THE *NANOLEAP* PROJECT
EVALUATION REPORT
2007–2008

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EXECUTIVE SUMMARY

OVERVIEW

After three years of research and development, Mid-continent Research for Education and Learning (McREL), the Stanford Nanofabrication Laboratory (SNF), and ASPEN Associates have advanced the field of nanoscale science, technology, engineering, and mathematics (STEM) education with support from the National Science Foundation (NSF).[1] During the 2007–2008 school year, the *NanoLeap* project field tested two instructional modules designed to teach high school students core science concepts while introducing nanoscale science and technology. Two different modules were developed and tested, one for physical science and one for general chemistry. Both were designed to promote standards- and inquiry-based teaching and learning. This report summarizes the findings from the field test of the *NanoLeap* physical science and chemistry modules and summarizes findings of the viability of the development process.

THE *NANOLEAP* MODULES

The *NanoLeap* modules were specifically designed to enhance student learning of the core concepts in high school science through the introduction of nanoscale science concepts. Each of the standards- and inquiry-based modules included student activities, experiments, and assessments that were intended to be implemented over a period of about three weeks. Both of the modules were designed for general education classes (i.e., not Advanced Placement or Honors).

During the development process, it was determined that the physical science module would be best implemented in a 9th-grade physical science class as a replacement unit for the following concepts: scientific investigation, measurement, and static forces. The chemistry module was viewed as an end-of-year cumulative unit for use in general chemistry classes in which students studied applications of concepts they learned throughout the school year but at the nanoscale level.

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[1] This work is supported by the National Science Foundation, Division of Elementary, Secondary and Informal Education award # ESI-0426401.

KEY FINDINGS

PARTICIPANTS

TEACHERS

A total of seventy-five public high school science teachers participated in the *NanoLeap* field tests. Thirty-eight teachers completed the field test of the physical science module; another thirty-seven teachers completed the field test of the *NanoLeap* chemistry module.

Both the *NanoLeap* physical science and chemistry field tests included new and veteran teachers from across the United States, thus representing secondary teachers with a range of experience (i.e., a "broad base") as intended for the field test. The final sample included both small and large schools and a diverse population of students from across the United States.

Teachers in the treatment and control groups for both the *NanoLeap* physical science and the chemistry field tests were equivalent in their teaching experience and preparedness to teach in their subject area (i.e., there were no significant differences in teacher characteristics between treatment and control groups).

STUDENTS

A total of 1,380 high school students participated in the *NanoLeap* field test. Of these, 766 students participated in the physical science field test and another 614 students participated in the chemistry field test.

Students in the physical science field test were primarily ninth graders, reflecting the placement of this module in ninth grade physical science or similar courses. Students in the chemistry pilot test were primarily enrolled in grades ten and eleven, again reflecting when the general chemistry topics included in the module are typically taught.

The participating students represented the target group of traditionally underserved populations of girls and students of color. Students of all ability levels were also represented in both field tests.

INQUIRY-BASED LEARNING

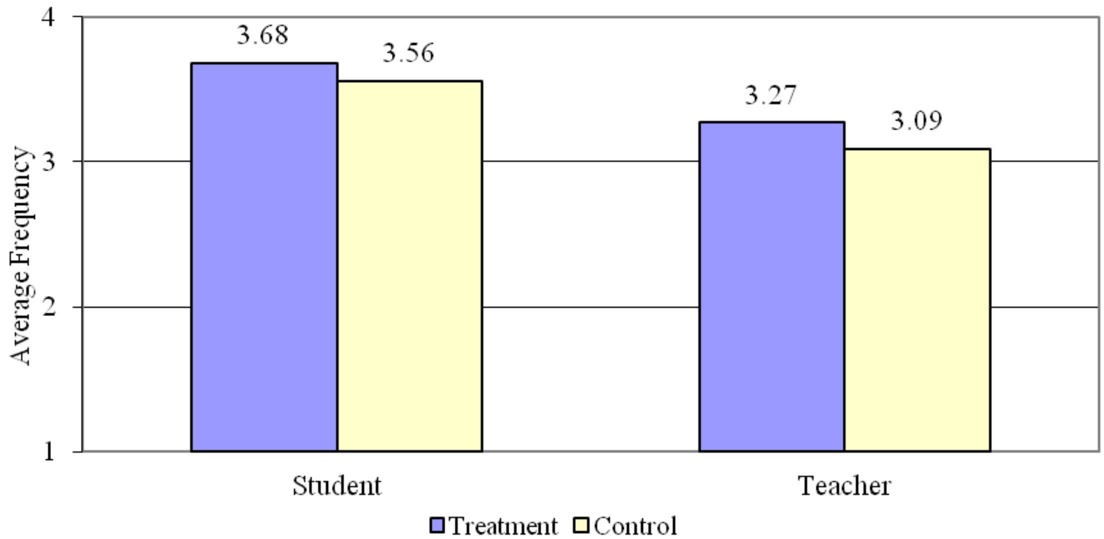
To achieve the goal of supporting students' learning of core science concepts, the *NanoLeap* project set out to develop instructional materials that promote inquiry-based teaching and learning (see pages 15–23).

OUTCOME 1: Teachers will be able to implement the *NanoLeap* curriculum modules in a manner that supports inquiry-based learning.

FINDING 1: Student and teacher reports of classroom practices indicate that teachers in the treatment group were able to implement both the physical science and the chemistry modules in a manner that supports inquiry-based learning.

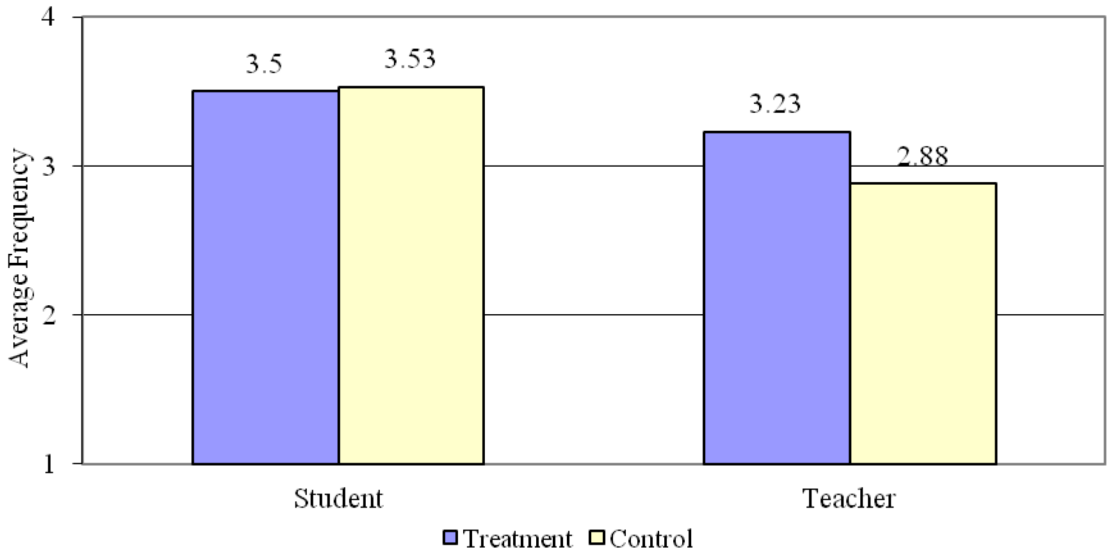
Students and teachers in both the physical science and chemistry treatment groups reported engaging in inquiry-based practices at least "sometimes (every other week)." The few significant differences in instructional practices between treatment and control groups in the field test of each of the *NanoLeap* modules reflected intentional design elements to support inquiry-based teaching and learning. In contrast, both control groups tended to emphasize the use of experiments.

Figure 1: Student and Teacher **Perceptions of Inquiry-Based Classroom Practices in Physical Science Treatment Group, 2007–2008 *NanoLeap* Field Test.**



Note: Average across a 14-item scale for students and 36-item scale for teachers where 1 = never, 2 = rarely (a few times), 3 = sometimes (every other week), 4 = often (once or twice a week), and 5 = every or almost every lesson.
Source: *NanoLeap* physical science student and teacher surveys, 2007–2008.

Figure 2: Student and Teacher Perceptions of Inquiry-Based Classroom Practices in Chemistry Treatment Group, 2007–2008 *NanoLeap* Field Test.



Note: Average across a 14-item scale for students and 36-item scale for teachers where 1 = never, 2 = rarely (a few times), 3 = sometimes (every other week), 4 = often (once or twice a week), and 5 = every or almost every lesson. Source: *NanoLeap* chemistry student and teacher surveys, 2007–2008.

STUDENT INTEREST / ENGAGEMENT

The *NanoLeap* project also set out to develop instructional materials that increased student interest and engagement in science (see pages 24–29).

