing to follow without the accompanying facilitation. Like teachers in the facilitated group, team study participants also needed more guidance on what was expected in preparing their *NanoTeach* lesson plan. Although some teachers did, find the materials useful in learning NS&T and pedagogy, overall, there was such a degree of confusion that several teachers said they would not recommend the current team study approach for learning nanoscience and the related pedagogy.

Not surprisingly, team study teachers did *appreciate the freedom offered by a self-study approach* when they were not able to attend the two-week face-to-face workshop. And, they appreciated that an orientation was provided that included doing hands-on nanoscience activities and the opportunity to obtain more information about the project expectations.

Balance Time to Learn with Time to Clarify Project Expectations

Although the amount of time available to orient team study teachers to the project was only one day, it was still clear that *teachers needed time to both learn some NS&T content and dig into the DESI pedagogy*. The *NanoTeach* team felt that when teachers are able to explore, more deeply, the demonstration lessons, they may be more likely to implement lessons other than simply the ones presented during their orientation (team study) or summer professional development (facilitated). This involves *providing time for teachers to collaborate with one another to learn about and use lessons that are already developed*. Otherwise, as was also seen in the *NanoTeach* pilot test, teachers tend to implement in their classrooms only what they have seen demonstrated in the orientation (e.g., card sort, Dime Walk). It was also clear that a one-day team study orientation was *not enough time to provide participants with learning experiences and adequately explain the expectations for implementation*, including the required list of deliverables.

Just-in-Time Resources

Like participants in the facilitated group, the team study teachers appreciated having both a hard-copy teacher manual and electronic, just-in-time resources. Team study teachers were more likely to rely on the website than the teacher manual, which they felt was too large and onerous. Teachers also had difficulty identifying the most important information in the manual (e.g., forms, contact people) and suggested that more streamlined version and/or including bookmarks in the downloadable electronic version and highlighted links to key resources would be helpful. Team study teachers, like the facilitated group, also had access to sample lessons from the pilot test, including some with videos, on the Google site.

With regard to the science kits (i.e., lab materials) provided to team study teachers, some districts made them available at a central location while others let the teacher teams take the kits with them. This is a certainly a consideration for just-in-time access to the required physical materials. Regardless, the kits need to come already set up and not as supplies. Another suggestion from the *NanoTeach* team was to provide “flipped classroom” videos to support team study participants with their hands-on lab activities. These videos could include related background information (e.g., content) and short-cuts or tips like those provided to the facilitated group. In the future, if time and funding permits, it would be beneficial to include both a team study and facilitated option in the pilot test to work through the issues specific to each approach.

Relationships Matter
Another lesson learned with regard to the team study orientation was that the session should be led by the same person teachers would be connecting with as their *NanoTeach* site coordinator. That way, teachers would able to meet and get to know their coordinator in person to help build the relationship that is, eventually, conducted primarily at a distance. This may be one reason why team study teachers did not reach out to their site coordinators as resources much during the project. A lesson learned from the pilot test that may be of use is a more *blended model of support* in which the *NanoTeach* site coordinator participants in Peer Review Team meetings on a regular basis.

Leave with a Plan and Support the Plan in a Coordinated Manner
When reflecting on the team study approach at the end of the year, the *NanoTeach* team observed that teachers who attended the orientation were more likely to complete the project. One reason seemed to be that *teachers who attended orientation left with a plan*, whereas it was more difficult to communicate expectations and orient those that did not to the resources and other salient points. In the future, the *NanoTeach* team also thought it would be good to *provide team study participants with a set of concrete steps to follow* in their Peer Review Team, including suggestions for when to get together and what to do (e.g., locate kit, related PowerPoints, and go to online resources).

Another lesson learned was the need to inform team study participants that the "front-end" (i.e., modules 1-3) were the most dense and would require more time. On a related note, the *NanoTeach* team felt that in hindsight sending emails that were more specifically about "you should be implementing X at this time" to keep team study participants on track throughout the process would be more helpful than "can I assist you?" Regardless, it is important that participants know the one person to go to on the *NanoTeach* team.

Composition of Peer Review Teams
Some lessons learned with regard to Peer Review Teams was that they tended to work best if *at least 2-3 people were involved from the initial orientation* and that they were more successful if *teachers were in the same school building*. Being in the same building was useful in sharing similar content and context. As one team study teacher said" If it weren't for so and so, I wouldn't have made it to the end." With two of the eight team study Peer Review Teams "falling apart," it was clear that particularly in the team study approach it is *important for participants to have at least one "buddy."* Overall, it seemed "when there's a will, there's a way." Teachers who were *confident* were able to get through both the NS&T content and the DESI framework; *self-motivation* was also essential.

Lessons Learned: Facilitated Group Virtual Classroom
Midway through the year-long *NanoTeach* project, participants in the facilitated and team study groups had the opportunity to participate in a virtual session for a check-in and, additional professional development for the facilitated group, only. These virtual sessions for both groups were comprised of teachers from different site locations who had never met before; this was intended as a way to disseminate learning across sites. The facilitated group participated in a 1-hour Virtual Classroom: Learning through Video Analysis session while the team study group participated in a virtual question-and-answer session. Both sessions were intended to help

teachers reconnect with their colleagues and share their experiences in an effort to refocus their attention in preparation for developing and delivering their spring *NanoTeach* lessons.

Deeper Learning through Video Coding

The Virtual Classroom sessions for participants in the facilitated group were scheduled at different times to allow teachers to opt into a time that worked best with their schedule. The sessions were led by two members of the *NanoTeach* team, one of whom participated in all of the sessions for continuity. The focus of the session was an interactive process of video coding[18]in which teachers viewed a video of a *NanoTeach* lesson, recorded evidence of the science content storyline, and discussed their findings with the group. The process of video coding was introduced on day ten of the face-to-face sessions. This was important because this provided teachers with an experience of video coding with support while together and prior to using synchronous online video during the winter sessions. The five strategies for establishing a storyline were: focus on one main learning goal (one 'big science idea'), linking the learning goal to previous lessons, setting the purpose of the lesson by using a focus question or goal statement, referring back to the purpose throughout the lesson, and selecting activities and content matched to the learning goal.

The *NanoTeach* facilitators for the Virtual Classroom noted that participants at each session brought out new observations, which the facilitators were able to bring forward to the next session. As such, the Virtual Classroom served as a learning opportunity for both the participants and the *NanoTeach* facilitators. In the end, the participants were a*ble to demonstrate movement from what was a more surface understanding to a deeper understanding of effective lessons through the use of storylines*.

Logistics

From the perspective of the facilitators, some lessons learned about how to implement a Virtual Classroom included having *multiple participants and multiple districts* (at least two sites) to enhance learning; a*ssigning each participant a different strategy* to watch for; and *offering different ways for teachers to share their feedback*, including the actual evidence observed for their strategy as well as wrap-up questions to identify two best practices they observed in the lesson, in general, and something they would incorporate into their own practice from what they learned.

Virtual Classroom participants also commented that the *technology was easy to use* (video, chat box, verbal discussion, raising hand to speak) and suggested providing a YouTube video of how the technology works prior to the session to assist teachers new to using the software. *Watching the video ahead of time*, as recommended, was also encouraged as it would answer questions during the session about whether the teacher in the abbreviated lesson would eventually address a strategy.

Being Able to Go Deep with the Support of Other Teachers

[18] Roth, K. J., Garnier, H. E., Chen, C., Lemmens, M., Schwille, K., & Wickler, N. (2011). Videobased lesson analysis: Effective science PD for teacher and student learning. *Journal of Research in Science Teaching, 48*(2), 117-148. doi: 10.1002/tea.20408

Participants also felt that having *a more complete lesson video available* would be helpful to see other teaching techniques (e.g., how students were engaged through discussion), and perhaps stopping to debrief as the lesson progressed could be helpful. While a full-length, 90-minute lesson video might be useful to have available for participants to review after the session, if their interest was piqued, the intent of the Virtual Classroom was to introduce teachers to the process through an abbreviated experience. Participants liked *assigning each person a strategy* to watch for, rather than being responsible for all five, and then *being able to actually "speak" to the group* to hear input from others. "We all saw the same video, but not all perceived the information the same way." Overall, participants shared the sentiment of one teacher about the utility of the Virtual Classroom: "I think this will really help teachers to analyze their own videos for strengths/weaknesses. I like that you work with other and get to hear/see their insights as well as your own."

Lessons Learned: Mid-Year Team Study Webinar

The team study group participated in a virtual question-and-answer session about the time that teachers in the facilitated group were participating in the Virtual Classroom. The team study session was literally an opportunity to *"touch base"* for the purpose of helping teachers reconnect with their colleagues and share their experiences in an effort to refocus their attention in preparation for developing and delivering their spring *NanoTeach* lessons. The team study check-in did not include additional professional development, such as video coding, but rather was *kept "short, light, and social"*; a combination that worked well.

Reconnect and Reengage for Spring

Participants reported that they *"needed to reconnect"* with each other, with the *NanoTeach* team, and with what they needed to do for spring, including reengaging with the content and exploring the online resources available on the Google site. In the process, participants were able to *share what they had done with their fall lesson implementation* and what they were thinking of implementing in the spring. They were also able a*sk questions to better understand the NS&T content and DESI concepts* in preparation for their spring *NanoTeach* lesson. Overall, it was clear that the fall implementation varied in terms of how successful teachers felt they were and that many teachers were struggling to see *where their NanoTeach lesson would fit in the spring*.

Time to Ask Questions

Team study participants acknowledged that they loved the pieces of the DESI framework that they "understood', but said it was sometime *"intimidating" to understand some things and not others*. Some teachers also reiterated that the amount of work required for the team study approach was more than they had expected and that even though their *NanoTeach* site coordinator held office hours, that sometimes email was best. Consequently, it was clear that this midyear check-in was a necessary element for team study teachers.

Lessons Learned: Final Participant Summer Session Debriefings

At the end of the field test, *NanoTeach* participants attended a final summer 2013 debriefing (2-days for the facilitated group at McREL and 1-day for the team study group at their local sites). Teachers particularly enjoyed the Share-a-Thon where they set up displays about one or both of the lessons they had created and discussed their own lessons learned from implementation with

other participants.[19] Teachers also participated in new NS&T lessons led by Georgia Tech partners and shared anticipated next steps with most saying they would be likely to include "mini-lessons" of NS&T, rather than a full lesson or unit. For the facilitated sessions, the *NanoTeach* team hosted a panel discussion featuring volunteers from the *NanoTeach* pilot test (2010-11) teachers who shared what they had done following their year-long experience.
In discussing the impact of participation on their NS&T content knowledge with the external evaluator, it was clear that most teachers in the facilitated group came into the project with only a basic knowledge of NS&T. As such, they felt the *NanoTeach* experience was "transformative." They cited not only learning more about the 'big ideas' in NS&T, but also about materials, applications, and careers. Teachers in the facilitated group expressed that *NanoTeach* provided them with a "working knowledge of the topics and an understanding of the connections so they could integrate NS&T topics into their curriculum. (This growth in teachers' content knowledge was also noted in the main *NanoTeach* research study.[20])

With regard to the impact on their teaching, teachers in the facilitated group said the *NanoTeach* experience helped them learn both how to create new lessons using effective pedagogy and to integrate NS&T throughout their curriculum. Teachers commented that the increased knowledge of NS&T content gave them the background needed to integrate such concepts into their curriculum while the DESI strategies they learned helped them modify their instructional practices. Overall, as noted in the main *NanoTeach* research study,[21] teachers seemed to focus most on DESI strategies related to sense-making and environment.

Lessons Learned: Best of Both Worlds?

Given the time- and resource-intensive nature of the facilitated model and current concerns about the viability of a self-paced, team study model the *NanoTeach* team spent time discussing which features of each model seem to be most essential to teacher success. In considering the "best of both worlds" for a more "flexible" or potentially a "hybrid" model, the *NanoTeach* team discussed how much time should be required; the balance of facilitated to peer group and individual work; methods of delivering training, resources and support; who might be best served by such a model. Although no final model was formally developed, the *NanoTeach* team did articulate key considerations which are presented here.

Amount of Time and Duration

Although the *NanoTeach* team did *not have enough evidence to specify a set amount of time* (as in the 80 hours of professional development required for the facilitated and team study approaches in the field test), it was agreed that a sustained, year-long professional development experience that is job-embedded continues to be a viable model for effecting change. However, as is noted in a recent article describing the case studies (see separate case study report and article[22]), it is noted that one year is not enough time to show significant improvements in teacher practice. Following the project, team members conceptualized a multi-year approach

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[19] Huffman, D. (2013). *NanoTeach* 2-Day Workshop Evaluation Results – Impact of *NanoTeach*. External evaluation report.
[20] Palmer, E. (2014) The *NanoTeach* Project Evaluation Report: 2012-2013 Field Test. Internal evaluation report.
[21] Ibid.
[22] Huffman, D., Tweed, A. Ristvey, J. and Palmer, E. "Integrating Nanoscience and Technology in the High School Science Classroom" accepted for publication by NanoTechnology Reviews, August 2014.

along with intentional system-wide support. The subsequent proposal called NanosySTEM submitted to NSF was not funded.

Face-to-Face vs. Peer Review Teams vs. Individual Work

With regard to the different models, the *NanoTeach* team was in agreement that a combination of face-to-face, work in Peer Review Teams, and individual work would provide the most flexibility. Having a face-to-face element was deemed essential to allow participants an opportunity to interact sufficiently with the nanoscience content and DESI pedagogy through facilitated discussion. Specifically, the *face-to-face format allows for just-in-time feedback, modeling, and time for sense-making around both the nanoscience content and pedagogy*. In addition, the opportunity for individual teachers to *interact with their colleagues through Peer Review Teams, mid-year check-ins, and a final share-a-thon* offers a personal and transformative element to support participants in take their teaching to the next level. Finally, *time for individual, self-paced study and practice in between the face-to-face and work in Peer Review Teams* can provide a necessary element of flexibility for teachers' schedules. What proportion of each is necessary will require further exploration.

Method of Delivery, Resources, and Supports

The *NanoTeach* team and teachers in both the facilitated and team study groups had the following suggestions regarding ways to enhance the delivery, resources and supports associated with *NanoTeach* for both approaches:

- Streamlined, downloadable teacher manual that includes features such as bookmarking and the ability to highlight or take notes.
- Pacing guide embedded within the teacher manual to support self-paced work during team study or a return to the *NanoTeach* pedagogy and content after the project has concluded for either group.
- Flipped videos for teachers to view sample lesson implementation and other online resources to just-in-time support for further developing content knowledge and pedagogy.
- Access to content and pedagogy experts in a timely manner via archived resources available online.
- Simplified process for submission of project deliverables via district coordinators and/or an online submission process.
- Direct support to participants from *NanoTeach* team members who attend Peer Review Team meetings at specified intervals.

A Model for Whom?

The *NanoTeach* field test provided an opportunity to examine how each model worked for different teachers. In terms of the effects on teachers' pedagogy and NS&T content knowledge, there were no differences between the fully facilitated and self-paced, team study approaches. There were differences, however, in teacher satisfaction with team study participants being much more mixed in their reviews of this model while teachers in the facilitated group were generally satisfied. And, of course, there is a significant difference in the costs associated with offering the fully facilitated model versus the team study model. That said, the feedback from the *NanoTeach* team and participants did identify some key features that are beneficial to all participants.

Connecting with experts and other teachers through *face-to-face interactions* at professional development sessions or with peer groups and *real-time online meetings was clearly beneficial for all teachers*; hearing from one another and being able to share and ask questions was essential. *Peer groups of at least 3 teachers and within the same school building* was also important to facilitate sharing within a common curriculum and provide support should any member drop out. *Self-paced work needs to be kept to a minimum, interspersed with other real-time interactions, and supported through more videos and access to other resources*, including expert advice on NS&T content and pedagogy.

Another element to be explored further is *opportunities for teachers' to examine their personal and professional goals to consider how these align with the goals of the project*. Although the *NanoTeach* team reviewed data from the teacher application to assess participants' NS&T content and pedagogical experiences coming into the project, further exploration to clarify teachers' goals can greatly support and guide their learning.

Key outcomes or other achievements

What opportunities for training and professional development has the project provided?

See Year Five Report

How have the results been disseminated to communities of interest?

Several presentations were given at science education meetings at national, regional and state levels by McREL and SNF staff and pilot teacher participants. Included in the year five report are abstracts from each presentation. Additional dissemination efforts in the no-cost extension year follow.

Presentation

NARST 2014 Annual International Conference
Pittsburgh, PA USA
March 30-April 2, 2014
Integrating Nanoscience and Technology in the High School Science Classroom: Face-to-Face vs. Asynchronous Professional Development. Douglas W. Huffman University of Kansas, John D. Ristvey, McREL

Publications

Huffman, D., Tweed, A. Ristvey, J. and Palmer, E. (2014). *Integrating Nanoscience and Technology in the High School Science Classroom* accepted for publication by NanoTechnology Reviews.