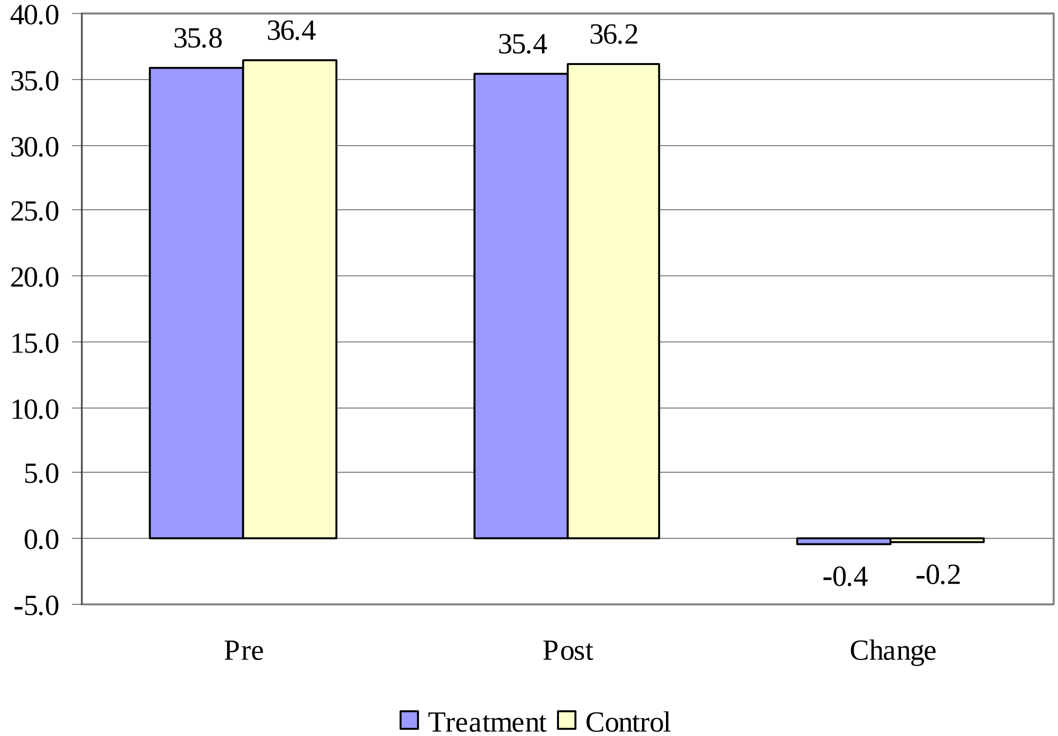
OUTCOME 2: Students in classrooms where teachers fully implement the *NanoLeap* materials (treatment group) will demonstrate greater levels of interest and engagement in learning science than students in classrooms where the *NanoLeap* materials are not implemented (control group).

FINDING 2: Students in both the treatment and control groups for the physical science and chemistry field tests did not show an increased interest and/or engagement in science.

With two exceptions, students in both the treatment and control groups for the *NanoLeap* physical science and chemistry field tests came into the project expressing an interest in science. As a whole, students did not enter the project with an interest in becoming scientists or in obtaining a job in nanoscale science or technology nor did they express one after participating.

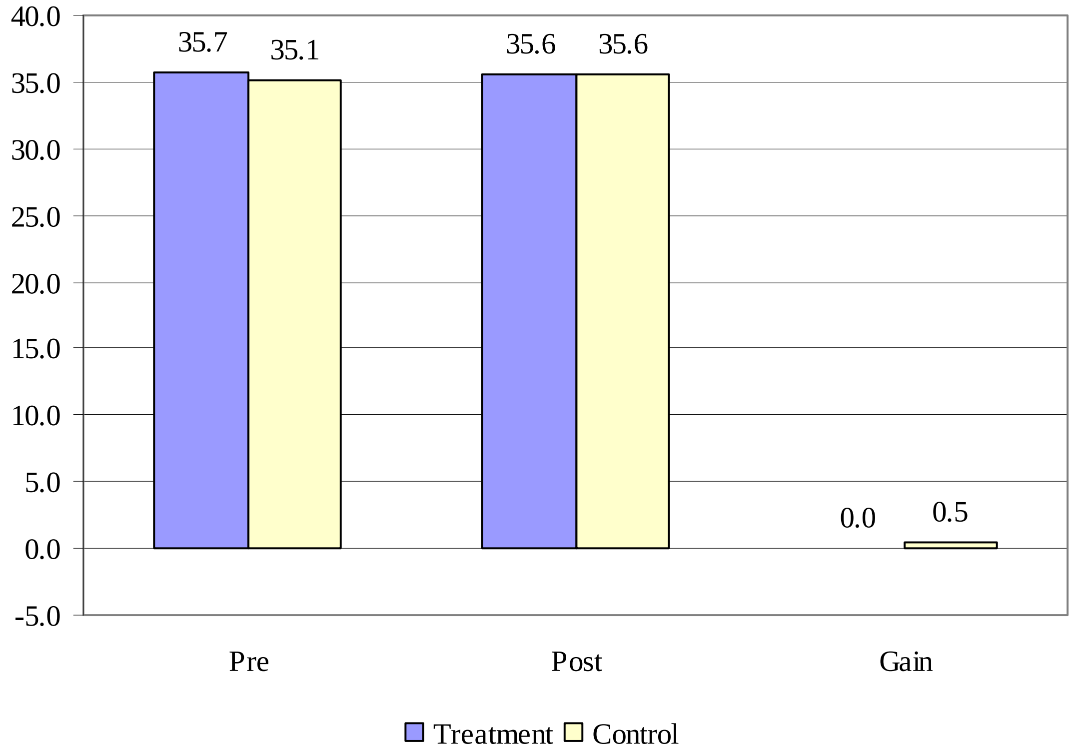
Over the course of the project, students in both the treatment and control groups for the physical science and chemistry field tests did not show an increased interest and/or engagement in science as a result of the NanoLeap project. This is likely a reflection of the fact that they came into the project with a high interest in science leaving little room for improvement.

Figure 3: Comparison of Treatment and Control Group Student Motivation in Physical Science, 2007–2008 *NanoLeap* Field Test.



Note: 15-item motivation scale with each item rated as 1 = strongly disagree, 2 = disagree, 3 = agree, and 4 = strongly agree.
Source: *NanoLeap* physical science student survey, 2007–2008.

Figure 4: Comparison of Treatment and Control Group Student Motivation in Chemistry, 2007–2008 *NanoLeap* Field Test.



Note: 15-item motivation scale with each item rated as 1 = strongly disagree, 2 = disagree, 3 = agree, and 4 = strongly agree.
Source: *NanoLeap* chemistry student survey, 2007–2008.

STUDENT LEARNING

The ultimate goal of the *NanoLeap* project was to develop instructional materials that would improve student learning of science (see pages 30–41).

OUTCOME 3: Students in classrooms where teachers fully implement the *NanoLeap* materials (treatment group) will demonstrate a level of understanding of core science concepts that is at least equal to, if not greater than, that of students in classrooms where the *NanoLeap* materials are not implemented (control group).

FINDING 3: Students in both the physical science and chemistry treatment groups significantly outperformed their peers in the control groups in their knowledge of core science concepts.

OUTCOME 4: Students in classrooms where teachers fully implement the *NanoLeap* materials (treatment group) will demonstrate an increased understanding of nanoscale science, technology, engineering, and mathematics concepts, applications, and careers.

FINDING 4: Students in both the physical science and chemistry treatment groups significantly outperformed their peers in the control groups in their knowledge of nanoscale science and concepts. Student understanding of nanoscale applications and careers was not formally assessed.[2]

PHYSICAL SCIENCE

Students in the *NanoLeap* physical science treatment group significantly outperformed their peers in the control group in terms of the gain in knowledge demonstrated from the pre- to the post-test (see Figure 5). Treatment group students outperformed control group students overall, and with regard to "core science" concepts, and "nanoscale science" concepts, in physical science.

The students in the physical science treatment group most likely to show the greatest gains in knowledge overall were those that:

- speak English in the home (*student characteristics*),
- find physical science interesting (*student characteristics*),
- find physical science is easy for them to learn (*student engagement*), or
- have a teacher who emphasizes learning basic science in class (*instructional practices*).

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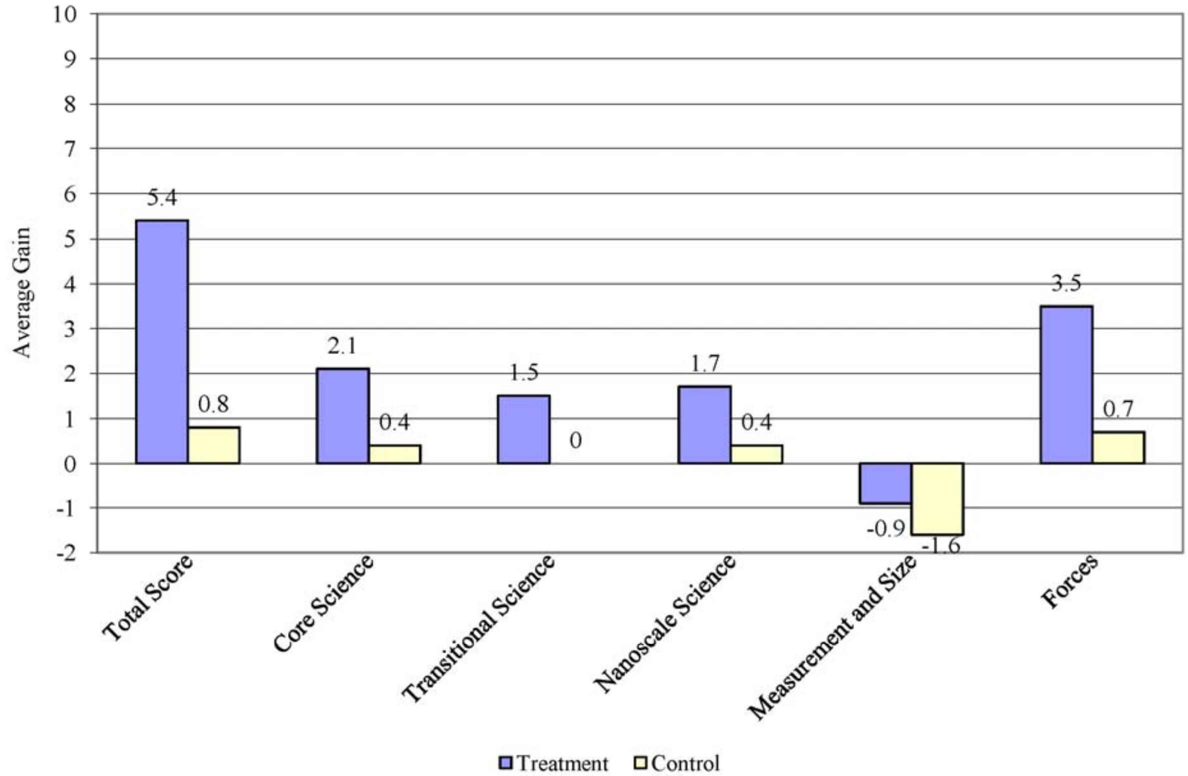
[2] The *Nanoleap* modules were designed to increase student understanding of nanoscale science, technology, engineering, and mathematics concepts through their application and through exposure to related careers. As such, nanoscale applications and careers were used as pedagogical vehicles to promote greater understanding of nanoscale concepts and were not measured directly.

Figure 5: Comparison of Treatment and Control Group Performance on Physical Science Student Assessment, 2007–2008 *NanoLeap* Field Test.

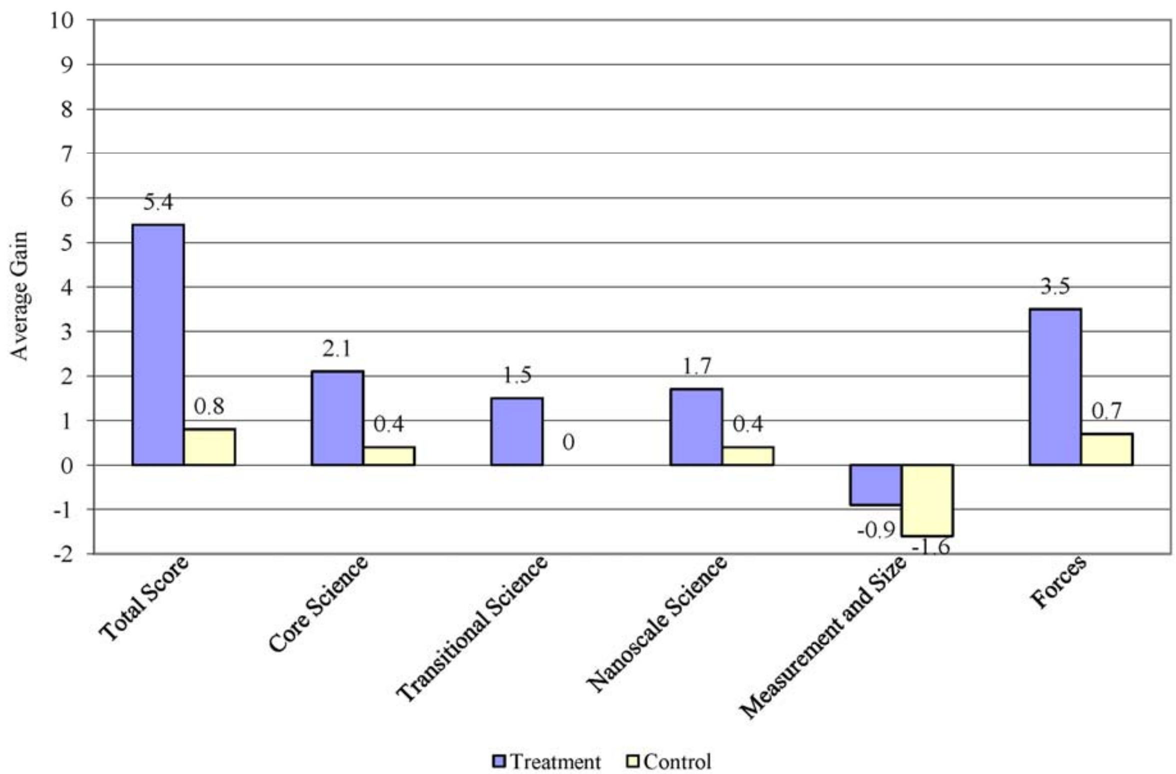


Source: *NanoLeap* physical science student assessment, 2007–2008.

CHEMISTRY

Students in the *NanoLeap* chemistry treatment group significantly outperformed their peers in the control group in terms of the gain in knowledge that was demonstrated from the pre- to the post-test (see Figure 6). Treatment group students outperformed control group students overall, and with regard to “core science” concepts, and “nanoscale science” concepts, in chemistry.

Figure 6: Comparison of Treatment and Control Group Performance on Chemistry Student Assessment, 2007–2008 *NanoLeap* Field Test.



Source: *NanoLeap* chemistry student assessment, 2007–2008.

The students in the chemistry treatment group most likely to show the greatest gains in knowledge overall were those that:

- feel comfortable in science class (*student characteristics*),
- find chemistry is easy for them to learn (*student engagement*),
- completed all of their assignments (*student engagement*),
- have a teacher who emphasizes learning basic science in class (*instructional practices*), or
- have a teacher that asks them to consider alternative explanations (*instructional practices*).

VIABILITY OF DEVELOPMENT APPROACH

From the very beginning, the *NanoLeap* project engaged in a design process that kept the end in mind. The project partners focused on creating standards- and inquiry-based instructional materials that could bring nanoscale science into high school science courses in a manner that supported student learning of core science concepts. As noted above, the *NanoLeap* project demonstrated through the achievement of its intended outcomes related to teaching and learning that it was indeed based on a viable model for instructional materials development.

The viability of the instructional materials development process utilized by *NanoLeap* reflected *early* and *ongoing* attention to the following design elements:

- inclusion of project partners from a variety of sectors within education who provided expertise in nanoscale science content and pedagogy, instructional materials design, and evaluation;
- relationship- and network-building to engender trust in working relationships and leverage resources;
- planning, review, and refinement of project outcomes and development process to monitor feasibility and promote clarity of purpose and role expectations among project partners;
- needs assessment to verify assumptions about classroom practices, teacher preparedness, and general feasibility of proposed activities against current and emerging realities;
- opportunities for professional learning about nanoscale science concepts, content, tools, and resources that could be utilized in direct instruction or in providing background information for teachers; and
- project coordination and management to monitor progress and ensure enough flexibility in the development process to remain open to unanticipated opportunities.

SUMMARY

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

1. CURRICULUM FIT: To explore where nanoscale science, technology, engineering, and mathematics concepts can fit into high school physical science and chemistry classes in a manner that supports students in learning core science concepts.

2. MATERIALS DEVELOPMENT PROCESS: To determine a viable approach for instructional materials development in the areas of nanoscale science, technology, engineering, and mathematics.

With regard to the curriculum fit, during the development process, it was determined that the physical science module would be best implemented in a 9th-grade physical science class as a replacement unit for the following concepts: scientific investigation, measurement, and static forces. The chemistry module was viewed as an end-of-year cumulative unit for use in general chemistry classes in which students apply concepts they learned throughout the school year but at the nanoscale level. The fact that teachers were able to implement both the physical science and chemistry modules in a manner that supported inquiry-based learning and that student learning was enhanced, confirms that this placement within the curriculum was indeed a good "fit."

In the achievement of key outcomes – promoting inquiry-based practices and student learning of core science concepts – the *NanoLeap* project also demonstrated the viability of its instructional materials design process. Throughout the project, the project partners had an opportunity to stand back and reflect on the development process as they prepared for next steps. In doing so, they were able to continually refine the process to ensure feasibility while being open to unanticipated opportunities.

FOR MORE INFORMATION

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Overview

After three years of research and development, Mid-continent Research for Education and Learning (McREL), the Stanford Nanofabrication Laboratory (SNF), and ASPEN Associates have advanced the field of nanoscale science, technology, engineering, and mathematics (STEM) education with support from the National Science Foundation (NSF).[3]

During the 2007–2008 school year, the *NanoLeap* project field tested two instructional modules designed to teach high school students core science concepts while introducing nanoscale science and technology. Two different modules were developed and tested, one for physical science and one for general chemistry; both were designed to promote standards- and inquiry-based teaching and learning. The purpose of the field test was to gather data from a broad base of high school teachers (NanoLeap B-Team) to examine the effectiveness of the physical science and chemistry modules. The field test examined whether teachers were able to implement the modules, which were developed and pilot tested with a group of master teachers (NanoLeap A-Team), in a manner that supported inquiry-based learning and promoted student engagement and learning of core science and nanoscale science concepts.