Ristvey, J. Pacheco, K.A (2013). *Atomic Force Microscope Mobile Lab Inspires High School Teachers Participating in NanoTeach Workshops*. Journal of Nano Education 5, 148-153.

Video Collaboration
Hitachi Brand Channel (You Tube). Case Study: Hitachi Helps Improve STEM Education in the USA. Over 55,500 views. https://m.youtube.com/watch?v=8nDZo3xFWiM

What do you plan to do during the next reporting period to accomplish these goals?

N/A

Products

NanoTeach Web Site and Google Sites

Google site
The Google site provided an online platform for participants to access resources during the professional development *and* throughout the school year as they implemented nanoscience lessons with students. It housed the PowerPoint slides (with notes) used during the professional development. The site allowed participants to quickly access links to many online resources and to download lessons from the professional development. Table 1 describes the specific expectations for field test teachers. Table 2 is the deliverable checklist provided to field test teachers.

During Year Five the NanoTeach team made use of the Web sites and delivery platforms developed during year two (http://www.mcrel.org/nanoteach/).

Google Site pages were used as the platform for delivering content for the field test participants.

Participants

NanoTeach Team

John Ristvey (PI), McREL
Anne Tweed (Co-PI), McREL
Elisabeth Palmer (Co-PI), Aspen Associates
McREL International
Whitney Cobb, Judy Counley, Mary Cullen, Christine Morrow (Smart Bridges Inc.), Talliver Hare, Nicole Hess, Cyndi Long, Geraldine Robbins, Sharon Unkart, Sandra Weeks
Stanford Nanofabrication Facility (SNF)
Maureen Baran, Mike Deal, Maurice Stevens, Mary Tang, Uli Thumser, Grace Wu
Georgia Institute of Technology
Nancy Healy, Joyce Palmer
ASPEN Associates
Susanne Joyce
University of Kansas

Doug Huffman

Collaborations:

National Nanotechnology Infrastructure Network (NNIN) http://www.nnin.org/
The NNIN is an integrated networked partnership of user facilities, supported by the National Science Foundation, serving the needs of nanoscale science, engineering, and technology. SNF and Georgia Tech are members of this network and in support of *NanoTeach* have been in communication with the Network members with regard to providing content expertise through webinars and live presentations for the two-week summer field test seminar.

Stanford Nanofabrication Facility (SNF)
Stanford Nanofabrication Facility is tasked with developing remote access experiences to provide content knowledge and experiences for participants. Dr. Michael Deal coordinated remote access experiences for the *NanoTeach* field test at three sites (Houston, TX, Denver, CO, and Shreveport LA) and made an in-person presentation at the Shreveport site during the summer of 2012. Teachers in the facilitated group of the field test remotely attended a seminar on nanofabrication techniques by Dr. Deal. Then they took a live remote tour of the labs at SNF and watched a nanolithography demonstration. They communicated with PhD students and doing research in the facility about their work, and looked at images obtained from the Transmission Electron Microscope (TEM) and Atomic Force Microscope (AFM). High-resolution, high-speed web cameras and wireless phones were utilized for interactive experiences between the workshop participants at each of the three sites (Houston, Denver, and Shreveport) and the nanofabrication facilities at Stanford. SNF recruited Professor Tom Kenny and prepared a recorded presentation for use with the facilitated groups. Additionally, SNF provided content expertise for participants as well as development and revision of assessments for use with the field test during year four and five. Dr. Deal also assisted the development team in scoring the open-ended assessment items for the pre-test (see findings) and will do so for the post-test during the summer of 2013 as well. Mike is scheduled to provide a content update ("Graphene - The Next Big Thing Beyond Carbon Nanotubes") for summer two seminar field test participants on June 14, 2013.

Georgia Tech (GT)
GT provided scoring on pre- test (see findings) and will assist in scoring post-test open ended items for our field test content assessment taken by both facilitated and team study participants. The GT team also participated in monthly conference calls and review of materials related to *NanoTeach*. In addition, the GT team worked with the McREL development team to identify new nano-lessons linked to the Big Ideas in Nanoscale Science. The GT group also revised and printed nine Big Ideas posters, which identify each big idea, provide examples of the big idea, connect the big idea to current research, and include questions to ponder. These posters were used in the summer field test (2012) with our facilitated participants. Electronic versions are posted with resource materials on the Google Site for all participants to download for classroom use. GT supported the team-study orientations at the beginning and end of field test for the Georgia cohort. GT recruited Dr. John McDonald for the field test facilitated workshop content presentation (ovarian cancer research) in which he provided an update to his research for the Houston facilitated cohort. GT provided support during the two day follow-up field test convocation in June 2013 (presentations of new NNIN lessons, and connections with Hitachi

Scanning Electron Microscope (SEM) presentation in Denver, CO for both team study and CO team study teachers. Finally in order to ensure sustainability of the *NanoTeach* program beyond the funding of the current project, Nancy Healy will be working with *NanoTeach* staff to determine lessons from the pilot and field test teachers to feature in future Next Generation NNIN website and elements from the *NanoTeach* professional development model for inclusion in future professional development efforts for NNIN.

Advisory Board (AB)

Advisory Board members (Tina Stanford, co-PI from the NSF-funded SRI International NanoSense Project; Dr. Kimberly Pacheco, University of Northern Colorado, PI for the Developing Undergraduate Experiences in the Sciences (DUNES) project for the NSF Nanotechnology in Undergraduate Education Project; Nick Giordano and Lynn Bryan (Purdue University), who led the National Center of Learning and Teaching of Nanoscience (NCLT) professional development; and Andrew Greenberg (University of Wisconsin-Madison) did not meet during year five of the project. Based on recommendations at previous, meetings we have worked with Andrew Greenberg to modify and use one of the University of Wisconsin-Madison lessons on nanotechnology in society in place of what was used for this Big Idea in the pilot test. We have continued to work with Kim Pacheco on providing mobile Atomic Force Microscope and Scanning Tunneling Microscope opportunities to both the facilitated and team-study members of the field test team in all locations. We have updated website information for NanoSense from Tina Stanford and reached out to Lynn Bryan for updated lessons developed by Purdue University.

Presentations by Content Experts

NanoTeach has arranged for the following content experts to provide presentations that connect the Big Ideas of Nanoscience and Technology to their research during the summer 2012 field test.

- Dr. Tom Tretter: Size and Scale
  Doctoral Program Director, Associate Professor, Science Education
  Department of Teaching and Learning, University of Louisville
- Dr. Kim Pacheco and Jesus Tapia: Mobile AFM Lab: Tools and Instrumentation
  Associate Professor, Ph.D., Department of Chemistry, University of Northern Colorado
- Dr. John McDonald: Ovarian Cancer Research
  Director, Integrative Cancer Research Center, School of Biology, Georgia Institute of Technology
- Professor Tom Kenny: Forces and Interactions and Gecko Adhesion
  Department of Mechanical Engineering, Stanford University

NanoLink (Deb Newberry, PI)

Ristvey and Robbins attended the Nano-Link Winter Conference in Phoenix, AZ in February, 2013. The PI of the project asked McREL to share about the Nanoscience and technology education projects currently underway and how we might leverage project materials. Ristvey shared an overview of NanoLeap, *NanoTeach*, and NanoExperiences with the meeting participants and offered connections to the *NanoTeach* Layer One tool developed in the first year of the *NanoTeach* project as a way to analyze and characterize the secondary education content developed by NanoLink. We also shared copies of the *Designing Effective Science Instruction* book with participants as a way of assisting those responsible for developing modules on a framework to improve existing content. Finally, we shared about the Virtual Classroom (VC-LVA) and the *NanoTeach* resource inventory and curriculum maps which might benefit NanoLink. Following this meeting, McREL was invited to present this work at the Micro, Nano Technology conference in Minneapolis, MN (see below) in May of 2013 and the corresponding National Visiting Committee meeting. McREL has used the *NanoTeach* Layer One tool to provide an initial analysis of the NanoLink Polymers module as a starting point to further working together.

Pilot Test Teachers
Five pilot teachers helped test Virtual Classroom Fall 2012 and four pilot teachers joined us as panelists on a Google Hangout with Field Test teachers on June 14, 2013. Additionally, a physics teacher conducted modified NanoLeap lesson for use in the Virtual Classroom.

Field Test Teachers
The following contains a brief summary of the vital statistics for each of the sessions:

Face-to-Face Sessions
Houston Facilitated: June 4–15, 2012
Fifteen participants from Houston, TX, East Baton Rouge, LA, and Atlanta, GA
Facilitators: Tweed, Jones, Ristvey
Archivists: Unkart, Long
Research and Evaluation: Palmer, Huffman
Teledyne Office Building
5827 Chimney Rock
Houston, TX 77081

Multi-state Site One, Houston, TX

Colorado Facilitated: June 18–29, 2012
Twelve participants from Cherry Creek and Jefferson County School Districts
Facilitators: Tweed, Jones
Archivists: Unkart, Long, Weeks, Cobb
Research and Evaluation: Palmer, Huffman

Cherry Creek Instructional Support Facility
5416 S. Riviera Way, Centennial, CO 80015

Colorado Site Two, Centennial, CO

Louisiana Facilitated: July 9–20, 2012
Eighteen participants from Shreveport, LA
Facilitators: Cobb, Ristvey, Long, Weeks
Archivists: Weeks, Unkart
Research and Evaluation: Palmer, Huffman
Bossier Instructional Center
2719 Airline Drive
Bossier City, LA 71111

Louisiana Site Three, Shreveport, LA

Team Study Orientations
Orientation 1: Atlanta, GA: Joyce Palmer, May 31, 2012
Orientation 2: Shreveport, LA: Anne Tweed, June 1, 2012
Orientation 3: Pasadena, TX: Anne Tweed, June 2, 2012
Orientation 4: Denver, CO: Sandra Weeks, June 8, 2012

The team-study pre-program orientation included an opportunity for participants take the pre-test if they hadn't completed it prior to the meeting. After introductions, participants learned about the roles and responsibilities of district coordinators and McREL contacts. Throughout the day-long session participants learned about the website, manual and book resources, logistical information, expectations for working through materials with their peer review teams and scheduling times for meetings and accessing lab materials. Time was also provided for questions and answers, along with a short presentation on the research components of the program from the research and evaluation team members via teleconferencing. Participants completed the "card sort" and "dime walk" activities to get a sense of size and scale related to a definition of nanoscience and technology.

Participant Attrition
As expected, several teachers that were originally recruited to participate in this year-long field test needed to withdraw.

Field Test participant in the *NanoTeach* program had access to many different resources. In addition to the books (*The Big Ideas of Nanoscale Science and Engineering: A Guidebook for Secondary Teachers* and *Designing Effective Science Instruction: What Works in Science Classrooms*), a hard copy participants manual was provided along with access to a Google Site with additional support through office hours and e-mail.

Impacts

What is the impact on the development of the principal discipline(s) of the project?

1. Implementing and completing our field test with approximately 60 teachers integrating the *DESI* Framework and the Nano Big Ideas.
    a. Implementing the remote access materials through Stanford Nanofabrication Facility.
    b. Implementing pre-pilot and post-pilot assessment for our project aligned to Big Ideas and specific learning goals and the development of anchor papers for constructed response items.
    c. Completion of curriculum maps and links to sequence by approximately 80 high school teachers with links to unit, lesson plans, abstracts, and video clips.
    d. Completion of Nano Resource Inventory and use of Layer One Tool with NanoLink project
    e. Sustaining efforts through Next Generation NNIN proposal/project if funded
2. Completion for Field Test
    a. Implementation and further revision of two-week summer sequence based on evaluation findings from field test
    b. Revising the *NanoTeach* Resource Manual based on the *Designing Effective Science Instruction* framework to be used in future projects and possible scale-up.
    c. Development of data analysis protocol for pilot and field test (LQAT, see Appendix C)

   d. Full development and deployment of Virtual Classroom: Learning through Video Analysis platform to help participants analyze their practice following the implementation
3. Completion of viability report/findings
4. Sharing what we have learned
   a. Through posters and talks at professional meetings: NARST 2014, NSTA National, Regional and State conferences, STEM conferences, and MNT conference and connecting with NanoLink.
   b. Through journal article: "Student Understanding of Nanoscience through the Gecko's Surface to Surface Interactions," which was accepted for publication in the Special issue of the *International Journal of Engineering Education* on the theme "Current Trends in Nanotechnology Education"
   c. An article was accepted for publication: *(DUNES Mobile Lab Inspires High School Teachers)* for a special NUE issue of the *Journal of Nano Education* with Dr. Kim Pacheco (advisory board member from University of Northern Colorado).

What is the impact on other disciplines?

The *NanoTeach* team anticipates that the most significant contribution of the project to NSEE will be to determine multiple logical integration points where nanoscale physical science concepts can fit into an existing high school curriculum in a manner that supports students in learning core science concepts and aligns with state and national standards documents. By linking the content integration to the instructional framework, the *NanoTeach* project will also have articulated a viable model for professional development that may be used by staff developers in the future. Curriculum maps for the field test are currently being added to those completed by the pilot teachers during our Summer Seminar 2 session in 2011 in Denver. These maps will be included on the external *NanoTeach* website upon completion.

What is the impact on the development of human resources?

The *NanoTeach* project solicited contributions from and provides contributions to many individuals and institutions concerning Nanoscale Science and Engineering Education (NSEE) efforts during the project's first year. Some highlights:

A. *NanoTeach* worked with our 60 field test teachers as we implemented the *NanoTeach* program.
B. *NanoTeach* developed relationships with world-class scientists and implemented and filmed their expertise of content presentations during the pilot test.
C. *NanoTeach* revised the *NanoTeach DESI* manual and *DESI* practice guides.
D. Leveraged expertise in mobile AFM/STM from Dr. Kim Pacheco and Jesus Tapia.
E. Connections with local STEM efforts through science coordinators in Gwinnett County (GA), Houston, Pasadena, Clear Creek (TX) ISD, Bozier, Cado, and East Baton Rouge (LA) Schools.
F. *NanoTeach* provided professional development in *DESI* and NS&T content to McREL and NNIN staff and RET teachers.

What is the impact on physical resources that form infrastructure? N/A

What is the impact on institutional resources that form infrastructure? N/A

What is the impact on information resources that form infrastructure? N/A

What is the impact on technology transfer? N/A

What is the impact on society beyond science and technology?

Science teachers at the secondary level are struggling to include emerging science content into existing curricula that is already filled with content that must be taught to prepare students for both large scale assessments and classroom assessments. As teachers work to understand and implement the Next Generation Science Standards, teachers are interested in continuing to provide opportunities for students to explore new technologies through authentic investigations and connections to scientists conducting research.

As shown in the teacher testimonial videos, the field test teacher profiles, and LQAT assessments, we expect teachers improved their practice and made science more relevant to their students by including emerging content ideas while integrating *DESI* strategies to improve their instructional practice.

Participation with the project partners, our 80 teachers and their students has led to an increased level of understanding of the Nanoscale science and engineering Big Ideas, helped to increase the number of students and public learning about nanoscience and the impact of new technologies on their everyday lives and has support STEM education and 21st Century skills among teachers and students.

Changes / Problems

Changes in approach and reason for change:
N/A

Actual or Anticipated problems or delays and actions or plans to resolve them:
As expected, several teachers that were originally recruited to participate in this year-long field test needed to withdraw.

To address the primary research question, the *NanoTeach* project originally intended to recruit 150 teachers with 75 in the facilitated group and 75 in the team study group. This sample size would have supported a comparison of the facilitated to the team study group, as well as a subgroup comparison of impact by site (All State, Colorado, Louisiana) by having a sample of 25 teachers per site per study group (facilitated, team study).