This report summarizes the findings from the field tests of the *NanoLeap* physical science and chemistry modules and summarizes the viability of the development process for the four-year project.

Project Goals and Objectives

The *NanoLeap* project had two overarching goals:

1. <u>Curriculum Fit</u>: To explore where nanoscale science, technology, engineering, and mathematics concepts can fit into high school physical science and chemistry classes in a manner that supports students in learning core science concepts.

2. <u>Materials Development Process:</u> To determine a viable approach for instructional materials development in the areas of nanoscale science, technology, engineering, and mathematics.

[3] This work is supported by the National Science Foundation, Division of Elementary, Secondary and Informal Education award # ESI-0426401.

To achieve these goals, the *NanoLeap* project has completed all of the planned activities:

1. CURRICULUM MODULES: Developed two, three-week standards- and inquiry-based curriculum modules (one in physical science and one in chemistry) that embed nanoscale science, technology, engineering, and mathematics (STEM) concepts in a manner that supports student understanding of core science concepts on both the macroscale and nanoscale.

2. TEACHER GUIDES: Developed teacher guides for each of the curriculum modules that support teachers in delivering standards- and inquiry-based instruction and assessing students' understanding of core science concepts on both the macroscale and nanoscale.

3. PILOT TEST: Tested and refined the two curriculum modules with master high school science teachers (NanoLeap A-Team).

4. ORIENTATION: Conducted orientation sessions for teachers implementing the standards- and inquiry-based *NanoLeap* curriculum modules (NanoLeap B-Team).

5. FIELD TEST: Tested and refined the two curriculum modules with a broad base of high school science teachers (NanoLeap B-Team).

6. EVALUATE VIABILITY: Evaluated the effectiveness of the design process utilized in developing the *NanoLeap* curriculum modules and teachers' guides.

As a result of these activities, the *NanoLeap* project intended to achieve four outcomes:

1. INQUIRY-BASED TEACHING: Teachers will be able to implement the *NanoLeap* curriculum modules in a manner that supports inquiry-based learning.

2. INCREASED STUDENT INTEREST/ENGAGEMENT: Students in classrooms where teachers fully implement the *NanoLeap* materials (treatment group) will demonstrate greater levels of interest and engagement in learning science than students in classrooms where the *NanoLeap* materials are not implemented (control group).

3. INCREASED STUDENT SCIENCE KNOWLEDGE: Students in classrooms where teachers fully implement the *NanoLeap* materials (treatment group) will demonstrate a level of understanding of core science concepts that is at least equal to, if not greater than, that of students in classrooms where the *NanoLeap* materials are not implemented (control group).

4. INCREASED STUDENT UNDERSTANDING OF NANOSCALE STEM: Students in classrooms where teachers fully implement the *NanoLeap* materials (treatment group) will demonstrate an increased understanding of nanoscale science, technology, engineering, and mathematics concepts, applications, and careers.

THE *NANOLEAP* MODULES

Over a three year period, the *NanoLeap* project developed and tested two instructional modules for use at the high school level; one for physical science and one for chemistry. Both modules were developed and pilot tested during the 2006–2007 school year with a group of master teachers (NanoLeap A-Team) to inform changes to the materials prior to a field test during the 2007–2008 school year with a broad base of teachers (NanoLeap B-Team).

The *NanoLeap* modules were specifically designed to promote student learning of the core concepts in high school science through the introduction of nanoscale science concepts. The *NanoLeap* modules were designed to increase student understanding of nanoscale science, technology, engineering, and mathematics concepts through their application and through exposure to related careers. As such, nanoscale applications and careers were used as pedagogical vehicles to promote greater understanding of nanoscale concepts and were not measured directly.[4] Each of the standards- and inquiry-based modules included student activities, experiments, and assessments that were intended to be implemented over a period of about three weeks. Both of the modules were designed for general education classes (i.e., not Advanced Placement or Honors).

During the development process, it was determined that the physical science module would be best implemented in a 9th-grade physical science class as a replacement unit for the following concepts: scientific investigation, measurement, and static forces. Likewise, the chemistry module was viewed as an end-of-year cumulative unit for use in general chemistry classes in which students apply concepts they learned throughout the school year but at the nanoscale level.

For a more detailed description of the *NanoLeap* development process, modules, and student assessments, and the development process, see Appendices A, B, and C.

METHODS

The evaluation of the *NanoLeap* project involved a quasi-experimental design in which treatment group teachers were matched to a comparable control group teacher. Teachers completed a formal application process to participate in the *NanoLeap* field test as a treatment or control school (see Appendix D). Teachers were assigned to the implementation (treatment) group on a first come basis. Once assigned, the treatment group teachers were then matched with a comparable control group teacher in their region. Teachers were matched on school

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[4] In the future, instructional materials design projects may wish to include experiences in which students' ability to apply nanoscale science concepts and demonstrate an understanding of related career options is measurable (e.g., through performance-based assessments and how a particular career aligns with a student's own skills and values).

characteristics, which included school size and student demographics, including the percentage of students of color, poverty, and achievement.

Field testing of the *NanoLeap* materials occurred during the 2007–2008 school year with nineteen physical science and twenty chemistry teachers representing a broad base of high school teachers. Whereas the teachers selected for the development process and pilot test (the NanoLeap A-Team) were master science teachers from public high schools, the field test was designed for public school teachers who represented a broader base of teacher preparedness in order to better examine the effectiveness of the *NanoLeap* modules when used by a diverse group of teachers and students in classrooms across the United States.

Prior to the field test, the teachers who would be implementing the *NanoLeap* materials (i.e., treatment group teachers) participated in a two-hour orientation session via conference call one to three weeks before they were scheduled to begin. The orientation was designed to introduce teachers to the instructional materials and collection procedures, and to discuss issues related to fidelity of implementation (see Appendix E). Treatment group teachers were also able to access additional support throughout the project (e.g., contacting the development team via telephone and e-mail, participating in online discussion boards). Teachers in the control group received the data collection materials and instruction manual. The evaluation coordinator reviewed data collection procedures with the control group teachers.

The timing of the implementation varied for the physical science and chemistry field tests. Teachers in the physical science treatment group implemented the *NanoLeap* three-week module as a replacement unit at the time they would normally teach scientific investigation, measurement, and static forces. The physical science control group taught their regular curriculum for these topics. Both the treatment and control group teachers collected data during the period of time in which these topics were being taught. In contrast, teachers in the chemistry treatment group implemented the three-week *NanoLeap* module at the end of the school year as a cumulative unit. The chemistry control group taught their regular end-of-year curriculum. Both treatment and control group teachers collected data during this three week period at year’s end.

Three physical science and two chemistry teachers field tested the *NanoLeap* materials in more than one class to allow them a single course preparation across all of their classes. However, data were only collected from the first class of the day in which the unit was taught. In this manner, the research team was able to study the effects of the modules on teaching and learning as a new set of instructional materials, “just out-of-the-box,” as it were. This approach avoided a “practice” effect, which might accrue, as a teacher became more familiar with a module through repeated use.[5]

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[5] Teachers received only one set of instructional materials (Teacher Guide, Student Journals, etc.) and one set of data collection protocols (Teacher Survey, Student Surveys, Student Pre- and Post-Assessments) for use in a single class. While we have no evidence of effects related to teacher’s use of the instructional materials in multiple classes, the possibility exists.

The four project outcomes were assessed during the field test with all teachers – treatment and control – using the following data collection protocols: teacher survey, student survey, pre- and post-assessment of student knowledge and motivation, and classroom observation (see Table 1). In addition, the treatment group teachers completed an implementation fidelity checklist. Each of these protocols, which were pilot tested by the NanoLeap A-Team (development team) teachers along with the *NanoLeap* modules, is described below.[6]

TABLE 1: DATA COLLECTION PROTOCOLS BY PROJECT OUTCOME, 2007–2008 *NANOLEAP* FIELD TEST

	DATA COLLECTION PROTOCOLS			
PROJECT OUTCOMES	TEACHER SURVEY	STUDENT SURVEY	PRE/POST ASSESSMENT	CLASSROOM OBSERVATION
1. Inquiry-based teaching	X	X		X
2. Increased interest & engagement in science			X	
3. Increased science knowledge			X	
4. Increased understanding of nanoscale STEM			X	

TEACHER SURVEY

The post-only teacher survey assessed teacher preparedness to teach key concepts and applications in their subject area and in nanoscale science, their preparedness to teach using inquiry methods, current classroom practices, and perceptions of student engagement. These data were used to examine whether teachers were able to implement the *NanoLeap* modules in a manner that supports inquiry-based teaching and learning (Outcome 1). Data from the teacher survey were also used to describe the characteristics of teachers in the treatment and control groups to assess the comparability of the two groups; and to examine the relationship between teacher preparedness, classroom practices, and student performance.

The *NanoLeap* teacher survey was developed from three existing surveys. Questions regarding teacher preparation, classroom practice, and student motivation were taken from the science teacher questionnaire used in the *2000 National Survey of Science and Mathematics Education* (Horizon Research, 2000) and the teacher questionnaire used in the study of *Local Systemic Change through Teacher Enhancement* (Horizon Research, 2006). Questions related to teacher

[6] See 2007 *NanoLeap* Pilot Test Report, December 2007. Copies of the data collection protocols used in the field test are available upon request.

characteristics were taken from the teacher questionnaire used by the *Center for Organization and Restructuring of Schools* in its study of school restructuring (Wisconsin Center for Education Research, 1994).

STUDENT MULTIPLE CHOICE ASSESSMENT

The *NanoLeap* project developed parallel pre- and post-assessments for each of the modules to document changes in student knowledge of key concepts within the subject matter (e.g., physical science or chemistry) and the nanoscale extensions of those concepts (Outcomes 3 and 4). Questions on the assessments were designed to align with the content, standards, and essential ideas represented in the *NanoLeap* modules. Questions were categorized as addressing either core science concepts, nanoscale science concepts, or concepts that represented the knowledge needed to make the transition from core science to nanoscale science concepts (see results for Student Learning for detailed descriptions of these concepts and Appendix C for further detail on the assessments).

During the pilot test, the functioning of the knowledge items on the student assessments were examined through a formal item analysis. This analysis, which is documented in a separate pilot test report, included an examination of the difficulty, discrimination, and reliability of individual items and the assessment as a whole. The results of this analysis were reviewed by the development team and used to inform changes to the assessments prior to the field test. In addition, the content validity of the assessments was examined through an external review by experts in the field. A final item analysis was conducted using data from the field test (see section on Student Learning).

Fifteen items that assessed student motivation to learn science were also included on the pre-and post-assessment to determine changes in student interest and engagement in learning science (Outcome 2). The relationship between student engagement and student performance was also examined. The motivation items were taken from an existing instrument, the Relevance of Science Education (ROSE) student survey developed by Schreiner and Sjøberg (2004).

STUDENT SURVEY

A student survey was used to document students' interest and engagement in learning science, student perceptions of their teacher's classroom practices, and other factors related to student learning (e.g., demographic characteristics, support for learning). Like the teacher survey, the data on classroom practices were used to examine whether teachers were able to implement the *NanoLeap* modules in a manner that supports inquiry-based teaching and learning (Outcome 1). Data from the student survey were also used to describe the characteristics of students in the treatment and control groups to assess the comparability of the two groups; and to examine the relationship between student characteristics, student engagement, classroom practices, and student performance.

As a survey of secondary students, the *NanoLeap* student survey was developed from two existing teacher surveys and one student survey. Questions regarding students' perceptions of teacher's classroom practice were adapted from the science teacher questionnaire used in the *2000 National Survey of Science and Mathematics Education* (Horizon Research, 2000) and the teacher questionnaire used in the study of *Local Systemic Change through Teacher Enhancement* (Horizon Research, 2006). Questions related to students' interest and engagement in learning and other factors related to learning were taken from the students questionnaire used by the *Center for Organization and Restructuring of Schools* in its study of school restructuring (Wisconsin Center for Education Research, 1992).

CLASSROOM OBSERVATIONS/TEACHER INTERVIEW

In the field test, classroom observations were conducted by evaluators from ASPEN Associates in six physical science and six chemistry classrooms where teachers are implementing the *NanoLeap* module. The six classrooms were selected to represent the six regions in the United States where the field test is occurring: East, Midwest, South, Central, Southwest, and West. The observations were used to gather information on the ways in which students and teachers are interacting with each other and with the *NanoLeap* materials in order to identify any design issues that may need to be addressed. The observations and brief interview with the teacher immediately following the observation focused on whether teachers and students are able to use the materials in a way that supports inquiry-based teaching and learning. All observations were videotaped to inform the subsequent revisions for the development process.

The observation protocol that was developed by the *NanoLeap* evaluation team was based on the structure of protocols used in the *Local Systemic Change through Teacher Enhancement* (Horizon Research, 2006), which included a debriefing with the teacher after the observation and an observation summary.

IMPLEMENTATION FIDELITY CHECKLIST

Teachers who implemented the *NanoLeap* modules also completed a Fidelity Checklist to document the extent to which they were able implement each lesson as intended, what modifications, if any, they needed to make, and whether they incorporated any supplemental materials into the module. This information was used to elaborate on the findings related to student performance and to identify the need for modifications and revisions to the modules (see Appendix E). The Fidelity Checklist was developed by the *NanoLeap* evaluation team to align with the content and structure of the final modules.

VIABILITY INTERVIEWS

After the field test, key project stakeholders were interviewed to gather their perceptions of the viability of the development process used in the *NanoLeap* project. A total of eleven interviews were conducted with key stakeholders that included the two leads on the McREL development team, two teachers from the physical science NanoLeap A-Team and two teachers from the chemistry NanoLeap A-Team, a representative from the Stanford Nanofabrication Facility team, the project's assessment expert, a representative from the multimedia team, and two members of the evaluation team. These interviews, which were developed by the *NanoLeap* evaluation team, were designed to allow key participants on the design team to reflect on what worked and what did not with regard to the development process.

FINDINGS

PARTICIPANT CHARACTERISTICS

The 2007–2008 field test of the *NanoLeap* materials involved seventy-five (75) public high school science teachers, thirty-eight (38) physical science and thirty-seven (37) chemistry teachers.

SCHOOLS

The characteristics of the schools represented in the final sample (i.e., teachers who completed all of the data collection) are presented in Table 2. The final sample included both small and large schools and a diverse population of students from all six regions of the country. Most of the schools were making Adequate Yearly Progress under the No Child Left Behind Act of 2001.

TABLE 2: B-TEAM SCHOOL CHARACTERISTICS, 2007–2008 *NANOLEAP* FIELDTEST

	PHYSICAL SCIENCE		CHEMISTRY	
	TREATMENT (N=18)	CONTROL (N=20)	TREATMENT (N=19)	CONTROL (N=18)
Region				
East	1	1	4	4
Midwest	7	7	2	3
South	2	3	2	4
Central	5	4	6	3
Southwest	1	2	3	3
West	1	2	2	1
Enrollment Grades 9–12	118 to 4400	95 to 2500	120 to 3538	140 to 2766
Percent Free/Reduced Lunch	12 to 62%	19 to 100%	0 to 58%	0 to 84%
Percent Students of Color	0 to 90%	0 to 99%	0 to 80%	0 to 99%
Percent English Language Learners	0 to 8%	0 to 40%	0 to 14%	0 to 40%
Number Not Making AYP	2 of 18	2 of 20	4 of 19	5 of 18

Notes: States participating by region were Maine, Pennsylvania, Ohio, and Vermont in the Eastern region; Indiana, Illinois, Iowa, Michigan, Minnesota, Wisconsin in the Midwest; Florida, Georgia, Kentucky, North Carolina, South Carolina, West Virginia in the South; Arizona, New Mexico, and Texas in the Southwest Region; and California, Colorado, Hawaii, and Washington in the Western region.
Source: *NanoLeap* Sampling Records, 2007–2008.

TEACHERS

Of the seventy-five (75) public high school science teachers who participated in the *NanoLeap* field test, thirty-eight (38) teachers completed the field test of the *NanoLeap* physical science module; eighteen (18) in the treatment group and twenty (20) in the control group. Another thirty-seven (37) teachers completed the field test of the chemistry module; nineteen (19) in the treatment group and eighteen (18) in the control group.

Teachers in the treatment and control groups for the *NanoLeap* physical science and the chemistry field tests were equivalent in their teaching experience and preparedness to teacher in their subject area (i.e., there were no significant differences in teacher characteristics between treatment and control groups).

Both the *NanoLeap* physical science and chemistry field tests included new and veteran teachers, thus representing teachers with a range of experience (i.e., a “broad base”) as intended for the field test (see Table 3). Chemistry teachers were more likely than their physical science counterparts to be involved in activities that supported their professional learning; including attending science-related professional development, subscribing to science publications, and holding memberships in professional organizations related to science education (see Table 3). Differences between the treatment and control groups within physical science and chemistry were not statistically significant.

With regard to teacher preparedness to teach the core science content and processes included in the *NanoLeap* physical science module, physical science teachers participating in the project felt prepared to teach the topics in the module (see Table 4). There were no significant differences between treatment and control group in teachers’ preparedness to teach physical science topics.

Chemistry teachers participating in the project felt prepared to teach most of the core science content and processes included in the *NanoLeap* chemistry module (see Table 5). Chemistry teachers felt least prepared to teach nanoscale production techniques and band theory. Chemistry teachers in the control group were also less likely to report that topics of nanoscale production techniques, band theory, carbon chemistry, and hybridization were included in their school’s curriculum. There were no significant differences between treatment and control groups in teachers’ preparedness to teach chemistry.