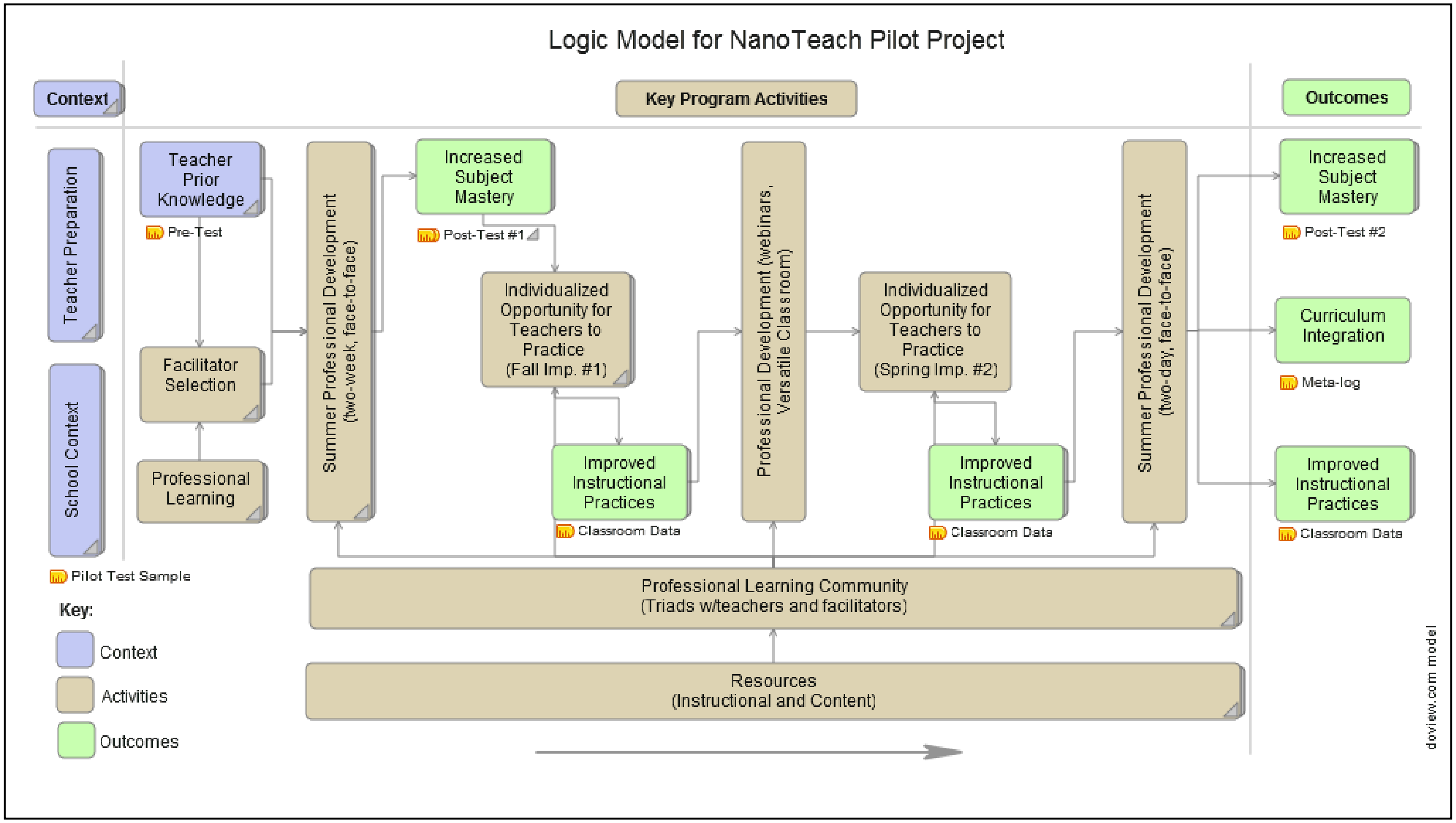
With attrition, the total number of teachers participating across all three sites is 79 with 43 in the facilitated group and 36 in the team study group. The final sample still allows for the primary comparison of the facilitated to the team study approaches to professional development. The smaller sample size does not allow for subgroup comparisons by site. In lieu of subgroup data, the research design was modified to include an in depth case study of a sample of teachers.

Changes that have a significant impact on expenditures:
N/A

Significant changes in use or care of human subjects:
N/A

Significant changes in use or care of biohazards:
N/A

Appendix A: *NanoTeach* Logic Model



Appendix B: *NanoTeach* Field Test Report by Dr. Elisabeth Palmer

OVERVIEW

NanoTeach is a DRK-12 National Science Foundation (NSF) project[23] that developed and tested a model of professional development utilizing an instructional framework designed to support science teachers in integrating nanoscience and technology (NS&T) into their high school curricula. NanoTeach was a collaboration between Mid-continent Research for Education and Learning (McREL), the Stanford Nanofabrication Facility (SNF), the Georgia Institute of Technology, the National Nanotechnology Infrastructure Network (NNIN), and ASPEN Associates, an applied research and evaluation organization.

The year-long, professional development experience supported the integration of NS&T into existing science curriculum through ongoing reflective experiences using two different approaches, a fully facilitated and a team study model. The field test commenced in the summer of 2012 at four locations: Houston Texas, Atlanta Georgia, Aurora Colorado, and Shreveport, Louisiana and concluded in the summer of 2013.

Both approaches were designed to promote standards- and inquiry-based teaching and learning. This report summarizes the findings from the *NanoTeach* field test.

PROJECT GOALS AND OBJECTIVES

The *NanoTeach* project had two overarching goals:

1. INTEGRATION OF INQUIRY-BASED NS&T: To support teachers' ability to learn NS&T content and integrate it into their classes in an inquiry-based manner.
2. VIABLE DEVELOPMENT PROCESS: To create a viable approach to the development of professional development materials and experiences that support integration of NS&T in high school science.

Toward this end, the *NanoTeach* project has completed all of the planned activities:

1. PROFESSIONAL DEVELOPMENT APPROACHES: Developed two models of professional development, one a fully facilitated and one a team study approach.
2. TEACHER MANUAL: Developed a teacher manual that supports teachers in learning and integrating inquiry-based instruction around NS&T in each approach.

[23] This work is supported by the National Science Foundation, Division of Elementary, Secondary and Informal Education award # DRL-0822128.

3. PILOT TEST: During the 2010-2011 school year, the project tested and refined the fully facilitated professional development model, including the Teacher Manual, in preparation for a field test to include both the fully facilitated model and a team study model.

4. FIELD TEST: During the 2012-2013 school year, the project tested two professional development approaches, fully facilitated and team study, to better assess the elements of each that best support teachers in the integration of NS&T into high school science.

5. EVALUATE VIABILITY: Evaluated the effectiveness of the design process utilized in developing the *NanoTeach* professional development offerings and materials.

As a result of these activities, the *NanoTeach* project intended to achieve three outcomes:

1. INQUIRY-BASED TEACHING: Teachers will be able to integrate NS&T into their existing curricula in a manner that supports inquiry-based learning.

2. STUDENT INTEREST/ENGAGEMENT: Teachers will be able to integrate NS&T into their existing curricula in a manner that is engaging to students.

3. INCREASED TEACHER NS&T KNOWLEDGE: Teachers will enhance their knowledge of NS&T in support of integrating this content into their classrooms.

THE *NANOTEACH* MODELS

The year-long *NanoTeach* professional development experience supported the integration of NS&T into existing science curriculum through ongoing reflective experiences using two different approaches:

1. FULLY FACILITATE MODEL: This model combined face-to-face and online training, peer groups, a participant manual and resources including Virtual Classroom: Learning Through Video Analysis synchronous online sessions following the first semester of implementation and prior to the second semester of implementation and ongoing support for participants.
2. TEAM STUDY MODEL: This model included a self-paced, team-study approach and guided teachers in peer groups through the *NanoTeach* process with a step-by-step manual and related resources.

The *NanoTeach* model delivered professional development through five (5) core elements (see Logic Model in Appendix A):

1. *SUMMER PROFESSIONAL DEVELOPMENT*
   a. *FACILITATED: 2-WEEK SEMINAR (SUMMER 2012). Face-to-face Seminar (80 hours) in which participants explored NS&T using the DESI framework with the goal of integrating NS&T into existing curricula that include physical*

science concepts. Participants began working with Peer Review Teams to develop their first lessons (one size and scale lesson and one lesson for another 'Big Idea') in preparation for fall implementation.

b. *TEAM-STUDY: 8-WEEK SELF-STUDY (SUMMER 2012). Team-study participants began with a one-day orientation to the NanoTeach model, materials and resources. Then participants worked individually and within their Peer Review Teams to explore NS&T using the DESI framework with the goal of integrating NS&T into existing curricula that include physical science concepts(80 hours). Participants began working with Peer Review Teams to develop their first lessons (one size and scale lesson and one lesson for another 'Big Idea') in preparation for fall implementation.*

2. *IMPLEMENTATION I (FALL 2012). All participants taught an introductory lesson on Size and Scale prior to implementing their revised NS&T lesson with support from their Peer Review Team. Teachers were required to have at least one portion of the lesson videotaped for the project evaluation. Participants completed a unit plan, lesson plan and began working on self-reflection logs.*

3. *FACILITATED: VIDEO CODING (WINTER 2013). Teachers in this group participated in a synchronous online group video session (Virtual Classroom: Learning through Video Analysis) to practice video coding as a means of peer and self-reflection and review of elements of developing/improving a content storyline and revision of an NS&T sample lesson.*

   SELF-STUDY: WEBINAR (WINTER 2013). Teachers in this group participated in a webinar question/answer session.

4. *IMPLEMENTATION II (SPRING 2013). If working with new students, participants taught an introductory lesson on Size and Scale prior to implementing their second revised lesson with support from their Peer Review Team. Participants were required to videotape the lesson for use in evaluation and at the final seminar. Participants completed a unit plan, lesson plan and continued to work on self-reflection logs.*

5. *SUMMER 2013 REFLECTION SESSIONS. Face-to-face seminar to debrief on the year-long, NanoTeach professional development process (2-day facilitated seminar; 1-day self-study)**.** Teachers participated in a share-a-thon to share their lessons with others within their approach (facilitated or team study), developed curriculum insertion maps in each discipline and discussed lessons learned and effectiveness of the entire professional development experience.*

METHODS

The evaluation of the *NanoTeach* project was designed to address the two guiding research questions and three outcomes using the following data collection protocols: teacher survey, student survey, pre- and post-assessment of teacher knowledge, case studies and viability interviews (see Table 1).

TEACHER SURVEY

The post-only teacher survey was completed at the end of each lesson implementation (fall and spring). This survey asked teachers to assess their preparedness to teach key concepts in nanoscale science and technology, the classroom practices they employed in teaching the lesson, and their perceptions of student engagement. These data were used to examine whether teachers were able to implement the *NanoTeach* modules in a manner that supports inquiry-based teaching and learning (Outcome 1).

The *NanoTeach* teacher survey was adapted from the *Horizon's 2000 National Survey of Science and Mathematics Education Science Questionnaire* (Weiss, et. al, 2003) to collect information on teacher background, opinions, preparation, and teacher practice. In addition to the analysis presented in this report regarding inquiry-based teaching practices, another analysis was conducted in which the variables were aligned to the DESI-CUE instructional strategies.

TABLE 1: DATA COLLECTION PROTOCOLS BY PROJECT OUTCOME, 2012-2013 *NANOTEACH* FIELD TEST

	DATA COLLECTION PROTOCOLS		
PROJECT OUTCOMES	TEACHER SURVEY	STUDENT SURVEY	PRE/POST ASSESSMENT
1. Inquiry-based teaching and learning	X	X	
2. Student interest & engagement in science	X	X	
3. Increased teacher knowledge of NS&T			X

STUDENT SURVEY

The post-only student survey was used to document students' interest and engagement in learning science (Outcome 2) and student perceptions of their teacher's classroom practices. Like the teacher survey, the data on classroom practices were used to examine whether teachers were able to implement their *NanoTeach* lessons in a manner reflective of inquiry-based teaching and learning (Outcome 1).

As with the teacher survey, the student survey was adapted from *Horizon's Classroom Observation and Analytic Protocol—Inside the Classroom Observation and Analytic Protocol* (Weiss, et. al, 2003) to examine the design, implementation, science content, and culture of classroom instruction. In addition to the analysis presented in this report regarding inquiry-based teaching practices, another analysis was conducted in which the variables were aligned to the DESI-CUE instructional strategies.

TEACHER PRE/POST NS&T KNOWLEDGE ASSESSMENT

Pre- and post-assessments documented changes in teacher knowledge of key NS&T concepts over the course of the one-year project (Outcome 3). Teachers completed the pre-assessment just prior to engaging in the first stage of the *NanoTeach* project, which included professional development to enhance their knowledge of effective instructional practices in science and NS&T. Teachers completed the post-assessment at the end of the school year and prior to the final summer debriefing.

CASE STUDIES

In this field test, six teachers were selected to provide baseline data for a more in-depth case study of the effects of the *NanoTeach* project. Of these teachers, four completed the project. These baseline data included the same teacher and student surveys for a non-NS&T science lesson and a videotape of the lesson, and a review the related unit and lesson plans. The results of these four case studies will be available in another report.

VIABILITY INTERVIEWS

Throughout the field test key project stakeholders were interviewed to gather their perceptions of the viability of the development process used in the *NanoTeach* project. This included interviews and debriefings with key participants from each of the project partners to allow reflection on what worked and what didn't with regard to the development process. The results of the viability analysis will be presented in another report that includes related findings from the external evaluation.

FINDINGS

PARTICIPANT CHARACTERISTICS

The 2012-2013 *NanoTeach* field test involved 45 public high school science teachers who completed all of the requirements for the study and 1,637 students.

TEACHERS

Of the 45 public high school science teachers who completed the *NanoTeach* field test, 24 participated in the fully facilitated approach and 21 participated in the team study approach. Teachers in the fully facilitated and team study approaches were equivalent in their teaching and NS&T experience coming into the project (see Table 3). Each group had new to veteran teachers and teachers of biology, chemistry, physical science and physics. With regard to familiarity with NS&T, both the facilitated and team study approaches included a range of teachers from those with very little awareness to those with a more sophisticated understanding of NS&T and the implications for teaching and learning.

STUDENTS

A total of 1,637 students participated in the *NanoTeach* field test, 842 in the fully facilitated approach and 789 in the team study approach.

Students whose teachers participated in the *NanoTeach* facilitated approach were primarily enrolled in grades ten and eleven while students in team study classrooms were primarily enrolled in grades nine and ten (see Table 4).

The participating students represented the NSF target group of traditionally underserved populations of girls and students of color (see Table 4). Boys and girls were equally represented in both the facilitated and team study classrooms. Students of color comprised about half of the sample with the team study classrooms being more diverse overall.

Table 3: Teacher Characteristics, 2012-2013 *NanoTeach* Field Test

	Facilitated (n=24)	Team Study (n=21)
Years Teaching		
Mean (S.D.)	10.4 (8.5)	10.9 (7.1)
Median	7.5	8.0
Range	1.5 to 36	2 to 29
Years Teaching Science		
Mean (S.D.)	9.6 (8.6)	10.5 (7.2)
Median	6.0	8.0
Range	1.5 to 36	2 to 29
Subject Areas		
Biology	6 of 24	9 of 21
Chemistry	6 of 24	8 of 21
Physical Science	8 of 24	7 of 21
Physics	8 of 24	4 of 21
Rating NS&T Familiarity/Understanding[1]		
Mean (S.D.)	2.6 (1.0)	2.2 (0.8)
Median	3.0	2.0
Range	1 to 4	1 to 4

Note: * = statistical significance at $p < .05$

[1] On scale of 1 to 5 with 1 = “Wondering, what is nanoscience and technology?” and 5 = “Have a depth of understanding of nanoscience concepts and know that nanoscience and technology introduces new concepts and knowledge that differs from traditional science content and thus requires new ways of teaching and learning."

Source: *NanoTeach* Teacher Field Test Application. These data were collected prior to the start of the NanoTeach field test.

TABLE 4: CHARACTERISTICS OF STUDENTS, 2012-2013 *NANOTEACH* FIELD TEST

	FACILITATED		TEAM STUDY	
	FALL (N=315)	SPRING (N=451)	FALL (N=315)	SPRING (N=451)
Grade Level				
9th	13.3 %	20.0 %	30.5 %	29.9 %
10th	45.1	40.4	44.6	45.5
11th	28.0	34.2	16.2	15.8
12th	13.5	5.5	8.7	8.8
Percent female	48.4 %	54.4 %	52.3 %	48.4 %
Ethnicity				
American Indian / Alaskan Native	1.0 %	1.0 %	0.5 %	1.3 %
Asian or Pacific Islander	4.5	5.0	10.3	11.6
Black or African American	23.8	22.6	17.1	13.9
Hispanic (non-white)	10.9	9.0	17.8	17.6
White, non-Hispanic	51.8	54.3	46.5	46.3
Multiple	7.6	6.7	7.0	7.6
Other	0.5	1.4	0.8	1.8

Notes: * = statistical significance at $p < .05$
Source: *NanoTeach* Student Survey, 2012-2013.

INQUIRY-BASED TEACHING AND LEARNING

To achieve the goal of supporting teachers in integrating NS&T through effective science instruction the *NanoTeach* project set out to develop models of professional development that promote inquiry-based teaching and learning.[24]

OUTCOME 1:	Teachers will be able to integrate NS&T content into their classes in an inquiry-based manner.

FINDING 1A: Teachers in the facilitated and team study approaches were equally prepared to teach the NS&T topics they had selected for their *NanoTeach* lesson and felt *most prepared to teach* Structure of Matter; Size and Scale; Size Dependent Properties; Models and Simulations; and Science, Technology and Society. Not surprisingly, teachers felt *least prepared* to teach Quantum Effects as it was not one of the 'big ideas' emphasized by the project and only briefly introduced.

FINDING 1B: Teachers in the facilitated and team study approaches were similar in that they were *most likely to report that they emphasized* learning basic science concepts, learning science investigation skills, and preparing students for further study in science as their key learning objectives.

FINDING 1C: Students and teachers in both the fully facilitated and team study groups reported engaging in a variety of inquiry-based practices. The most common inquiry-based practices suggested a greater emphasis on developing *student understanding* and promoting *student engagement* with less emphasis on formal scientific investigation.

TEACHER PREPAREDNESS AND NATURE OF THE LESSONS

PREPAREDNESS

Teachers in the facilitated and team study approaches were equally prepared to teach the NS&T topics they had selected for their *NanoTeach* lesson.