TABLE 3: B-TEAM TEACHER CHARACTERISTICS, 2007–2008 *NANOLEAP* FIELDTEST

	PHYSICAL SCIENCE		CHEMISTRY	
	TREATMENT (N=18)	CONTROL (N=20)	TREATMENT (N=19)	CONTROL (N=18)
Years Teaching				
Average (S.D.)	11.3 (8.1)	15.0 (9.2)	13.9 (7.5)	11.5 (5.7)
Median	10.0	13.0	11.0	11.0
Range	4 to 39	3 to 35	5 to 31	1 to 21
Years Teaching Science				
Average (S.D.)	11.0 (8.2)	13.3 (7.1)	13.9 (7.5)	11.3 (5.9)
Median	10.0	13.0	11.0	11.0
Range	4 to 39	3 to 31	5 to 31	1 to 21
Hours of science-related professional development	6.1	15.4	30.0	23.5
Subscribes to science publications	77.8%	55.0%	84.2%	66.7%
Member of a science-related professional organization or club	67.0%	55.0%	78.9%	77.8%

Note: * = statistical significance at $p < .05$
Source: *NanoLeap* Teacher Survey, 2007–2008.

TABLE 4: B-TEAM TEACHER PREPAREDNESS IN PHYSICAL SCIENCE, 2007–2008 *NANOLEAP* FIELD TEST

	TREATMENT (N=18)		CONTROL (N=20)	
TOPICS	MEAN	N	MEAN	N
a. Forces and Motion	4.59 (0.62)	17	4.70 (0.66)	20
b. Energy	4.56 (0.62)	18	4.50 (0.83)	20
c. Light and Sound	4.06 (1.14)	17	4.00 (0.94)	19
d. Electricity and magnetism	3.86 (1.01)	14	4.16 (0.96)	19
e. Properties of matter	4.94 (0.24)	18	4.95 (0.23)	19
f. Chemical reactions	4.76 (0.44)	17	4.68 (0.95)	19
g. Formulating hypotheses, drawing conclusions, making generalizations	4.50 (0.86)	18	4.50 (0.76)	20
h. Experimental Design	4.33 (0.97)	18	4.20 (0.89)	20
i. Describing, graphing, and interpreting data	4.67 (0.69)	18	4.50 (0.69)	20

Notes: On a scale of 1 = 'not at all prepared' to 5 = 'very prepared' to teach when topic was included in school curriculum.
* = statistical significance at $p < .05$
Source: *NanoLeap* Teacher Survey, 2007–2008.

TABLE 5: B-TEAM TEACHER PREPAREDNESS IN CHEMISTRY, 2007–2008 *NANOLEAP* FIELD TEST

	TREATMENT (N=19)		CONTROL (N=18)	
TOPICS	MEAN	N	MEAN	N
a. Physical and chemical properties	4.53 (0.77)	19	4.78 (0.43)	18
b. Energy	4.26 (0.87)	19	4.33 (0.49)	18
c. Chemical bonding	4.74 (0.56)	19	4.56 (0.51)	18
d. Size and scale	4.42 (0.77)	19	3.94 (1.12)	16
e. Chemical reactions	4.68 (0.48)	19	4.61 (0.50)	18
f. Science Process (formulating hypotheses, drawing conclusions, making generalizations, describing, graphing and interpreting data)	4.47 (0.84)	19	4.56 (0.51)	18
g. Ethics and decision making	3.61 (1.04)	18	3.07 (1.03)	15
h. Metallic and ionic structures	4.26 (1.05)	19	4.06 (0.80)	18
i. Band theory	2.00 (1.12)	17	2.33 (1.51)	6
j. Carbon chemistry	4.16 (1.17)	19	3.75 (1.01)	12
k. Hybridization	3.69 (1.45)	16	3.08 (1.00)	12
l. Nanoscale production techniques	2.05 (0.85)	19	1.50 (0.54)	8

Notes: On a scale of 1 = 'not at all prepared' to 5 = 'very prepared' to teach when topic was included in school curriculum.
* = statistical significance at $p < .05$
Source: *NanoLeap* Teacher Survey, 2007–2008.

STUDENTS

A total of 1,456 students participated in the *NanoLeap* field test.[7] Of these 766 students participated in the physical science field test, 315 in the treatment group and 451 in the control group. Another 690 students participated in the chemistry field test; 365 in the treatment group and 325 in the control group.

By design, the grade level of students participating in the field tests reflected the placement ("fit") of the module as determined by the pilot test. Students in the physical science field test were primarily ninth graders, reflecting the placement of this module in ninth grade physical science or similar courses (see Table 6). Students in the chemistry pilot test were primarily enrolled in grades ten and eleven, again reflecting when the general chemistry topics included in the module are typically taught (see Table 7).

The participating students represented the target group of traditionally underserved populations of girls and students of color (see Tables 6 and 7). Both boys and girls participated equally in the physical science and chemistry field tests. And, although the final sample was primarily Caucasian, 30 percent of the students participating in the field test were students of color. The vast majority of students were born in the United States and reported that English was the language spoken most often at home.

The physical science field test included primarily Caucasian, Hispanic, and Black students (see Table 6). The control group had significantly more Hispanic students than the treatment group (26% versus 13%). This difference was reflected in the fact that significantly fewer students in the control group reported speaking English at home (83% versus 93%). The potential effect on student performance is examined later in this report. The chemistry field test included primarily Caucasian and Hispanic students (see Table 7). There were no differences between treatment and control groups at the onset of the study.

Students of all ability levels were also represented in the field test, as noted by typical grades in school and in science (see Tables 6 and 7). The physical science field test included students of all ability levels (As through Fs). In addition, these physical science students reported that the grades they received in science reflected the grades they typically received in school (see Table 6). The chemistry field test included students across all ability levels, but mostly in the upper grade ranges of As to Cs (see Table 7).

Not surprisingly, in the chemistry field test in which most of the students were enrolled in grades ten through twelve, two-thirds of the students were also working at a job compared to only one-third of the ninth graders in the physical science field test (see Tables 6 and 7). The potential effect on student performance of students working a job is examined later in this report.

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[7] Accurate enrollment records were not readily available to the evaluation team. Thus, the totals for participation are based on the number of students participating in any data collection.

TABLE 6: CHARACTERISTICS OF STUDENTS IN B-TEAM TEACHER PHYSICAL SCIENCE CLASSES, 2007–2008 *NANOLEAP* FIELD TEST

	TREATMENT (N=315)	CONTROL (N=451)
Grade Level		
9th	76.4%	73.2%
10th	10.5	11.3
11th	4.5	12.6
12th	8.6	2.9
Percent female	47.6%	54.1%
Born in the United States	95.6%	94.7%
English language spoken most often at home	93.3%	83.3%*
Ethnicity		
American Indian / Alaskan Native	3.9%	2.0%
Asian or Pacific Islander	1.9	2.2
Black or African American	11.9	7.3
Hispanic (non-white)	12.5	25.6*
White, non-Hispanic	68.5	61.0
Other	1.3	1.8
Grades usually get in school		
Mostly As	16.0%	20.2%
Mostly As and Bs	35.5	33.6
Mostly Bs and Cs	31.9	30.3
Mostly Cs and Ds	14.1	13.7
Mostly Ds and Fs	2.6	2.2
Grades usually get in science		
Mostly As	16.8%	16.3%
Mostly As and Bs	33.0	31.2
Mostly Bs and Cs	29.0	25.5
Mostly Cs and Ds	12.5	17.2
Mostly Ds and Fs	8.6	9.9
Percent working at a job during typical school week	34.1%	29.5%

Notes: * = statistical significance at $p < .05$
Source: *NanoLeap* Student Survey, 2007–2008.

TABLE 7: CHARACTERISTICS OF STUDENTS IN B-TEAM TEACHER CHEMISTRY CLASSES, 2007–2008 *NANOLEAP* FIELD TEST

	TREATMENT (N=299)	CONTROL (N=325)
Grade Level		
9th	0.0%	0.6%
10th	26.0	27.7
11th	66.0	63.1
12th	8.0	8.6
Percent female	56.9%	51.7%
Born in the United States	95.0%	97.8%
English language spoken most often at home	93.6%	90.4%
Ethnicity		
American Indian / Alaskan Native	1.7%	1.2%
Asian or Pacific Islander	8.7	2.5
Black or African American	5.4	4.3
Hispanic (non-white)	13.4	14.2
White, non-Hispanic	69.6	76.2
Other	1.3	1.5
Grades usually get in school		
Mostly As	28.4%	17.8%
Mostly As and Bs	51.2	53.1
Mostly Bs and Cs	17.4	25.0
Mostly Cs and Ds	2.7	3.4
Mostly Ds and Fs	0.3	0.6
Grades usually get in science		
Mostly As	24.4%	17.0%
Mostly As and Bs	37.3	37.9
Mostly Bs and Cs	30.0	31.8
Mostly Cs and Ds	8.0	10.3
Mostly Ds and Fs	0.3	2.9
Percent working at a job during typical school week	61.2%	60.9%

Notes: * = statistical significance at $p < .05$
Source: *NanoLeap* Student Survey, 2007–2008.

INQUIRY-BASED LEARNING

To achieve the goal of supporting students' learning of core science concepts, the *NanoLeap* project set out to develop instructional materials that promote inquiry-based teaching and learning. The resulting materials were designed to incorporate the "essential features of classroom inquiry" (Olson & Loucks-Horsley, 2000):

- engaging learners through scientifically oriented questions,
- giving priority to evidence,
- formulating explanations from evidence to address scientifically oriented questions,
- evaluating explanations in light of alternative explanations, and
- communicating and justifying proposed explanations.

OUTCOME:	Teachers will be able to implement the *NanoLeap* curriculum modules in a manner that supports inquiry-based learning.
FINDING:	Student and teacher reports of classroom practices indicate that teachers in the treatment group were able to implement both the physical science and the chemistry modules in a manner that supports inquiry-based learning.

STUDENT PERCEPTIONS

Overall, students in both the physical science treatment and control groups reported engaging in inquiry-based practices at least "sometimes (every other week)" (see Table 8). Although there were statistically significant differences between the physical science treatment and control groups on some classroom practices, these differences were "small" as indicated by the effect size. Only two of the differences were of a magnitude to be deemed "educationally significant" (Cohen, 1988), that is, likely to have an impact on student learning: the introduction of content through formal presentation (e.g., the use of PowerPoint for presentation), and asking students to consider alternative explanations. Both of these instructional practices reflect design elements of the *NanoLeap* physical science module that were intentionally included to support inquiry-based teaching and learning. Thus, students in the physical science treatment group were more likely than their counterparts in the control group to say that their teacher engaged in these classroom practices.

In the chemistry field test, students in both the treatment and control groups also reported engaging in inquiry-based practices at least "sometimes (every other week)" (see Table 9). Again, although there were statistically significant differences between the treatment and control groups on some classroom practices, these differences were "small" as indicated by the effect size. Only one of the differences (i.e., conduct experiments to test different explanations) in instructional practices was of a magnitude to be deemed "educationally significant." This practice reflects the design of the chemistry module as a culminating end-of-year unit that relied more on the Socratic questioning and discussion. In this instance, students in the chemistry treatment group were *less* likely than students in the control group to report that their teacher had them conduct experiments to test different explanation.

The relationship of all "educationally significant" instructional practices and others were examined with regard to student achievement. These findings are presented in the section on "Student Learning."

TABLE 8: STUDENT PERCEPTIONS OF *NANOLEAP* B-TEAM TEACHERS' INQUIRY-BASED CLASSROOM PRACTICES IN PHYSICAL SCIENCE, 2007–2008 (FIELD TEST).

INQUIRY-BASED PRACTICES	TREATMENT (N=308)		CONTROL (N=445)		EFFECT SIZE
	MEAN	S.D.	MEAN	S.D.	
a. Introduce content through formal presentation	3.97	1.02	3.68	1.14	0.27*
b. Engage the whole class in discussion	3.99	1.03	3.86	1.13	0.12
c. Pose open-ended questions	3.86	1.02	3.68	1.06	0.17*
d. Require students to supply evidence to support their claims	3.85	1.07	3.63	1.12	0.20*
e. Ask students to explain concepts to one another	3.56	1.18	3.35	1.13	0.18*
f. Ask students to consider alternative explanations	3.64	1.00	3.38	1.10	0.25*
g. Formulate a testable hypothesis	3.42	1.05	3.37	1.13	0.05
h. Conduct experiments to test different explanations	3.64	0.94	3.66	1.05	-0.02
i. Record, represent, and/or analyze data	3.85	0.98	3.77	1.03	0.08
j. Write explanations about what was observed and why it happened	3.80	0.95	3.70	1.03	0.10
k. Debate different scientific explanations	3.41	1.11	3.31	1.12	0.09
l. Discuss the nature of science	3.31	1.17	3.31	1.15	0.00
m. Share ideas or solve problems with each other in small groups	3.59	1.04	3.52	1.12	0.06
n. Engage in hands-on science activities	3.60	0.97	3.73	1.08	-0.13
o. Total across 14-item scale	3.68	0.68	3.56	0.74	0.17*

Notes: On a scale of 1 = never, 2 = rarely (a few times), 3 = sometimes (every other week), 4 = often (once or twice a week), and 5 = every or almost every lesson.
* = statistical significance at $p < .05$.
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: *NanoLeap* Student Survey, 2007–2008.

TABLE 9: STUDENT PERCEPTIONS OF *NANOLEAP* B-TEAM TEACHER'S INQUIRY-BASED CLASSROOM PRACTICES IN CHEMISTRY, 2007–2008 (FIELD TEST).

INQUIRY-BASED PRACTICES	TREATMENT (N=275)		CONTROL (N=317)		EFFECT SIZE
	MEAN	S.D.	MEAN	S.D.	
a. Introduce content through formal presentation	4.01	0.95	3.77	1.12	0.23*
b. Engage the whole class in discussion	3.92	1.01	3.82	1.15	0.09
c. Pose open-ended questions	3.85	0.99	3.63	1.12	0.21*
d. Require students to supply evidence to support their claims	3.77	0.95	3.80	1.07	-0.03
e. Ask students to explain concepts to one another	3.43	1.01	3.37	1.18	0.05
f. Ask students to consider alternative explanations	3.51	1.14	3.35	1.17	0.14
g. Formulate a testable hypothesis	3.03	1.11	3.14	1.10	-0.10
h. Conduct experiments to test different explanations	3.26	1.03	3.59	1.00	-0.33*
i. Record, represent, and/or analyze data	3.64	1.01	3.76	0.99	-0.12
j. Write explanations about what was observed and why it happened	3.51	1.05	3.70	1.02	-0.18*
k. Debate different scientific explanations	3.16	1.13	3.13	1.10	0.03
l. Discuss the nature of science	3.21	1.11	3.20	1.16	0.01
m. Share ideas or solve problems with each other in small groups	3.39	1.14	3.45	1.12	-0.05
n. Engage in hands-on science activities	3.54	1.01	3.76	0.98	-0.22*
o. Total across 14-item scale	3.53	0.69	3.53	0.73	0.00

Notes: On a scale of 1 = never, 2 = rarely (a few times), 3 = sometimes (every other week), 4 = often (once or twice a week), and 5 = every or almost every lesson.
* = statistical significance at $p < .05$.
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: *NanoLeap* Student Survey, 2007–2008.

TEACHER PERCEPTIONS

Overall, teachers in both the physical science treatment and control groups reported engaging in inquiry-based practices at least “sometimes (every other week)” (see Table 10). Treatment group teachers, however, were more likely than control group teachers to report that their classroom practices included the following inquiry-based methods:

- *not* assigning science homework,
- gathering and reviewing student reflections in journals,
- use of simulation models,
- use of computers and the Internet,
- allowing students to work at their own pace,
- students making formal presentations to the class, and
- student- and teacher-led discussions.

As indicated by effect sizes, these differences between the physical science treatment and control groups were of a moderate magnitude (0.50 or greater) and thus likely to have an impact on student learning. All of these instructional practices reflect design elements of the *NanoLeap* physical science module that were intentionally included to support inquiry-based teaching and learning.

In contrast, the physical science control group teachers were more likely than treatment group teachers to report that their classroom practices utilized science experiments as an inquiry-based method:

- debating scientific explanations,
- students designing or implementing their own experiments,
- engaging in hands-on science activities, and
- preparing written reports.

Although these differences were “educationally significant,” they were small in magnitude (effect sizes less than 0.50).

Overall, only teachers in the chemistry treatment group reported engaging in inquiry-based practices at least “sometimes (every other week)” (see Table 11). Treatment group teachers were more likely than control group teachers to report that their classroom practices included the following instructional practices, which reflect the five “essential features of inquiry” noted above and other practices, that when implemented within an inquiry-rich environment, also support inquiry-based learning:

- assessing students knowledge before the unit,
- gathering and reviewing student reflections in journals,
- promoting an interdisciplinary focus,
- using real-world contexts, and
- open-ended questioning.

As indicated by effect sizes, these differences between the chemistry treatment and control groups were of a moderate magnitude (0.50 or greater) and thus likely to have an impact on student learning. All of these instructional practices reflect design elements of the *NanoLeap* chemistry module that were intentionally included to support inquiry-based teaching and learning.

In contrast, like the physical science control group the chemistry control group teachers were more likely than treatment group teachers to report that their classroom practices utilized science experiments as an inquiry-based method:

- students designing or implementing their own experiments,
- sharing ideas or solving problems in small groups,
- engaging in hands-on science activities, and
- preparing written reports.

All of these differences were "educationally significant" and represented small to moderate magnitude (effect sizes greater than 0.25 and less than 0.75).

TABLE 10: TEACHER PERCEPTIONS OF *NANOLEAP* B-TEAM TEACHER'S INQUIRY-BASED CLASSROOM PRACTICES IN PHYSICAL SCIENCE, 2007–2008 (FIELD TEST).