With regard to teacher preparedness to teach NS&T topics, teachers in both approaches were more likely to include the topics they felt *most prepared to teach*: Structure of Matter; Size and Scale; Size Dependent Properties; Models and Simulations; and Science, Technology and Society (see Table 5). Teachers felt *least prepared* to teach Quantum Effects, a 'big idea' that was not a focus of the project, and yet, half included this topic in their lesson. Teachers felt *moderately prepared* to teach Forces and Interactions, Tools and Instrumentation, and Self-Assembly.

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[24] See also Appendix A: Special Analysis of DESI Instructional Strategies for a more detailed analysis of student engagement and motivation.

The fact that teachers in the facilitated and team study approaches shared a common sense of preparedness to teach certain NS&T topics more than others is in line with what the *NanoTeach* team noticed in both the pilot and field tests in terms of a potential learning sequence NS&T concepts from more basic or foundational topics to more advanced applications.

Learning Objectives

Teachers in the facilitated and team study approaches had a similar emphasis when it came to the learning objectives for their *NanoTeach* lessons. The *most common* learning objectives, from the teacher survey, were to:

- learn basic science concepts,
- learn science investigation skills, and
- prepare students for further study in science

Moreover, during the spring semester, teachers tended to emphasize learning about the applications of science in business and industry and about the relationship between science, technology and society, which is more common in the spring term according to the teacher survey.

The *least common* learning objectives were to:

- learn important terms and facts of science and
- learn to evaluate arguments based on scientific evidence.

Inquiry-Based Teaching

Students and teachers in both the fully facilitated and team study groups reported engaging in a variety of inquiry-based practices.

Student Perceptions

Across both approaches, students consistently reported that their teachers were *most likely* to engage in practices that suggest an emphasis on student understanding (see Tables 7A and 7B):

- engaging the whole class in discussion,
- asking open-ended questions, and
- requiring students to supply evidence to support their claims.

Students also consistently reported that their teachers were *least likely* to utilize the following classroom practices related to formal investigations:

- asking students to formulate a testable hypothesis
- asking students to design or implement their own investigation

- having students work on solving real-world problems

Although there were statistically significant differences between students' perceptions of classroom practice in the facilitated and team study approaches, these differences were "small" as indicated by the effect size and did not follow any particular pattern.

TEACHER PERCEPTIONS

Across both approaches, teachers consistently reported that they were *most likely* to engage in practices that suggest an emphasis on student engagement (see Tables 8A and 8B):

- having students work in cooperative groups,
- having students engage in hands-on science activities, and
- teaching science using real-world contexts.

Like students, teachers consistently reported that they were *least likely* to ask students to engage in formal investigations, despite highlighting this as a key learning objective:

- formulate a testable hypothesis,
- design or implement their own investigation,
- conduct experiments to test different explanations, and
- work on solving real-world problems.

In addition, teachers were *least likely* to have students debate different scientific explanations and discuss the nature of science.

The few statistically significant differences between teachers' perceptions also did not suggest a pattern that could be related back to the intervention.

TABLE 5: TEACHER PREPAREDNESS IN NANOSCIENCE AND TECHNOLOGY, 2012-2013 *NANOTEACH* FIELD TEST

	FACILITATED (N=24)				TEAM STUDY (N=21)			
	FALL		SPRING		FALL		SPRING	
TOPICS	MEAN	N	MEAN	N	MEAN	N	MEAN	N
Structure of Matter	4.19 (0.75)	21	4.19 (1.17)	16	4.50 (0.63)	16	4.16 (0.83)	19
Size and Scale	4.54 (0.66)	24	4.59 (0.73)	22	4.30 (0.73)	20	4.42 (0.77)	19
Size Dependent Properties	4.00 (1.11)	22	4.24 (0.94)	21	3.82 (0.64)	17	4.00 (0.88)	19
Forces and Interactions	3.76 (0.97)	17	4.20 (0.95)	20	3.27 (1.28)	15	3.94 (0.93)	16
Tools and Instrumentation	3.31 (0.95)	16	3.72 (0.96)	18	3.27 (1.28)	15	3.14 (0.86)	14
Self-Assembly	3.20 (1.15)	15	3.39 (1.42)	18	2.60 (1.17)	10	3.14 (1.17)	14
Quantum Effects	2.67 (1.30)	12	2.93 (1.10)	15	2.64 (1.29)	11	2.55 (1.21)	11
Models and Simulations	3.91 (0.95)	23	4.05 (1.08)	19	3.89 (1.02)	18	3.53 (1.18)	17
Science, Technology and Society	4.30 (0.87)	20	4.21 (0.88)	24	4.22 (0.81)	18	3.95 (1.00)	20

Notes: On a scale of 1 = 'not at all prepared' to 5 = 'very prepared' to teach when topic was included in school curriculum.
N = number of teachers who included this topic in their lesson.
* = statistical significance at $p < .05$
Source: *NanoTeach* Teacher Survey, 2012-2013.

TABLE 6A: LEARNING OBJECTIVES FOR *NANOTEACH* LESSONS, 2012-2013, FIELD TEST.

	FACILITATED (N=24)		TEAM STUDY (N=21)		EFFECT SIZE
	MEAN	S.D.	MEAN	S.D.	
FALL					
Learn basic science concepts	3.17	0.70	3.19	0.75	-0.03
Learn important terms and facts of science	2.71	0.75	2.75	0.91	-0.05
Learn science investigation skills	3.08	0.97	2.95	0.74	0.15
Learn to evaluate arguments based on scientific evidence	2.54	0.83	2.76	1.04	-0.23
Prepare for further study in science	2.92	0.72	2.86	0.85	0.08
Learn about the applications of science in business and industry	2.63	1.10	2.52	1.29	0.08
Learn about the relationship between science, technology and society	2.75	1.22	2.62	1.28	0.10
SPRING					
Learn basic science concepts	3.00	0.78	2.81	0.75	0.25
Learn important terms and facts of science	2.71	0.86	2.48	0.81	0.28
Learn science investigation skills	2.88	0.95	3.33	0.80	-0.53
Learn to evaluate arguments based on scientific evidence	2.21	0.93	2.57	1.08	-0.36
Prepare for further study in science	2.92	0.83	2.86	0.85	0.07
Learn about the applications of science in business and industry	3.13	0.95	2.86	1.15	0.26
Learn about the relationship between science, technology and society	3.25	0.94	3.29	0.96	-0.04

Notes: "Emphasis" rated on a scale of 1 = no emphasis, 2 = minimal emphasis, 3 = moderate emphasis, and 4 = heavy emphasis.
Statistical significance * = p < .05, ** = p < .01, *** = p < .001.
Effect size = (mean treatment) – (mean control) / (average S.D. treatment and control).
Effect size less than 0.20 = little or no difference; 0.20 to 0.49 = small difference; 0.50 to 0.79 = moderate difference; 0.80 or higher = large difference.
Effect sizes of .25 or greater are considered "educationally significant" (Cohen, 1988).
Source: *NanoTeach* Teacher Survey, 2012-2013.

TABLE 7A: STUDENT PERCEPTIONS OF *NANOTEACH* TEACHERS' INQUIRY-BASED CLASSROOM PRACTICES, FALL 2012, FIELD TEST.

INQUIRY-BASED PRACTICES: TEACHER	FACILITATED (N=423)		TEAM STUDY (N=392)		EFFECT SIZE
	MEAN	S.D.	MEAN	S.D.	
a. Engage the whole class in discussion	3.27	0.67	3.29	0.71	-0.03
b. Ask open-ended questions	3.17	0.70	3.22	0.64	-0.09
c. Require students to supply evidence to support their claims	3.15	0.71	3.20	0.68	-0.08
d. Ask students to explain concepts to one another	3.11	0.73	2.96	0.75	0.20**
e. Ask students to consider alternative explanations	2.98	0.77	3.05	0.68	-0.09
f. Allow students to work at their own pace	3.12	0.74	3.15	0.71	-0.05
g. Help students see connections between science and other disciplines	3.05	0.76	3.21	0.71	-0.21**
INQUIRY-BASED PRACTICES: STUDENT					
h. Formulate a testable hypothesis	2.75	0.92	2.76	0.78	-0.02
i. Conduct an experiment to test different explanations	2.91	0.86	3.01	0.77	-0.11
j. Record, represent, and/or analyze data	3.16	0.73	3.21	0.67	-0.07
k. Write explanations about what was observed and why it happened	3.15	0.71	3.14	0.68	0.01
l. Debate different scientific explanations	2.95	0.77	2.90	0.75	0.06
m. Discuss the nature of science	2.94	0.78	2.98	0.79	-0.05
n. Participate in student-led discussions	2.94	0.78	2.77	0.86	0.20**
o. Participate in discussions with the teacher to further science understanding	3.07	0.74	3.14	0.69	-0.10
p. Work on solving a real-world problem	2.69	0.83	2.61	0.81	0.09
q. Share ideas or solve problems with each other in small groups	3.11	0.71	2.99	0.73	0.17*
r. Engage in hands-on science activities	3.09	0.75	3.18	0.72	-0.12
s. Design or implement your own investigation	2.83	0.84	2.57	0.85	0.31***
t. Total across 19-item scale (alpha = 0.91)	56.91	9.40	56.98	8.64	-0.01

Notes: On a scale of 1 = Strongly disagree, 2 = Disagree, 3 = Agree, 4 =Strongly agree.
Statistical significance * = $p < .05$, ** = $p < .01$, *** = $p < .001$.
Effect size = (mean treatment) – (mean control) / (average S.D. treatment and control).
Effect size less than 0.20 = little or no difference; 0.20 to 0.49 = small difference; 0.50 to 0.79 = moderate difference; 0.80 or higher = large difference.
Effect sizes of .25 or greater are considered "educationally significant" (Cohen, 1988).
Source: *NanoTeach* Student Survey, 2012-2013.

TABLE 7B: STUDENT PERCEPTIONS OF *NANOTEACH* TEACHERS' INQUIRY-BASED CLASSROOM PRACTICES, SPRING 2013, FIELD TEST.

INQUIRY-BASED PRACTICES: TEACHER	FACILITATED (N=422)		TEAM STUDY (N=400)		EFFECT SIZE
	MEAN	S.D.	MEAN	S.D.	
a. Engage the whole class in discussion	3.40	0.65	3.19	0.78	0.31***
b. Ask open-ended questions	3.37	0.66	3.21	0.73	0.23**
c. Require students to supply evidence to support their claims	3.29	0.65	3.27	0.69	0.03
d. Ask students to explain concepts to one another	3.14	0.72	3.06	0.77	0.11
e. Ask students to consider alternative explanations	3.14	0.69	3.03	0.73	0.16*
f. Allow students to work at their own pace	3.25	0.66	3.12	0.78	0.18**
g. Help students see connections between science and other disciplines	3.25	0.68	3.17	0.70	0.12
INQUIRY-BASED PRACTICES: STUDENT					
h. Formulate a testable hypothesis	2.80	0.87	2.85	0.87	-0.06
i. Conduct an experiment to test different explanations	2.99	0.86	3.00	0.85	-0.01
j. Record, represent, and/or analyze data	3.12	0.80	3.20	0.74	-0.10
k. Write explanations about what was observed and why it happened	3.07	0.77	3.06	0.79	0.01
l. Debate different scientific explanations	3.01	0.75	2.92	0.78	0.13
m. Discuss the nature of science	3.02	0.76	2.92	0.80	0.12
n. Participate in student-led discussions	2.97	0.79	2.88	0.85	0.10
o. Participate in discussions with the teacher to further science understanding	3.17	0.64	3.05	0.77	0.18*
p. Work on solving a real-world problem	2.87	0.81	2.75	0.84	0.14
q. Share ideas or solve problems with each other in small groups	3.18	0.67	3.07	0.71	0.15*
r. Engage in hands-on science activities	3.16	0.76	3.12	0.77	0.05
s. Design or implement your own investigation	2.87	0.85	2.82	0.88	0.06
t. Total across 19-item scale (alpha = 0.91)	58.62	9.16	57.25	9.33	0.14*

Notes: On a scale of 1 = Strongly disagree, 2 = Disagree, 3 = Agree, 4 =Strongly agree.
Statistical significance * = $p < .05$, ** = $p < .01$, *** = $p < .001$.
Effect size = (mean treatment) – (mean control) / (average S.D. treatment and control).
Effect size less than 0.20 = little or no difference; 0.20 to 0.49 = small difference; 0.50 to 0.79 = moderate difference; 0.80 or higher = large difference.
Effect sizes of .25 or greater are considered "educationally significant" (Cohen, 1988).
Source: *NanoTeach* Student Survey, 2012-2013.

TABLE 8A: TEACHER PERCEPTIONS OF *NANOTEACH* TEACHER'S INQUIRY-BASED CLASSROOM PRACTICES, FALL 2012, FIELD TEST.

INQUIRY-BASED PRACTICES: TEACHER	FACILITATED (N=24)		TEAM STUDY (N=21)		EFFECT SIZE
	MEAN	S.D.	MEAN	S.D.	
a. Demonstrate a science-related principle or phenomenon	2.88	0.90	3.35	0.49	-0.68*
b. Teach science using real-world contexts	3.25	0.85	3.30	0.66	-0.07
c. Arrange seating to facilitate student discussion	2.70	1.15	2.35	1.18	0.30
d. Use open-ended questions	2.92	0.93	3.30	0.57	-0.51
e. Require students to supply evidence to support their claims	3.00	0.93	2.95	0.94	0.05
f. Encourage students to explain concepts to one another	3.13	0.85	3.20	0.83	-0.09
g. Encourage students to consider alternative explanations	2.75	0.90	2.85	0.93	-0.11
h. Allow students to work at their own pace	2.88	0.80	2.90	0.79	-0.03
i. Help students see connections between science and other disciplines	2.79	0.93	2.85	0.93	-0.06

Notes: On a scale of 1 = No emphasis, 2 = Minimal emphasis, 3 = Moderate emphasis, 4 = Heavy emphasis.
Statistical significance * = $p < .05$, ** = $p < .01$, *** = $p < .001$.
Effect size = (mean treatment) – (mean control) / (average S.D. treatment and control). Effect size less than 0.20 = little or no difference; 0.20 to 0.49 = small difference; 0.50 to 0.79 = moderate difference; 0.80 or higher = large difference. Effect sizes of .25 or greater are considered "educationally significant" (Cohen, 1988).
Source: *NanoTeach* Teacher Survey, 2012-2013.

TABLE 8A: TEACHER PERCEPTIONS OF *NANOTEACH* TEACHER'S INQUIRY-BASED CLASSROOM PRACTICES, FALL 2012, FIELD TEST (CONTINUED).

INQUIRY-BASED PRACTICES: STUDENTS	FACILITATED (N=24)		TEAM STUDY (N=21)		EFFECT SIZE
	MEAN	S.D.	MEAN	S.D.	
j. Formulate a testable hypothesis	2.33	1.09	2.19	0.93	0.14
k. Conduct experiments to test different explanations	2.50	1.14	2.52	1.03	-0.02
l. Record, represent, and/or analyze data	2.83	1.05	3.19	0.98	-0.35
m. Write explanations about what was observed and why it happened	3.00	0.93	3.24	0.89	-0.26
n. Debate different scientific explanations	2.71	0.86	2.14	0.79	0.68*
o. Discuss the nature of science	2.54	1.06	2.48	1.08	0.06
p. Participate in student-led discussions	3.00	0.98	2.48	0.93	0.55
q. Participate in discussions with the teacher to further science understanding	3.13	0.80	3.14	0.57	-0.03
r. Work in cooperative learning groups	3.46	0.59	3.29	1.15	0.20
s. Work on solving a real-world problem	2.21	1.06	2.29	1.01	-0.07
t. Share ideas or solve problems with each other in small groups	2.92	0.97	3.05	1.07	-0.13
u. Engage in hands-on science activities	3.21	1.18	3.29	0.96	-0.07
v. Design or implement their own investigation	2.33	1.17	1.81	0.93	0.50
w. Total across 22-item scale (alpha = 0.85)	62.33	10.53	60.86	10.97	0.14

Notes: On a scale of 1 = No emphasis, 2 = Minimal emphasis, 3 = Moderate emphasis, 4 = Heavy emphasis.
Statistical significance * = $p < .05$, ** = $p < .01$, *** = $p < .001$.
Effect size = (mean treatment) – (mean control) / (average S.D. treatment and control). Effect size less than 0.20 = little or no difference; 0.20 to 0.49 = small difference; 0.50 to 0.79 = moderate difference; 0.80 or higher = large difference. Effect sizes of .25 or greater are considered "educationally significant" (Cohen, 1988).
Source: *NanoTeach* Teacher Survey, 2012-2013.

TABLE 8B: TEACHER PERCEPTIONS OF *NANOTEACH* TEACHER'S INQUIRY-BASED CLASSROOM PRACTICES, SPRING 2013, FIELD TEST.

INQUIRY-BASED PRACTICES: TEACHER	FACILITATED (N=24)		TEAM STUDY (N=21)		EFFECT SIZE
	MEAN	S.D.	MEAN	S.D.	
a. Demonstrate a science-related principle or phenomenon	3.54	0.59	2.70	0.86	0.11
b. Teach science using real-world contexts	2.75	1.11	3.45	0.69	0.14
c. Arrange seating to facilitate student discussion	3.04	0.86	2.55	1.10	0.18
d. Use open-ended questions	2.88	0.85	2.95	0.83	0.11
e. Require students to supply evidence to support their claims	3.00	1.06	3.10	1.07	-0.23
f. Encourage students to explain concepts to one another	2.67	1.09	2.85	1.09	0.14
g. Encourage students to consider alternative explanations	2.92	0.78	2.25	0.72	0.46
h. Allow students to work at their own pace	2.88	0.74	2.75	0.85	0.20
i. Help students see connections between science and other disciplines	3.54	0.59	2.70	1.13	0.19

Notes: On a scale of 1 = No emphasis, 2 = Minimal emphasis, 3 = Moderate emphasis, 4 = Heavy emphasis.
Statistical significance * = $p < .05$, ** = $p < .01$, *** = $p < .001$.
Effect size = (mean treatment) – (mean control) / (average S.D. treatment and control). Effect size less than 0.20 = little or no difference; 0.20 to 0.49 = small difference; 0.50 to 0.79 = moderate difference; 0.80 or higher = large difference. Effect sizes of .25 or greater are considered "educationally significant" (Cohen, 1988).
Source: *NanoTeach* Teacher Survey, 2012-2013.

TABLE 8B: TEACHER PERCEPTIONS OF *NANOTEACH* TEACHER'S INQUIRY-BASED CLASSROOM PRACTICES, SPRING 2013, FIELD TEST (CONTINUED).

INQUIRY-BASED PRACTICES: STUDENTS	FACILITATED (N=24)		TEAM STUDY (N=21)		EFFECT SIZE
	MEAN	S.D.	MEAN	S.D.	
j. Formulate a testable hypothesis	2.46	1.25	2.00	1.05	0.40
k. Conduct experiments to test different explanations	2.50	1.29	2.24	1.22	0.21
l. Record, represent, and/or analyze data	2.63	1.31	2.95	1.16	-0.26
m. Write explanations about what was observed and why it happened	2.83	1.20	2.90	1.34	-0.06
n. Debate different scientific explanations	2.58	1.02	2.19	1.17	0.36
o. Discuss the nature of science	2.63	1.13	2.19	0.93	0.42
p. Participate in student-led discussions	3.00	1.06	2.57	0.81	0.46
q. Participate in discussions with the teacher to further science understanding	3.17	0.76	2.67	0.80	0.64*
r. Work in cooperative learning groups	3.63	0.65	3.57	0.81	0.07
s. Work on solving a real-world problem	2.83	1.05	2.86	1.06	-0.02
t. Share ideas or solve problems with each other in small groups	3.13	0.99	3.00	0.89	0.13
u. Engage in hands-on science activities	3.25	1.11	3.29	1.19	-0.03
v. Design or implement their own investigation	2.21	1.28	2.00	1.18	0.17
w. Total across 22-item scale (alpha = 0.89)	2.46	1.25	2.00	1.05	0.40

Notes: On a scale of 1 = No emphasis, 2 = Minimal emphasis, 3 = Moderate emphasis, 4 = Heavy emphasis.
Statistical significance * = $p < .05$, ** = $p < .01$, *** = $p < .001$.
Effect size = (mean treatment) – (mean control) / (average S.D. treatment and control). Effect size less than 0.20 = little or no difference; 0.20 to 0.49 = small difference; 0.50 to 0.79 = moderate difference; 0.80 or higher = large difference. Effect sizes of .25 or greater are considered "educationally significant" (Cohen, 1988).
Source: *NanoTeach* Teacher Survey, 2012-2013.

STUDENT INTEREST AND ENGAGEMENT IN SCIENCE

The *NanoTeach* project also set out to support teachers in developing lessons that promote student interest and engagement in science.[25]

OUTCOME 2:	Students in classrooms where teachers implement inquiry-based NS&T lessons will report high levels of interest and engagement.

FINDING 2: Teachers and students in both the facilitated and team study approaches reported high levels of engagement and interest in learning science and nanoscience.

In both the facilitated and team study approaches, teachers and students noted that the *NanoTeach* lessons led to further interest in science, nanoscience and related careers and that the instruction motivated student participation as evidenced by teacher and student reports of engagement (see Tables 9 and 10). There were no particular patterns of statistical differences between the facilitated and self-study approaches.

[25] See also Appendix A: Special Analysis of DESI Instructional Strategies for a more detailed analysis of student engagement and motivation.

TABLE 9: STUDENT PERCEPTIONS OF STUDENT INTEREST AND MOTIVATION, 2012-2013, *NANOTEACH* FIELD TEST.

	FACILITATED (N=423)		TEAM STUDY (N=392)		EFFECT SIZE
FALL	MEAN	S.D.	MEAN	S.D.	
a. I am more interested in science.	2.68	0.88	2.86	0.88	-0.20**
b. I have questions about nanoscience.	2.68	0.89	2.82	0.87	-0.16*
c. I would like to learn more about nanoscience at school.	2.70	0.90	2.85	0.87	-0.17*
d. I would like to learn more about careers in nanoscience.	2.50	0.91	2.53	0.97	-0.03
e. I felt bored in class.	2.45	0.97	2.37	0.92	0.08
f. I tried as hard as I could.	3.46	0.69	3.51	0.71	-0.06
g. I completed assignments.	3.64	0.58	3.65	0.64	-0.01
h. I paid attention in class.	3.55	0.72	3.65	0.58	-0.15*
Total across 8-item scale (alpha = 0.80)	23.71	4.30	24.41	4.32	-0.16**
SPRING	MEAN	S.D.	MEAN	S.D.	
a. I am more interested in science.	2.91	0.80	2.86	0.92	0.05
b. I have questions about nanoscience.	2.87	0.83	2.90	0.89	-0.03
c. I would like to learn more about nanoscience at school.	2.93	0.88	2.88	0.91	0.06
d. I would like to learn more about careers in nanoscience.	2.68	0.93	2.69	0.94	-0.01
e. I felt bored in class.	2.35	0.92	2.52	0.93	-0.17*
f. I tried as hard as I could.	3.57	0.63	3.46	0.69	0.16*
g. I completed assignments.	3.70	0.58	3.67	0.59	0.06
h. I paid attention in class.	3.65	0.57	3.61	0.59	0.08
Total across 8-item scale (alpha = 0.80)	24.86	4.01	24.52	4.34	0.08

Notes: a-d rated on a scale of 1 = strongly disagree, 2 = disagree, 3 = agree, 4 = strongly agree; e-h rated on a scale of 1 = never, 2 = rarely, 3 = sometimes, 4 = often.
Statistical significance * = p < .05, ** = p < .01, *** = p < .001.
Effect size = (mean treatment) – (mean control) / (average S.D. treatment and control). Effect size less than 0.20 = little or no difference; 0.20 to 0.49 = small difference; 0.50 to 0.79 = moderate difference; 0.80 or higher = large difference. Effect sizes of .25 or greater are considered “educationally significant” (Cohen, 1988).
Source: *NanoTeach* Student Survey, 2012-2013.

TABLE 10: TEACHER PERCEPTIONS OF STUDENT INTEREST AND MOTIVATION, 2012-2013, *NANOTEACH* FIELD TEST.

As a result of the lesson, students…	FACILITATED (N=24)		TEAM STUDY (N=21)		EFFECT SIZE
FALL	MEAN	S.D.	MEAN	S.D.	
a. seem to be more interested in science.	3.13	0.46	2.95	0.59	0.34
b. have questions about nanoscience.	2.96	0.69	3.24	0.54	-0.46
c. want to learn more about nanoscience at school.	2.92	0.65	3.00	0.77	-0.12
d. want to learn more about careers in nanoscience.	2.71	0.69	2.57	0.75	0.19
e. seemed bored in class.	1.43	0.59	1.48	0.51	-0.08
f. tried as hard as they could.	3.05	0.84	2.71	0.64	0.45
g. completed assignments.	3.78	0.52	3.48	0.60	0.55
h. paid attention in class.	3.41	0.59	3.52	0.60	-0.19
Total across 8-item scale (alpha = 0.78)	24.54	4.57	25.00	3.46	-0.11
SPRING	MEAN	S.D.	MEAN	S.D.	
a. seem to be more interested in science.	3.17	0.38	3.00	0.71	0.31
b. have questions about nanoscience.	3.29	0.55	3.24	0.83	0.08
c. want to learn more about nanoscience at school.	3.17	0.64	3.14	0.85	0.03
d. want to learn more about careers in nanoscience.	2.75	0.74	3.05	0.80	-0.39
e. seemed bored in class.	1.33	0.56	1.43	0.51	-0.18
f. tried as hard as they could.	3.33	0.76	3.00	0.84	0.42
g. completed assignments.	3.67	0.48	3.57	0.60	0.18
h. paid attention in class.	3.58	0.50	3.33	0.66	0.43
Total across 8-item scale (alpha = 0.82)	26.63	2.81	25.90	4.24	0.21

Notes: a-d rated on a scale of 1 = strongly disagree, 2 = disagree, 3 = agree, 4 = strongly agree; e-h rated on a scale of 1 = few or no students, 2 = some students (less than half), 3 = many students (more than half), 4 = all or almost all students.
Statistical significance * = p < .05, ** = p < .01, *** = p < .001.
Effect size = (mean treatment) – (mean control) / (average S.D. treatment and control). Effect size less than 0.20 = little or no difference; 0.20 to 0.49 = small difference; 0.50 to 0.79 = moderate difference; 0.80 or higher = large difference. Effect sizes of .25 or greater are considered "educationally significant" (Cohen, 1988).
Source: *NanoTeach* Teacher Survey, 2012-2013.

TEACHER LEARNING

Another goal of the *NanoTeach* project was to develop teachers' NS&T content knowledge to support their integration of the content into their lessons.

OUTCOME 3: Teachers knowledge of NS&T will increase over the course of the project.

FINDING 3: Teachers in both the facilitated and team study approaches demonstrated statistically significant *moderate to large gains* in their knowledge of NS&T from pretest to posttest.

The assessment of teacher knowledge[26] focused on the Big Ideas of NS&T content being presented in the *NanoTeach* professional development experiences: Size and Scale, Size Dependent Properties, Forces and Interactions, Tools and Instrumentation, Self-Assembly, and Nanoscience and Society. The assessment included a total of 39 questions representing different cognitive levels, including 34 multiple choice (MC) questions and 5 constructed response.

In this field test, the facilitated and team study models performed equally well on the assessment of nanoscience content knowledge with similar scores on the pretest and the posttest and *equal growth* from pretest to posttest (see Table 11). Both groups demonstrated statistically significant *moderate to large gains* from pretest to posttest..or over the school year.

[26] See Appendix B for a more detailed summary of the results from the teacher content knowledge assessment.

TABLE 11: WEIGHTED GROWTH (GAIN) FROM PRETEST TO POSTTEST FOR MULTIPLE CHOICE, CONSTRUCTED RESPONSE AND ALL RESPONSES, 2012-2013, *NANOTEACH* FIELD TEST.

		MEAN (S.D.)		GROWTH (GAIN)	
TYPE OF QUESTION	NUMBER POSSIBLE	PRETEST	POSTTEST	MEAN CHANGE PRETEST TO POSTTEST	EFFECT SIZE OF CHANGE PRETEST TO POSTTEST
ALL WEIGHTED MULTIPLE CHOICE (MC)					
All Teachers (n= 45)	87	50.3 (15.6)	60.3 (15.0)	10.1* (10.8)	+0.65 (moderate)
Facilitated Model (n=24)	87	48.3 (17.6)	59.8 (16.1)	11.5* (11.8)	+0.68 (moderate)
Team Study Model (n=21)	87	52.5 (13.0)	60.9 (14.1)	8.4* (9.6)	+0.62 (moderate)
ALL WEIGHTED CONSTRUCTED RESPONSE (CR)					
All Teachers (n= 45)	13	3.0 (2.5)	6.1 (4.5)	3.1* (3.9)	+0.89 (large)
Facilitated Model (n=24)	13	2.6 (2.5)	5.5 (4.1)	2.9* (4.0)	+0.88 (large)
Team Study Model (n=21)	13	3.5 (2.5)	6.7 (4.9)	3.2* (3.9)	+0.86 (large)
ALL WEIGHTED QUESTIONS (MC + CR)					
All Teachers (n= 45)	100	53.3 (17.1)	66.4 (18.7)	13.1* (12.8)	+0.73 (moderate)
Facilitated Model (n=24)	100	50.9 (19.1)	65.4 (20.0)	14.4** (13.5)	+0.74 (moderate)
Team Study Model (n=21)	100	56.0 (14.6)	67.6 (18.1)	11.7* (12.1)	+0.71 (moderate)

Notes: * statistically significant difference at minimum p <= .001; ** at p < .05
Effect size = (mean gain posttest – mean gain pretest) / [(s.d. posttest + s.d. pretest)/2]. Effect sizes of 0.20 to 0.49 are small; 0.50 to 0.79 are moderate; and 0.80+ are large.

SUMMARY

The results of this evaluation indicate that the *NanoTeach* project was successful in achieving both of its goals:

1. INQUIRY-BASED INTEGRATION OF NS&T: The *NanoTeach* professional development approaches support teachers' ability to integrate NS&T content into their classes in an inquiry-based manner.
2. VIABLE APPROACHES TO PROFESSIONAL DEVELOPMENT: The *NanoTeach* project did result in a viable approach to designing and implementing two different models of professional development experiences that support integration of NS&T in high school science. These findings will be summarized in a separate report.

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Appendix C: NanoTeach Field Test Case Studies

Case Study #1: Kendra[27] - *NanoTeach* Facilitated Model

Who is Kendra?[28]

Years of teaching H.S. science: 4
Subjects taught: Biology and Physical Science
Self rating-content (pre-*NanoTeach*): No experience
Self rating-pedagogy (pre-*NanoTeach*): Limited experience
Fall Lesson: "Self-assembly in DNA"
Spring Lesson: "Nano vs. Cancer"

Kendra was a relatively new teacher coming into the project having taught high school science for 4 years. Kendra taught Physical Science and participated in the fully Facilitated model of *NanoTeach* (see Table B1 in Appendix C2).

In the three years prior to the *NanoTeach* project, Kendra had no prior experience with nanoscience, but had been integrating technology into her classroom. She uses iPod touches, projectors, computers and graphics every day in her lessons.

With regard to curriculum development, during this same time Kendra was busy developing her own science lessons and had worked on pacing guides for the district during the summer.

Kendra was interested in participating in *NanoTeach* because she had "little knowledge of nanotechnology, but I think it is where science is leading and think it is important for my students to understand what it is. I want my students to have the tools to be successful in the future and think this will give that to them."

With regard to teaching in an inquiry-based manner, Kendra had "tried to integrate more inquiry-based methods into my teaching. I have only done a few activities in this, but the students need more problem-solving skills prior to the lessons."

As a relatively new teacher, Kendra was not familiar with current research on effective science instruction as it relates to brain research in science education, research-based instructional strategies, how students learn, and formative assessment.

Kendra's professional development in the three years prior to *NanoTeach* included an NSTA conference, annual pedagogical development through her district and school, annual science content by the district, her own doctoral work in curriculum and instruction, and self-study on classroom management. As a result of this professional development, Kendra has "implemented several new classroom management strategies and classroom activities."

Kendra's *NanoTeach* Lessons[29]

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[27] The names of the teachers have been changed.
[28] These data was taken from the *NanoTeach* Teacher Application.
[29] For more detail on these lessons see: Huffman, D., Tweed, A. Ristvey, J. and Palmer, E. "Integrating Nanoscience and Technology in the High School Science Classroom" accepted for publication by NanoTechnology Reviews, August 2014.

Kendra's fall *NanoTeach* lesson integrated self-assembly into the biology curriculum as part of her unit on DNA. The lesson focused on the relationship between DNA, proteins, and traits as seen in cells making protein through self-assembly.

The following description from her fall unit plan describes how the lesson was integrated with core science content:

- Regular content: Students understand how DNA is transferred into proteins.
- Transition to nanoscience: Proteins are made through self-assembly.
- Nanoscience: Self-assembly is the process of things assembling with the introduction of an outside force.

Kendra's spring *NanoTeach* lesson was called "nano vs. cancer." This lesson was meant to connect the concepts of cells, cancer, and nanotechnology. Kendra integrated this lesson as part of the study of the immune system and disease:

> "The students will follow a 'Do-Talk-Do' model in order to make these connections. The students will be cells in a game of the human body, then they will do research into cancer and nanotechnology and discuss that with their groups and the class, and then students will play the game again, but this time there are some twists in the game. After we have played the game a second time, we will talk about the changes and the meaning behind these changes and their relationship to their research. This lesson is placed here to review cells before continuing on into diseases."

The following description from her spring unit plan describes how the lesson was integrated with core science content:

- Core Science Content: Cancer is caused by cells with something wrong with them and there is no cure. DNA is the building block of life and stores information for all cells.
- Transition to Nanoscience: Technology is advancing to help address issues in living things.
- Nanoscience: Nanotechnology advances can lead to cures and treatments for cancer and other diseases.

NS&T Content Knowledge

When assessed on her knowledge of the six Big Ideas of NS&T, Kendra showed significant growth over the course of the project (see Table B2 in Appendix C2). Kendra's initial score was 41 out of a possible 100 points. By the end of the year, her knowledge had increased resulting in a score of 59. **Her 18-point growth was more than the 14-point average growth for teachers in the Facilitated model.**

While Kendra significantly improved her overall NS&T content knowledge she did not demonstrate the ability to apply that knowledge as assessed by the five constructed response questions (0 of 13 possible points). In the end, Kendra was able to **master 59% of the NS&T content; less than the 65% average** for teachers in the Facilitated model**.**

Inquiry-Based Teaching Practices

Over the course of the project from baseline to spring 2013 Kendra demonstrated small improvements in the DESI areas of Content and Understanding, large improvements in the area of classroom Environment, and moderate improvements in Student Engagement based on the student survey of teacher classroom practices (see Table B3).

Kendra's **greatest growth was in her mastery of the DESI Environment strategies.** At baseline, her level of mastery was at 58% of the maximum score; by the end of the project in spring 2013 she was at 69%. In addition, Kendra demonstrated **moderate growth in her ability to engage students** going from 67% of the maximum score to 75% in the end.

Overall, Kendra's ability to implement these strategies at the end of the project was similar to that of other teachers in the Facilitated group. Her DESI Content-related classroom practices represented 70% of the maximum for this scale score (as compared to 73% for all teachers in the Facilitated group), 68% of the maximum for Understanding (70%), and 69% of maximum for Environment (70%). The resulting level of student engagement was also similar to other teachers in the Facilitated group (75% vs. 78%). **As such, in the end, Kendra demonstrated the moderate levels of mastery with regard to the DESI strategies and student engagement as the other *NanoTeach* participants in both the Facilitated and Team Study approaches.**

Planned and Enacted Curriculum

In examining the extent to which Kendra's planned and enacted instructional practices were likely to result in deep student understanding (see Table B4 in Appendix C2), her ratings based on the available evidence were generally "low" in all three DESI areas: Content, Understanding, and Environment.

Reviewer comments with regard to Content noted that objectives in both the fall and spring lessons were stated as "topics" rather than the "learning goals" outlined in DESI. And, while the spring lesson plan showed attention to the Big Ideas of NS&T the **connection to nano was not made** when enacted. In the area of Understanding, reviewers commented that in the spring lesson it was unclear whether a scientific question was part of the lesson, the research was provided by the teacher rather than gathered by the students, and it was **unclear whether student understanding was achieved** as there was no "wrap-up". Finally, with regard to Environment, the reviewers noted that Kendra's fall lesson was of a very low, elementary level and that it was **unclear** from her spring video whether students were able to **think scientifically** and **be metacognitive about their learning**.

Overall, there were no consistent patterns, including any change from baseline to spring 2013. This was primarily due to a general lack of evidence resulting in fewer ratings.

Case Study #2: Lucy – *NanoTeach* Facilitated Model

Who is Lucy?

Years of teaching H.S. science: 15
Subjects taught: Biology
Self rating-content (pre-*NanoTeach*): Limited experience
Self rating-pedagogy (pre-*NanoTeach*): Some experience
Fall Lesson: "Size-Dependent Properties in Sunscreen"
Spring Lesson: "Forces and Interactions Found in Living Things"

Lucy was a seasoned teacher having taught high school science for 15 years. Lucy taught Biology and participated in the fully Facilitated model of *NanoTeach* (see Table B1 in Appendix C2).

In the three years prior to the *NanoTeach* project, Lucy was "not too familiar with nanoscience, in particular," but had integrated biotechnology into many of her lessons. "My lessons on Organic Chemistry include the use of a spectrophotometer and discussion of protein assays with Western Blots, etc. My lessons on Genetics include DNA fingerprinting and electrophoresis as well as the advancements for Stem Cell treatments and the ethics surrounding this controversial topic. Anytime that I can, I include advancements of science to show the students how quickly our world in changing and how it will affect their future."

During this same time, as a veteran teacher, Lucy was on a district-wide committee that "reviews and revisits our state and local curriculum, often. [The district] provides up-to-date pacing guides for our science teachers." She also served on state committees to update Grade Level expectations and EAGLE testing questions to help students prepare for the End of Course testing. "I like to be in the midst of discussion with regard to lessons and curriculum that I am expected to teach; therefore, I participate in as many committees, workshops and think tanks as possible.

Lucy was interested in participating in *NanoTeach* because "I love to learn about and then teach the latest advancements in science. Creating interest of Biology at a "Real World" level is one of my goals as an educator. Also revealing careers in science is a focus that will always remain in my lessons. I feel that it is important that students understand all of the options that they have with regards to a career in science. They simply do not know what is out there and I like to enlighten them!"

With regard to teaching in an inquiry-based manner, Lucy said, "Inquiry based learning is a fantastic tool for creating thinkers instead of just learners. I use it when possible, but must admit that with the huge width of topics that we must cover, it is not always possible. I would like to make it more of my everyday plans."

As a veteran teacher, Lucy understood that "There is no doubt that students learn by DOING, not just by seeing or hearing. I am familiar with the latest trends to deepen the understanding of topics and lessen the breadth of such topics. Even the AP program in the sciences in particular is changing the way that they expect students to learn and perform on the AP exams. Fewer topics but with greater mastery and understanding is becoming the obvious way to teach. Having said this, research-based instruction is MUCH more effective than lecturing and memorizing many topics."

Lucy's professional development in the three years prior to *NanoTeach* included participating in district Pacing Guide reviews and updates every summer for the past 10 years; a summer workshop sponsored by an area college that include 40 hours of professional development and a fossil dig in the Mississippi River basin, all supported by Shell Oil company, that encouraged use of fossils to interest students in petroleum careers; EAGLE testing review committee for the state Dept. of Education; and a local and national Junior Science and Humanities Symposium (JSHS) competition for higher level students who are presenting work in research. Lucy said, "As a result of my experiences with these professional development opportunities, I feel that my practice as a classroom teacher has by enriched. Pacing guide review and EAGLE testing have made me aware of assessment tools that will be used to evaluate learning in the classroom. Other professional workshops surrounding special topics increase my experiences that I can share with my students. JSHS exposes me - and I in turn expose my students - to the latest topics and trends in science. It is here that I was first exposed to Nanotechnology while in Florida."

Lucy's *NanoTeach* Lessons[30]

Lucy's fall *NanoTeach* lesson, "Size-Dependent Properties in Sunscreen," focused on the properties of matter and changes with scale.

The following description from her fall unit plan describes how the lesson was integrated with core science content:

- Core Science: Properties of molecules and materials change as their surface to volume ratio changes.
- Nanoscience: Size dependent properties related to how molecules tend to become "invisible" when they reach nanosize.
- Core Science: The appearance of a substance (transparent vs. opaque) is dependent on the size of the individual molecules that make up that substance.
- Nanoscience: Not everything about a compound's appearance and effectiveness follows the rules when referring to smaller size particles. Light cannot reflect the same from a nanosized particle as it would from a micro or macro sized object, therefore certain substances may appear to be different, but have the same effectiveness with regards to the electromagnetic spectrum. In this case sunscreen with the active ingredient zinc.

Lucy's spring *NanoTeach* lesson was called "Forces and Interactions Found in Living Things" This lesson focused on the nature of forces, adhesion, and the factors that may affect the adhesion properties.

The following description from her spring unit plan describes how the lesson was integrated with core science content:

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[30] For more detail on these lessons see: Huffman, D., Tweed, A. Ristvey, J. and Palmer, E. "Integrating Nanoscience and Technology in the High School Science Classroom" accepted for publication by NanoTechnology Reviews, August 2014.

- Core Science: Form follows functions with regards to the shape and "job" of different anatomical structures. Organisms' homeostasis depends on these structures for survival and ultimately success as a species.
- Nanoscience: Forces and interactions. At the nanoscale, the dominant force shifts from gravity to electrostatic forces, specifically with the gecko, Van der Waal forces of attraction.
- Core Science: The shape of an object found in living things is directly related to its function.
- Nanoscience: Forces at work on the nanoscale are electrical in nature.

NS&T Content Knowledge

When assessed on her knowledge of the six Big Ideas of NS&T, Lucy showed significant growth over the course of the project. Lucy's initial score was 49 out of a possible 100 points (see Table B2 in Appendix C2). By the end of the year, her knowledge had increased resulting in a score of 72. Her **23-point growth was much more than the 14-point average growth** for teachers in the Facilitated model.

In addition to scoring well on the multiple choice portion of the assessment, Lucy was able to apply her knowledge more than Kendra. Lucy, however, **did not demonstrate any growth over time in her ability to apply this knowledge**, as assessed by the constructed response items, but rather came into the project at that level (5 out of the 13 possible points).

Of all the case study teachers, Lucy demonstrated the greatest mastery of NS&T content. In the end, Lucy was able to **master 72% of the NS&T content; more than the 65% average** for teachers in the Facilitated model**.**

Inquiry-Based Teaching Practice

Over the course of the project from baseline to spring 2013 Lucy demonstrated moderate improvements in the DESI areas of Content and classroom Environment and large improvement in the area of Understanding (see Table B3 in Appendix C2). Student Engagement, however, showed a small decline.

Lucy's **greatest growth was in her mastery of the DESI Understanding strategies.** At baseline, her level of mastery was at 62% of the maximum score; by the end of the project in spring 2013 she was at 75%. In addition, Lucy demonstrated **moderate growth in classroom Environment strategies** going from 64% of the maximum score to 73% in the end. At baseline, her ability to engage students was at 80%; this declined to 75% at the end of the project.

Overall, Lucy's ability to implement these strategies at the end of the project was similar to that of other teachers in the Facilitated group. Her DESI Content-related classroom practices represented 73% of the maximum for this scale score (the same as teachers in the Facilitated group), 75% of the maximum for Understanding (somewhat higher than the group average of 70%), and 73% of maximum for Environment (70%). The resulting level of student engagement was also similar to other teachers in the Facilitated group (75% vs. 78%). **As such, in the end, Lucy demonstrated the moderate levels of mastery with regard to the DESI strategies and student engagement as the other *NanoTeach* participants in both the Facilitated and Team Study approaches.**

Planned and Enacted Curriculum

In examining the extent to which Lucy's planned and enacted instructional practices were likely to result in deep student understanding (see Table B4 in Appendix C2), her ratings based on the available evidence were generally "moderate" or "high" in the DESI areas of Content and Environment and "low" or "moderate" for Understanding with the **higher ratings were generally for the planned curriculum**.

Reviewer comments with regard to Content noted the general **lack of NS&T content** in both the fall and spring lessons, no implementation around a conceptual goal in the fall, and lack of alignment between an activity and the content in the spring. With regard to Understanding, reviewers noted that in the fall lesson the **emphasis was on teacher-led** not student-led instruction. In the spring lesson, although there was evidence of inquiry and a wrap-up, however, **student understanding of nano forces was not achieved**. Finally, with regard to Environment, the reviewers noted that the fall lesson was not implemented as planned and that the learning environment for the spring lesson was "nice," but that **student-led inquiry, metacognition, and criterion-referenced feedback were lacking.**

Overall, the only **consistent pattern was higher ratings for planning and lower ratings for enactment.** There was no evidence of change from baseline to spring 2013; this was primarily due to a general lack of evidence resulting in fewer ratings for baseline artifacts.

Case Study #3: Julie – *NanoTeach* Team Study Model

Who is Julie?

Like Kendra who participated in the Facilitated model, Julie was a relatively new teacher coming into the project having taught high school science for 5 years (see Table B1 in Appendix C2). Julie taught Biology, Chemistry, Physical Science, and Physics and participated in the Team Study model of *NanoTeach*.

Years of teaching H.S. science: 5
Subjects taught: Biology, Chemistry, Physical Science and Physics
Self rating-content (pre-*NanoTeach*): Limited experience
Self rating-pedagogy (pre-*NanoTeach*): Some experience
Fall Lesson: "Diffusion"
Spring Lesson: "Nanoparticle Use in Medicine"

In the three years prior to the *NanoTeach* project, Julie participated in a workshop where "we discussed the use of nanotechnology to measure internal organelles of a cell." She did not get an opportunity to work hands on with the technology, however.

During this same time, as a new teacher, she was developing her science lesson plans for her high school Biology classes. Julie had no previous experience in developing nanoscience curriculum.

Julie was interested in participating in *NanoTeach* because, "I am always eager to learn more about emerging technology that will allow me to create creative and interesting lesson plans. I want my students to have as much exposure to new technology as possible. I believe the *NanoTeach* project will allow me to learn more about nano technology as it is related to biology and bring back a new approach to teaching the subject."

With regard to teaching in an inquiry-based manner, Julie said "I try to offer several inquiry-based activities to students throughout the school year. In a digestion lab I give students a list of possible materials and allow them to develop their own lab to explore the function of digestion. I give students research assignments that allow them to explore, on their own, a topic related to the biology curriculum. In the past I have had students develop a lab to test their own hypothesis on any topic they choose. I believe some students do well with lessons based on inquiry and others struggle. I try to find the correct approach to help all students."

As a relatively new teacher, Julie was unsure about "'research' based science instruction, but I can tell you through trial-and-error what has been successful in my classroom. I believe science is best taught to most students using a hands-on approach. Students tend to tie information to things they've experienced, not what they were told or things they've seen. I try a lot of demonstrations and modeling in teaching science. We make models of the cell, models of the body and others as well. For formative assessment I believe probes work well. It allows you to see what students know, what they think they know, and if there are misconceptions in what they know."

Julie's professional development in the three years prior to *NanoTeach* included annual summer workshops that involved three weeks of "investigating, learning and developing activities that we could bring back to the classroom. The workshops focused on different areas of the Life Science curriculum as it related to both high school and middle school sciences. I learned so many new strategies and a lot of content that has allowed me to grow significantly as a teacher." Julie said, "I have been able to engage students more often as a result of the summers spent at these workshops. After each summer session I was a little more confident about the upcoming school year and had new things to try and integrate into my lesson plans."

Julie's *NanoTeach* Lessons[31]

Julie's fall *NanoTeach* lesson integrated the concept of surface area to volume into the biology curriculum as part of her unit on cell transport.

The following description from her unit plan describes how the lesson was integrated with core science content:

- Core Science Content: Supplies enter and wastes leave the cell through plasma membrane which covers the circumference of the cell, therefore cells are small and cannot survive if they are too large.
- Nanoscience Content: The surface-area-to-volume ratio increases as objects become smaller.

Julie's spring *NanoTeach* lesson examined "Nanoparticle Use in Medicine." This lesson was meant to address the connections between science, technology, and society within a unit on the human body.

The following description from her unit plan describes how the lesson was integrated with core science content:

- Core Science Content: Structure and function are a repetitive theme in biology. The structure of things, especially in the human body, frequently determines their function. New technologies allow doctors and researchers to diagnose and treat many diseases that were unheard of or untreatable many years ago. These new technologies may save lives, but the risks of some are still unknown. Scientific advances and emerging technologies can affect society.
- Transition to Nanoscience: The properties of matter can change on the nanoscale.
- Nanoscience: Nanotechnology is being used to make many products that could revolutionize the medical industry. Many procedures are minimally invasive and provide doctors with new arsenal of tools to diagnose treat and cure many diseases.

[31] For more detail on these lessons see: Huffman, D., Tweed, A. Ristvey, J. and Palmer, E. "Integrating Nanoscience and Technology in the High School Science Classroom" accepted for publication by NanoTechnology Reviews, August 2014.

NS&T Content Knowledge

When assessed on her knowledge of the six Big Ideas of NS&T, Julie showed significant growth over the course of the project. Julie's initial score was 33 out of a possible 100 points (see Table B2 in Appendix C2). By the end of the year, her knowledge had increased resulting in a score of 57. **Her 23-point growth was almost twice the 12-point average** growth for teachers in the Team Study model.

While Julie significantly improved her overall NS&T content knowledge she did not demonstrate the ability to apply that knowledge as assessed by the five constructed response questions (0 of 13 possible points). **Like Kendra, the other relatively new teacher, Julie demonstrated less mastery of NS&T content.** In the end, Julie was able to **master 57% of the NS&T content; much less than the 68% average** for teachers in the Team Study model**.**

Inquiry-Based Teaching Practice

Over the course of the project from baseline to spring 2013 Julie demonstrated moderate improvements in the DESI areas of Content and Understanding and large improvement in the area of classroom Environment (see Table B3 in Appendix C2). Improvements in Student Engagement were small.

Julie's **greatest growth was in her mastery of the DESI classroom Environment strategies.** At baseline, her level of mastery was at 59% of the maximum score; by the end of the project in spring 2013 she was at 71%. In addition, Lucy demonstrated **moderate growth in Content strategies** going from 64% of the maximum score to 73% in the end and in **DESI Understanding (from 66% to 70%)**. At baseline, her ability to engage students was at 75%; this increased slightly to 81% at the end of the project.

Overall, Julie's ability to implement these strategies at the end of the project was similar to that of other teachers in the Team Study group. Her DESI Content-related classroom practices represented 77% of the maximum for this scale score (somewhat higher than the 73% average for the Team Study group), 70% for Understanding (about the same as the group average of 69%), and 71% for Environment (69%). The resulting level of student engagement was also similar to other teachers in the Team Study group (81% vs. 77%). **As such, in the end, Julie demonstrated the moderate levels of mastery with regard to the DESI strategies and student engagement as the other *NanoTeach* participants in both the Facilitated and Team Study approaches.**

Planned and Enacted Curriculum

In examining the extent to which Julie's planned and enacted instructional practices were likely to result in deep student understanding (see Table B4 in Appendix C2), her ratings based on the available evidence were generally "moderate" or "high" in all three of the DESI areas of Content, Understanding and Environment with the **higher ratings generally for the planned curriculum**.

Reviewer comments with regard to Content noted that although the fall lesson sufficiently addressed surface area to volume, the **NS&T content** and application was inadequate. In the spring the content of NS&T in Society seemed to be well implemented, though reviewers did not see students engaging with each other or discussing with the teacher (i.e., **teacher-led**). With regard to Understanding, reviewers noted that the fall activities seemed to help students understand the concept, but that the teacher did not make conceptual connections as it related to the nano content and that the instruction did **not**

actively engage students in inquiry. Reviewers also commented that the spring lesson **lacked a demonstration of student understanding** through students reporting out or a wrap-up. Finally, with regard to Environment, the reviewers commented that this was the **only case study teacher that engaged students in metacognition** through the use of the 3-2-1 activity. It was **unclear whether this teacher utilized the feedback data** she obtained. As for "engaging students with stimulating content," reviewers commented that the fall lesson was **"**too slow, too easy" and **connections to learning goals were not made**. The spring lesson, however, was noted as having high student engagement, being relevant to students, and that the research and reporting out went well.

Overall, the only **consistent pattern for Julie was higher ratings for planning and lower ratings for enactment.** There was no evidence of change from baseline to spring 2013; this was primarily due to a general lack of evidence resulting in fewer ratings for baseline artifacts.

Case Study #4: Shannon – *NanoTeach* Team Study Model

Who is Shannon?

Years of teaching H.S. science: 17
Subjects taught: Biology and Physical Science
Self rating-content (pre-*NanoTeach*): Limited experience
Self rating-pedagogy (pre-*NanoTeach*): Some experience
Fall Lesson: "Diffusion"
Spring Lesson: "Crystal Formation and Self-Assembly"

Like Lucy who participated in the Facilitated model, Shannon was a seasoned teacher having taught high school science for 17 years (see Table B1 in Appendix C2). Shannon taught Biology and Physical Science and participated in the Team Study model of *NanoTeach*.

Prior to the *NanoTeach* project, Shannon had "integrated very little in nanoscience or technology in the last three years of teaching. I hope to get more materials and ideas from this workshop to be able to incorporate it."

During this same time, as a veteran teacher, Shannon was "always looking for new information and activities or labs to help students gain a better understanding of the concepts we cover."

Shannon was interested in participating in *NanoTeach* because "I hope to get more materials and ideas from this workshop to be able to incorporate it. Nanotechnology is already integrated into my students' lives in ways neither they nor I know. It is also hold a great future occupation for them."

With regard to teaching in an inquiry-based manner, Shannon said, "I continue to try to add more labs and activities to help the students figure things out for themselves given a little background information. It continues to be frustrating, especially with the lower high school grade levels, to get them to do more than 'fill in the blank' work and actually think."

With regard to current research on effective science instruction, Shannon had "read a little on the topic" but actually felt that she knew very little.

Shannon's professional development in the three years prior to *NanoTeach* included a local "Nanotech" teacher lab experience in nanotechnology and several NSF-funded workshops on topics that included, astronomical physics, and pollution.

Shannon said “I have gained knowledge, gotten materials and gathered useful labs and activities from my professional development.”

Shannon’s *NanoTeach* Lessons[32]

Shannon’s fall *NanoTeach* lesson integrated the concept of surface area to volume into her unit on solutions. The lesson focused on calculations of surface area and volume for a variety of geometric shapes.

The following description from her unit plan describes how the lesson was integrated with core science content:

- Core Science Content: The rate of solubility depends on the surface area available.
- Nanoscience: An object’s surface-area-to-volume ratio depends on its size and shape. The surface-area-to-volume ratio increases as objects become smaller. As a result, as the size (length scale) of an object approaches the nanoscale, the fraction of the atoms on the surface increases dramatically, and surface-related properties become more important.

Shannon’s spring *NanoTeach* lesson was about “Crystal Formation and Self-Assembly.” This lesson was meant to model the idea of self-assembly. Shannon integrated this lesson as part of her unit on chemistry in her physical science course.

The following description from her unit plan describes how the lesson was integrated with core science content:

- Core Science: Entropy drives processes toward more disorder. To drive processes toward order energy must be put into the system. Compounds bond and arrange themselves in a specific way. Some elements are not found uncombined in nature due to their reactivity. Energy of reactions can be conserved even when self-assembly seems to violate entropy rules.
- Transition to Nanoscience: Even though we cannot see what is happening, chemical align themselves in specific ways.
- Nanoscience: Forces, attractive and repulsive, particularly charge, can be manipulated on structures. Due to the forces on nearby objects, objects themselves will move to minimize energy. For example, repulsive particles will push objects away, attractive forces will bring them together. By controlling these forces, and the environment, scientists can create structures with specific purposes.

NS&T Content Knowledge

When assessed on her knowledge of the six Big Ideas of NS&T, Shannon showed a **significant decline over the course of the project**. Shannon’s initial score was 62 out of a possible 100 points (see Table B2 in Appendix C2). At the end of the year her score on the assessment decreased to 49. **Her 13-point decline** was unusual given that the average 12-point growth for teachers in the Team Study model. Having demonstrated a high degree of knowledge on the initial assessment, these and other results may

[32] For more detail on these lessons see: Huffman, D., Tweed, A. Ristvey, J. and Palmer, E. “Integrating Nanoscience and Technology in the High School Science Classroom” accepted for publication by NanoTechnology Reviews, August 2014.

suggest other factors at play with regard to this teacher's declining performance over the course of the project.

Initially, Shannon scored 3 out of 13 possible points on the five constructed response questions, which required application of knowledge; at the end, she received no points. **Like Julie, the other Team Study teacher in the case study, Shannon demonstrated less mastery of NS&T content.** In the end, of all the case study teachers Shannon showed the **least mastery of the NS&T content at 49%; much less than the 68% average** for teachers in the Team Study model**.**

Inquiry-Based Teaching Practice

Over the course of the project from baseline to spring 2013 Shannon significantly declined in her demonstrated abilities in the DESI areas of Content, Understanding, classroom Environment (see Table B3 in Appendix C2). A similar, but less pronounced decline was also seen in her ability to engage students.

Shannon's **greatest area of decline was in her mastery of the DESI classroom Environment strategies.** At baseline, her level of mastery was at 65% of the maximum score; by the end of the project in spring 2013 she was at 53%. In addition, Shannon saw a decline in her demonstrated ability in **Content strategies** going from 72% of the maximum score to 67% in the end and in **DESI Understanding (from 69% to 62%)**. At baseline, her ability to engage students was at 70%; this also decreased 65% at the end of the project.

Overall, **Shannon's ability to implement these strategies at the end of the project was significantly less that of other teachers in the Team Study group.** Her DESI Content-related classroom practices represented 67% of the maximum for this scale score (lower than the 73% average for the Team Study group), 62% for Understanding (lower than the group average of 69%), and 53% for Environment (far lower than the group average of 69%). The resulting level of student engagement was also far below other teachers in the Team Study group (65% vs. 77%). **As such, in the end, Shannon demonstrated low levels of mastery with regard to the DESI strategies and student engagement in comparison with the other *NanoTeach* participants in both the Facilitated and Team Study approaches.**

Planned and Enacted Curriculum

In examining the extent to which Shannon's planned and enacted instructional practices were likely to result in deep student understanding (see Table B4 in Appendix C2), her ratings based on the available evidence were generally "moderate" or "high" in all three of the DESI areas of Content, Understanding and Environment with the **higher ratings generally for the planned curriculum**.

Reviewer comments with regard to Content noted that the fall lesson **lacked clarity regarding the purpose of the activity** and students struggling with mathematical calculations. The spring lesson, reviewers noted, provided some context for the content, but the instruction **did not address any nano forces at work**. With regard to Understanding, reviewers commented that in the fall lesson the teacher pushed forward after learning that **students did not have the requisite prior knowledge**. In the spring, reviewers noted there was **no inquiry**, **no wrap up** for student understanding, and **students were not engaged**. Finally, with regard to Environment, the reviewers commented that because the **expectations were low**, the pace of instruction **too slow** and mathematical problems **overshadowed the science** that most **students were not engaged** in the fall lesson. Much the same was true for the spring lesson with regard to low expectations, low-level content, and lack of student engagement.

Overall, the **consistent patterns for Shannon were higher ratings for planning and lower ratings for enactment** and **lack of ability to engage students through effective science instruction on many levels**. There was no evidence of change from baseline to spring 2013; this was primarily due to a general lack of evidence resulting in fewer ratings for baseline artifacts.

Reflections across the Case Studies

As was true in the analysis of all participating teachers, these case studies did not reveal a discernible pattern in the NS&T content knowledge and inquiry-based classroom practices by *NanoTeach* model Facilitated vs. Team Study nor by years of teaching (new vs. veteran teachers). Three of the four case study teachers demonstrated results similar to all *NanoTeach* participants. Findings related to the fourth case study teacher were unclear with the teacher's initially stellar performance significantly worsening at the end of the project.

NS&T Content Knowledge

Three out of the four case study teachers demonstrated significant growth in content knowledge. Of these, one reached a high level of mastery (72%) while the other two were below the mastery of other teachers in their respective *NanoTeach* models at or near 60% mastery.

Inquiry-Based Pedagogy and Student Engagement

The same three case study teachers typically demonstrated the greatest improvement in their ability to implement the DESI classroom Environment strategies, which included ways to motivate students, support them in taking responsibility for their learning, and fostering positive relationships with and among students. One teacher—the veteran teacher in the Facilitated group—also significantly improved her ability to enhance student Understanding. In the end, as was true for the project as a whole, three of the four case study teachers demonstrated moderate levels of mastery for all aspects of the DESI framework: Content, Understanding, and Environment. The same was true for these teachers' ability to promote student engagement.

Planned vs. Enacted Curriculum

For all four case study teachers, it was commonly noted that the quality of the planned curriculum was higher than what was enacted. In addition, the data emerging from the LQAT for all of the case study teachers indicated a general lack of the following elements within DESI C-U-E framework:

- Clear connections to NS&T content and between NS&T and the Big Idea or overarching concepts in science.
- Use of inquiry strategies that ensure learning is student-led rather than teacher-led.
- Evaluation of student understanding throughout the lesson and through a final wrap-up.
- Use of feedback on student performance to enhance and direct learning.
- Opportunities for students to be metacognitive about their learning.

And, as noted throughout, there was no evidence of change from baseline to spring 2013, due primarily to a general lack of evidence in the baseline artifacts which did not align with the LQAT as an analytical tool. The baseline data collection was designed to reflect the more typical inquiry-based analyses. The LQAT analytical framework, which was developed after these data were collected, emphasized the DESI strategies. As a result, fewer ratings were made at baseline.

Appendix C1: Lesson Quality Assessment Tool (LQAT) Training Guide

Lesson Quality Assessment Tool (LQAT): Training Guide

The purpose of *NanoTeach* is to support teachers in designing and implementing lessons that integrate new content (nanoscience and technology) in a manner that reflects effective science instruction.

Purpose of LQAT

This tool is designed to examine classroom artifacts to assess the extent to which the ***planned and enacted instructional practices*** *are likely to result in* ***deep student understanding***. <u>The focus should be on instruction, not on student performance</u>.

Definitions and Artifacts

- Planned instructional practices: What the teacher plans to do (lesson plan, unit plan).
- Enacted (implemented) instructional practices: What the teacher actually does in the classroom (video, reflection log, student handouts).
- Deep student understanding: Has a focus on understanding NS&T concepts within the discipline through higher order thinking (HOT), rather than more rote memorization of factual information.

Quality Ratings

H = High degree: Very likely to result in deep student understanding (i.e., primary emphasis on NS&T concepts/HOT and little emphasis on factual/memorization)

M = Moderate degree: Somewhat likely to result in deep student understanding (i.e., some emphasis on NS&T concepts/HOT and some emphasis on factual/memorization)

L = Low degree: Not likely to result in deep student understanding (i.e., little or no emphasis on NS&T concepts/HOT and primary emphasis on factual/memorization)

Structure of the LQAT Rating Form

The LQAT has three <u>areas</u> that align with the DESI model of Content, Understanding and Environment (C-U-E). Each part has multiple sub-<u>sections</u>.

For example, <u>Area 1: Content</u> has two subsections:

- Section 1: Learning Objectives
- Section 2: Presence of Nano Science Big Ideas

Within each section are individual DESI strategies to be assessed.

Rating the Evidence

Step 1: In the first step, you will be asked to look for evidence of (a) planning and (b) implementation of each of the <u>individual strategies</u> within an area. If there is no evidence, check the box for “N/A” (not available).

Step 2: If there is evidence, you will be asked to (a) rate the quality of that evidence as noted above and (b) provide a brief description of the evidence, including the data source (i.e., lesson plan, unit plan, video, reflection log, student materials).

Step 3: Repeat Steps 1 and 2 to provide an overall rating for the section and the broader DESI strategy area.

How to Review the Evidence – General Decision Rules

Planning and implementation of the strategies should be clearly in evidence:

- Do not score it if you have no evidence. Instead, check box for "N/A" (not available). Insufficient evidence does not mean that it was not done at a high level.
- Should be clear evidence of fidelity of implementation. Doing one strategy well, should be commended – doing more isn't necessarily the goal or the expectation.
- Do not hold the bar so high, that no one can get over it.
- Likewise, do not infer teacher intent beyond the evidence to get to a higher rating.
- Be aware of your own biases, such as personal knowledge of the subject area and/or a non-teacher perspective.
- *Remember to keep the focus on the instruction – planned and implemented – and not on student performance. If it is clear by student behavior that the teacher was not able to fully implement a strategy, then that should, however, reflect on the fidelity of instruction.*

How to Review the Evidence – By Artifact

- Lesson Plan
- Unit Plan
- Video
- Reflection Log

Lesson Quality Assessment Tool	**Instructional Quality: Extent to which instruction is likely to result in deep student understanding** H = High degree: primary emphasis on NS&T concepts /HOT and little emphasis on factual/memorization M = Moderate degree: some emphasis on NS&T concepts /HOT and some emphasis on factual/memorization L = Low degree: little or no emphasis on NS&T concepts /HOT and primary emphasis on factual/memorization N/E = No Evidence	**Sources of Evidence:** *L – Lesson Plan* *U – Unit Plan* *V – Video* *R – Reflection Log*
Lesson Title:		
Date: **Rater:**		

PART 1: CONTENT		**QUALITY**			**Evidence in Plan: Unit/Lesson Plan**	**Evidence in Plan Implementation: Video/Reflection**
Section 1: Learning Objectives	**N/E**	**H**	**M**	**L**		
• Clearly stated conceptual learning goal To be observed, it must be clearly communicated in some way (e.g., student handout, on board, in discussion). (record learning goal)						
• Linked to previous learning and stated to students (e.g., previous lesson on size and scale or size and scale board, or previous lessons) What do we know (e.g., through K-W-L or brainstorming)						
• Selected activity that is appropriate to help students develop understanding Did the selected activity align with the learning goal?						
• Engaging students intellectually with content Essential questions: why is it valuable to learn this (current science, interesting, addresses large questions, relevancy, etc.) – i.e., rationale.						
• Storyline (connecting ideas back to prior knowledge) evident Connecting ideas to prior knowledge (more conceptual, might be from previous learning in or out of class; purpose is to help students recognize a context for the lesson. Should clearly build on something that they've experienced.						
Section 2: Presence of Nano Science Big Ideas						
Nanoscale science concept addressed	1. Size & Scale Size-dep. properties					
	2. Size-dep. properties					
	3. Structure of matter					
	4. Forces & Interactions					
	5. Self-assembly					
	6. Tools & Instrumentation					
	7. Nano in society					
	8. Quantum mechanics					
	9. Models & simulations					
Overall Content Score		**H**	**M**	**L**		

Lesson Quality Assessment Tool		**Instructional Quality: Extent to which instruction is likely to result in deep student understanding** H = High degree: primary emphasis on developing conceptual understanding of NS&T concepts /HOT and little emphasis on factual/memorization M = Moderate degree: some emphasis on developing conceptual understanding of NS&T concepts /HOT and some emphasis on factual/memorization L = Low degree: little or no emphasis on developing conceptual understanding of NS&T concepts /HOT and primary emphasis on factual/memorization N/E = No Evidence	**Sources of Evidence:** *L – Lesson Plan* *U – Unit Plan* *V – Video* *R – Reflection Log*
Lesson Title:			
Date:	**Rater:**		

UNDERSTANDING		**QUALITY**			**Evidence in Plan: Unit/Lesson Plan**	**Evidence in Plan Implementation: Video/Reflection**
Addresses Prior Student Knowledge	**N/E**	**H**	**M**	**L**		
• Identifies needed background knowledge of students						
• Elicits and addresses students prior knowledge						
• Provides instruction that moves student's understanding from naïve to scientific (conceptual change model) ➢ Addresses and/or builds upon prior knowledge ➢ Pre- and misconceptions identified and addressed						
Provides Inquiry-based Instruction	**N/E**	**H**	**M**	**L**		
• Learner inquires when they: ➢ engage in scientifically oriented questions ➢ give priority to evidence ➢ formulate explanations from evidence (classroom discourse) ➢ connect explanations to scientific knowledge ➢ communicate and justify explanations						
Employs Formative Assessment Processes	**N/E**	**H**	**M**	**L**		
• Implements true formative assessment in the lesson						
• After instruction, gathers data to determine student progress relative to the learning goal						
• Uses data to inform instruction and/or provide feedback						
Engages Students in Sense-making or Wrap-up	**N/E**	**H**	**M**	**L**		
• Sense-making opportunities are provided that return students to the learning goal and concept development through structured activities such as: ➢ Discussion/science discourse ➢ Representations of the learning (written, nonlinguistic) ➢ Application of learning to new situations						
• Wrap-up facilitates: ➢ Reflecting on and connecting what was learned by ▪ Asking further questions ▪ Integrating into past learning						

▪ Building student's cognitive framework					
Overall Understanding Score	**H**	**M**	**L**		

Lesson Quality Assessment Tool		Instructional Quality: Extent to which instruction is likely to result in deep student understanding	Sources of Evidence:
Lesson Title:		H = High degree: Positive classroom environment where students ask questions, challenge thinking and are active learners. Discussion in support of understanding is clearly evident M = Moderate degree: Classroom environment has no behavioral management issues and students are primarily in a teacher centered classroom. Some discussion of observations is included L = Low degree: Little or no emphasis on a student-centered classroom environment and student work is more passive and activity based. Little or no student discussion is provided.	*L – Lesson Plan* *U – Unit Plan* *V – Video* *R – Reflection Log*
Date:	**Rater:**		

ENVIRONMENT		QUALITY			Evidence in Plan: Unit/Lesson Plan	Evidence in Plan Implementation: Video/Reflection
Develops Positive Attitudes and Motivation	**N/E**	**H**	**M**	**L**		
• Does the lesson intellectually engage the students? (intrinsic motivation, thinking about the topic at hand, asking questions, talking to peer group)						
• Procedures are in place to support a positive, collaborative environment (Students' know what is expected and realize the teacher is there to support them.)						
Thinks Scientifically	**N/E**	**H**	**M**	**L**		
• Student work collaboratively ➢ Use of different resources and expertise ➢ Researching prior studies/results						
• Asks and answering questions during discussion						
• Uses and testing hypothesis and predictions						
• Communicates findings from data						
• Argues the evidence and makes inferences from the data ➢ Error analysis. ➢ Recognizes bias in scientific explanations. ➢ Thinks critically and creatively						
Teaches Students to be Metacognitive	**N/E**	**H**	**M**	**L**		
• Students are asked to reflect on what they know, don't know, and need to work on next (e.g., reflection cards, Peer and self-assessment)						
Provides Feedback	**N/E**	**H**	**M**	**L**		
• Descriptive feedback (what they've done well and what to work on next) relates to the learning goal						
• Feedback is back-and-forth between students and teachers relative to the lesson learning goal						
Overall Environment Score		**H**	**M**	**L**		
COMMENTS:						

Appendix C2: Data Tables

Table B1: Characteristics of case study teachers.

	Kendra	Lucy	Julie	Shannon
NanoTeach Model	Facilitated	Facilitated	Team Study	Team Study
Years Teaching H.S. Science	4	15	5	17
Subject Areas Taught	Physical Science	Biology	Biology Chemistry Physical Science Physics	Biology Physical Science
Prior Experience with NS&T	No experience	Limited experience	Limited Experience	Limited Experience
Prior Experience with Inquiry-Based Teaching	Limited experience	Some experience	Some experience	Some experience

Source: *NanoTeach* Teacher Application, fall 2011 and winter 2012.

Table B2: Pre and post assessment data for case study teachers.

	Facilitated			Team Study		
Pre	**All**	**Kendra**	**Lucy**	**All**	**Julie**	**Shannon**
Weighted Multiple Choice (max. 87)	48.3	41.2	43.8	52.5	33.5	59.2
Weighted Constructed Response (max. 13)	2.6	0.0	5.2	3.5	0.0	2.6
Weighted Total (max. 100)	50.9	41.2	49.0	56.0	33.5	61.8
Post	**All**	**Kendra**	**Lucy**	**All**	**Julie**	**Shannon**
Weighted Multiple Choice (max. 87)	59.8	59.1	66.8	60.9	56.5	48.8
Weighted Constructed Response (max. 13)	5.5	0.0	5.2	6.7	0.0	0.0
Weighted Total (max. 100)	65.4	59.1	72.0	67.6	56.5	48.8
Growth	**All**	**Kendra**	**Lucy**	**All**	**Julie**	**Shannon**
Weighted Multiple Choice (max. 87)	+ 11.5	+ 17.9	+ 23.0	8.4	+ 23.1	- 10.5
Weighted Constructed Response (max. 13)	+ 2.9	0.0	0.0	3.2	0.0	- 2.6
Weighted Total (max. 100)	+ 14.4	+ 17.9	+ 23.0	11.7	+ 23.1	- 13.1

Source: *NanoTeach* Pre-Post Assessment of Teacher Knowledge, May 2012 and May 2013.

Table B3: Student perceptions of teacher use of DESI C-U-E instructional practices and student engagement.

	Facilitated						Team Study					
	KD			SW			JM			SC		
Content (max=24)	**N**	**Mean**	**S.D.**	**N**	**Mean**	**S.D.**	**N**	**Mean**	**S.D.**	**N**	**Mean**	**S.D.**
Baseline	20	16.5	2.4	21	16.8	1.8	28	17.1	2.6	17	17.2	2.0
Fall	23	16.8	1.6	19	17.4	1.0	14	17.6	1.6	2	16.5	0.7
Spring	15	16.9	1.5	22	17.6	1.4	12	18.4	2.2	25	16.0	1.6
B to S effect size[1]	0.21			0.50			0.54			-0.67		
% of Max – Baseline	69%			70%			71%			72%		
% of Max – Spring[2]	70% (73%)			73% (73%)			77% (73%)			67% (73%)		
Understanding (max=108)	**N**	**Mean**	**S.D.**	**N**	**Mean**	**S.D.**	**N**	**Mean**	**S.D.**	**N**	**Mean**	**S.D.**
Baseline	20	69.1	9.6	21	66.6	9.5	28	71.8	8.7	17	74.1	6.7
Fall	23	71.0	10.7	19	81.6	6.6	14	76.6	7.9	2	75.5	0.7
Spring	15	73.2	12.8	22	81.3	7.9	12	76.1	6.9	25	66.8	8.6
B to S effect size	0.37			1.69			0.55			-0.95		
% of Max – Baseline	64%			62%			66%			69%		
% of Max – Spring	68% (70%)			75% (70%)			70% (69%)			62% (69%)		
Environment (max=56)	**N**	**Mean**	**S.D.**	**N**	**Mean**	**S.D.**	**N**	**Mean**	**S.D.**	**N**	**Mean**	**S.D.**
Baseline	20	32.4	5.8	21	35.9	7.9	28	33.1	7.2	17	36.5	5.5
Fall	23	34.6	8.8	19	40.2	5.1	14	34.2	3.1	2	37.5	0.7
Spring	15	39.0	6.2	22	40.6	7.5	12	39.8	7.4	25	29.6	8.8
B to S effect size	1.10			0.61			0.92			-0.97		
% of Max – Baseline	58%			64%			59%			65%		
% of Max - Spring	69% (70%)			73% (70%)			71% (69%)			53% (69%)		
Source: *NanoTeach* Student Survey of Classroom Practices, fall 2012 and spring 2013.												

Table B3: Student perceptions of teacher use of DESI C-U-E instructional practices and student engagement (continued).

Engagement (max=32)	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.
Baseline	20	21.4	4.7	21	25.6	4.9	28	23.9	5.7	17	22.6	4.5
Fall	23	22.2	4.1	19	26.1	2.4	14	24.1	5.1	2	25.5	0.7
Spring	15	24.0	3.0	22	24.0	3.8	12	25.8	2.9	25	20.9	4.0
B to S effect size	0.68			-0.37			0.44			-0.40		
% of Max – Baseline	67%			80%			75%			70%		
% of Max - Spring	75% (78%)			75% (78%)			81% (77%)			65% (77%)		

Notes:

[1]Effect size = (mean spring score – mean baseline score) / [(s.d. spring + s.d. baseline)/2]. Effect sizes of 0.20 to 0.49 are small; 0.50 to 0.79 are moderate; and 0.80+ are large.

[2]Average percent of maximum for *NanoTeach* group (all facilitated or all team study teachers) is noted in parentheses.

Source: *NanoTeach* Student Survey (baseline spring 2012, fall 2012, and spring 2013).

Table B4: Consensus ratings from Lesson Quality Assessment Tool (LQAT) for case study teachers.

Participant	Category	Base Lesson Plan	Base Video	Fall Lesson Plan	Fall Video	Spring Video	Spring Video	Comments [NOTE – I left in the comments as is, but we may wish to edit or remove them]
Kendra Facilitated Model	**Content**							
	Learning Objectives	NE	NE	M	L	L	L	Fall and Spring: objectives not stated as learning goals, rather as topics Spring plan shows attention to nano big ideas Spring video shows cancer cures understanding was not developed, no nano connections made.
	Big Ideas	NE	NE	H	H	H	NE	
	Overall Score	NE	L	M	L	M	L	
	Understanding							
	Student Prior Knowledge	NE	L	L	L	M	L	Fall: incomplete lesson plan was posted. The unit plan was more complete and would possibly earn higher scores. Evaluators felt it should be based on lesson plan and video. Spring: Unclear if scientific question involved. Research was provided by teacher, and student understanding undetermined. No final wrap up in video
	Inquiry-based Instruction	NE	NE	L	L	L	L	
	Formative Assessment Process	NE	NE	NE	NE	L	L	
	Wrap-up - Student Engagement	NE	NE	NE	NE	M	L	
	Overall Score	NE	L	L	L	L	L	
	Environment							
	Positive Attitude and Motivation	NE	L	NE	L	L	L	Fall: Engagement with following direction, not the science content. Very low expectations shown in activity that could be done in 2nd grade. Spring: the evidence on the video lacked clarity as to what students may or may not be thinking.
	Thinks Scientifically	NE	L	NE	L	H	L	
	Metacognitive Teaching	NE	NE	NE	NE	NE	NE	
	Feedback	NE	NE	NE	NE	NE	NE	
	Overall Score	NE	L	NE	L	M	L	

Table B4: Consensus ratings from Lesson Quality Assessment Tool (LQAT) for case study teachers (continued)

Participant	Category	Base Lesson Plan	Base Video	Fall Lesson Plan	Fall Video	Spring Video	Spring Video	Comments
Lucy Facilitated Model	**Content**							
	Learning Objectives	NE	M	H	L	H	M	Fall: Little emphasis on nano content, and did not implement or carry forward a conceptual goal. Spring "M" rating gives credit for a good intro and plan, however the lesson in low quality as far as the activity matching the content, and the student engagement being missing on the nano content.
	Big Ideas	NE	NE	H	L	H	M	
	Overall Score	NE	M	H	L	H	M	
	Understanding							
	Student Prior Knowledge	NE	M	M	L	M	L	Fall: The teacher does not implement in the classroom what is planned on paper. The plan itself has elements of DESI , but emphasis is on teacher led, not student-led Spring: Evaluators gave the teacher credit for doing inquiry and a wrap-up. However overall student understanding of nano forces at work on gecko feet is not achieved.
	Inquiry-based Instruction	NE	L	M	L	M	M	
	Formative Assessment Process	NE	NE	M	L	L	L	
	Wrap-up - Student Engagement	NE	NE	M	L	H	M	
	Overall Score	NE	L	M	L	M	L	
	Environment							
	Positive Attitude and Motivation	NE	M	H	M	M	H	Fall: Does not implement as planned. Spring: Teacher has a nice environment, but has a long way to go toward student-led inquiry, metacognition and criterion referenced feedback.
	Thinks Scientifically	NE	NE	H	M	M	H	
	Metacognitive Teaching	NE	NE	NE	NE	NE	NE	
	Feedback	NE	NE	NE	NE	NE	NE	
	Overall Score	NE	M	H	M	M	H	

Table B4: Consensus ratings from Lesson Quality Assessment Tool (LQAT) for case study teachers (continued).

Participant	Category	Base Lesson Plan	Base Video	Fall Lesson Plan	Fall Video	Spring Video	Spring Video	Comments
Julie Team Study Model	**Content**							
	Learning Objectives	L	L	M	M	H	H	Fall: SA:V was covered pretty well, but nano content and application was inadequate. Spring: The content being Nano in Society, this seems to be an appropriate treatment of those concepts. Evaluators did not see the students report to one another or discuss with teacher.
	Big Ideas	NE	NE	H	L	H	M	
	Overall Score	L	L	H	M	H	H	
	Understanding							
	Student Prior Knowledge	NE	NE	H	M	H	H	Fall: The activities seemed to help the students understand the content, but the teacher did not make connects to a concept and particularly to the nano science content. The inquiry was spoon-fed. Spring: Difficult to evaluate overall since we did not see the student reporting or a wrap up.
	Inquiry-based Instruction	L	L	M	L	NE	NE	
	Formative Assessment Process	NE	M	H	M	H	M	
	Wrap-up - Student Engagement	NE	NE	H	M	H	NE	
	Overall Score	L	L	H	M	H	M	
	Environment							
	Positive Attitude and Motivation	H	H	H	L	M	H	
	Thinks Scientifically	M	M	H	L	L	NE	
	Metacognitive Teaching	NE	NE	NE	NE	NE	H	Spring: Teacher did 3-2-1. Asking them to reflect on their learning and remaining questions. SPECIAL EVALUATORS AWARD for the only teacher to address this!
	Feedback	L	L	NE	L	NE	NE	Spring: We didn't get to see if she used her eval data.
	Overall Score	M	M	H	L	M	H	Fall: Failed to engage students with stimulating content (too slow, too easy) and did not make connections to what

Table B4: Consensus ratings from Lesson Quality Assessment Tool (LQAT) for case study teachers (continued).

Participant	Category	Base Lesson Plan	Base Video	Fall Lesson Plan	Fall Video	Spring Video	Spring Video	Comments
								the students would be learning overall. Spring: Engagement high, relevant to students and the research and reporting went well.

Table B4: Consensus ratings from Lesson Quality Assessment Tool (LQAT) for case study teachers (continued).

Participant	Category	Base Lesson Plan	Base Video	Fall Lesson Plan	Fall Video	Spring Video	Spring Video	Comments
Shannon Team Study Model	**Content**							
	Learning Objectives	L	L	H	L	H	L	Fall: Evaluators saw only Activity 1 of 4, and it was unsuccessful due to math calculation problems or lack of clarity on purpose. Spring: While the plan provides same content context, the instruction does not address any nano, or even molecular assembly forces at work.
	Big Ideas	NE	NE	H	L	H	L	
	Overall Score	L	L	H	L	H	L	
	Understanding							
	Student Prior Knowledge	NE	M	M	L	H	L	Fall: Since the video covered only less than 25% of the lesson plan, we really saw no evidence of student understanding. What we did see was a failure, since the teacher pushed forward after finding out the students did not have the requisite prior knowledge. Spring: There was no inquiry, no wrap up at all, and students mostly disengaged.
	Inquiry-based Instruction	L	L	L	NE	H	L	
	Formative Assessment Process	NE	L	H	L	L	NE	
	Wrap-up - Student Engagement	NE	L	H	NE	NE	NE	
	Overall Score	NE	L	M	L	M	L	
	Environment							
	Positive Attitude and Motivation	NE	l	M	L	L	L	Fall: Expectations are low, pace is painfully slow, math problems obscure the science, students are mostly disengaged. Spring: Students disengaged, low expectation with low level content
	Thinks Scientifically	l	l	M	L	L	L	
	Metacognitive Teaching	NE	NE	NE	NE	NE	NE	
	Feedback	NE	NE	NE	NE	NE	NE	
	Overall Score	L	L	M	L	L	L	

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