INQUIRY-BASED PRACTICES: TEACHER	TREATMENT (N=18)		CONTROL (N=20)		EFFECT SIZE
	MEAN	S.D.	MEAN	S.D.	
a. Demonstrate a science-related principle or phenomenon	3.67	0.69	3.75	0.85	-0.10
b. Teach science using real-world contexts	3.83	0.86	3.95	0.83	-0.14
c. Arrange seating to facilitate student discussion	3.12	1.58	2.75	1.25	0.26
d. Use open-ended questions	3.89	0.90	3.85	0.99	0.04
e. Require students to supply evidence to support their claims	3.56	0.62	3.55	0.99	0.01
f. Encourage students to explain concepts to one another	3.50	1.15	3.45	1.00	0.05
g. Encourage students to consider alternative explanations	3.22	1.00	3.00	1.03	0.22
h. Allow students to work at their own pace	3.83	1.15	3.20	1.11	0.56
i. Help students see connections between science and other disciplines	3.44	0.98	3.40	1.00	0.04
j. Use assessment to find out what students know before or during the unit	3.39	1.04	3.25	1.37	0.12
k. Embed assessment in regular class activities	3.89	0.90	3.85	0.88	0.04
l. Assign science homework	2.65	1.06	4.15	0.59	-1.82*
m. Read and comment on the reflections students have written in their notebooks or journals	3.00	0.97	2.00	1.17	0.93*

Notes: On a scale of 1 = never, 2 = rarely (a few times), 3 = sometimes (every other week), 4 = often (once or twice a week), and 5 = every or almost every lesson.
* = statistical significance at $p < .05$.
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: *NanoLeap* Teacher Survey, 2007–2008.

Table 10: Teacher Perceptions of *NanoLeap* B-Team Teacher's Inquiry-Based Classroom Practices in Physical Science, 2007–2008 (Field Test) (Cont).

Inquiry-Based Practices: Students	Treatment (N=18)		Control (N=20)		Effect Size
	Mean	S.D.	Mean	S.D.	
n. Formulate a testable hypothesis	3.11	1.02	3.00	1.11	0.10
o. Conduct experiments to test different explanations	3.39	1.04	3.65	0.81	-0.28
p. Record, represent, and/or analyze data	3.78	0.94	3.85	0.75	-0.08
q. Write explanations about what was observed and why it happened	3.89	0.83	3.75	0.85	0.17
r. Debate different scientific explanations	2.83	0.99	2.50	1.05	0.32
s. Discuss the nature of science	2.83	1.15	2.80	1.51	0.02
t. Assess the quality of their own work	2.67	0.77	2.90	1.25	-0.23
u. Participate in student-led discussions	2.67	1.33	2.05	1.15	0.50
v. Participate in discussions with the teacher to further science understanding	3.94	0.73	3.45	1.19	0.51
w. Work in cooperative learning groups	4.11	0.90	4.05	1.00	0.06
x. Make formal presentations to the class	2.39	0.85	1.95	0.76	0.55
y. Work on solving a real-world problem	3.22	1.31	3.05	0.89	0.15
z. Share ideas or solve problems with each other in small groups	3.67	0.69	3.70	0.98	-0.04
aa. Engage in hands-on science activities	3.94	0.64	4.15	0.82	-0.29
bb. Follow specific instructions in an activity or investigation	3.89	0.68	3.85	0.75	0.06
cc. Design or implement their own investigation	2.39	0.70	2.60	1.05	-0.24
dd. Work on models of simulations	3.44	0.71	2.75	1.21	0.72*
ee. Work on extended science investigations or projects (a week or more in duration)	2.22	1.17	2.35	1.46	-0.10
ff. Participate in field work	1.44	0.86	1.45	0.69	-0.01
gg. Write reflections in a notebook or journal	4.00	1.14	2.10	1.45	1.47*
hh. Prepare written science reports	2.28	0.67	2.55	1.28	-0.28
ii. Use computers for modeling and simulations	3.28	0.96	2.15	0.99	1.16*
jj. Use the Internet	3.33	0.77	2.25	1.07	1.17*
kk. Total across 36-item scale (alpha = 0.93)	3.27	0.47	3.09	0.61	0.33

Notes: On a scale of 1 = never, 2 = rarely (a few times), 3 = sometimes (every other week), 4 = often (once or twice a week), and 5 = every or almost every lesson.
* = statistical significance at $p < .05$.
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: *NanoLeap* Teacher Survey, 2007–2008.

TABLE 11: TEACHER PERCEPTIONS OF *NANOLEAP* B-TEAM TEACHER'S INQUIRY-BASED CLASSROOM PRACTICES IN CHEMISTRY, 2007–2008 (FIELD TEST).

INQUIRY-BASED PRACTICES: TEACHER	TREATMENT (N=18)		CONTROL (N=20)		EFFECT SIZE
	MEAN	S.D.	MEAN	S.D.	
a. Demonstrate a science-related principle or phenomenon	3.53	0.80	3.39	0.85	0.17
b. Teach science using real-world contexts	4.11	0.66	3.44	0.71	0.98*
c. Arrange seating to facilitate student discussion	3.67	0.91	2.67	1.50	0.83*
d. Use open-ended questions	4.39	0.61	3.71	1.05	0.82*
e. Require students to supply evidence to support their claims	3.56	0.78	3.33	1.09	0.25
f. Encourage students to explain concepts to one another	3.68	0.82	4.17	0.86	-0.58
g. Encourage students to consider alternative explanations	3.67	0.69	3.22	0.94	0.55
h. Allow students to work at their own pace	3.63	1.01	3.83	1.10	-0.19
i. Help students see connections between science and other disciplines	4.05	0.71	3.22	0.94	1.01*
j. Use assessment to find out what students know before or during the unit	3.58	0.77	2.83	1.10	0.80*
k. Embed assessment in regular class activities	3.89	0.58	3.67	1.19	0.25
l. Assign science homework	3.37	0.68	3.72	1.27	-0.36
m. Read and comment on the reflections students have written in their notebooks or journals	2.58	1.17	1.39	0.50	1.43*

Notes: On a scale of 1 = never, 2 = rarely (a few times), 3 = sometimes (every other week), 4 = often (once or twice a week), and 5 = every or almost every lesson.
* = statistical significance at p < .05.
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: *NanoLeap* Teacher Survey, 2007–2008.

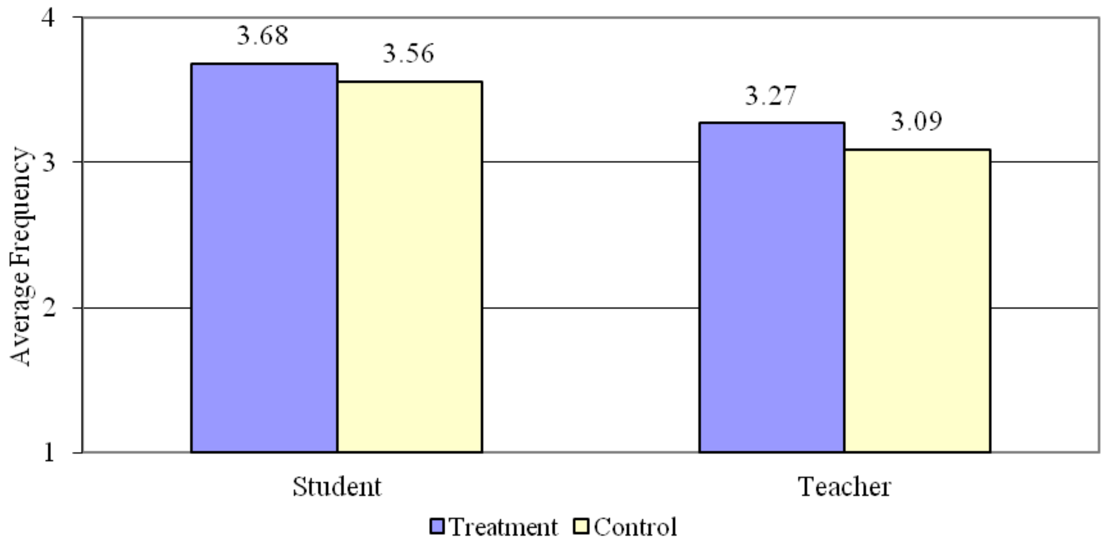
TABLE 11: TEACHER PERCEPTIONS OF *NANOLEAP* B-TEAM TEACHER'S INQUIRY-BASED CLASSROOM PRACTICES IN CHEMISTRY, 2007–2008 (FIELD TEST) (CONT).

INQUIRY-BASED PRACTICES: STUDENTS	TREATMENT (N=17)		CONTROL (N=18)		EFFECT SIZE
	MEAN	S.D.	MEAN	S.D.	
n. Formulate a testable hypothesis	2.47	0.84	2.61	1.04	-0.15
o. Conduct experiments to test different explanations	2.05	0.97	2.78	1.11	-0.70*
p. Record, represent, and/or analyze data	3.42	0.77	3.56	0.86	-0.17
q. Write explanations about what was observed and why it happened	3.26	0.73	3.44	0.86	-0.23
r. Debate different scientific explanations	3.00	0.94	2.00	0.84	1.12*
s. Discuss the nature of science	3.16	0.96	2.56	1.15	0.57
t. Assess the quality of their own work	3.11	0.74	3.00	1.06	0.12
u. Participate in student-led discussions	2.68	1.11	2.33	1.03	0.33
v. Participate in discussions with the teacher to further science understanding	4.05	0.62	3.28	1.18	0.86*
w. Work in cooperative learning groups	4.11	0.66	4.06	0.80	0.07
x. Make formal presentations to the class	2.26	0.73	1.56	1.04	0.79*
y. Work on solving a real-world problem	3.05	0.91	2.39	0.98	0.70*
z. Share ideas or solve problems with each other in small groups	3.32	0.95	3.61	0.85	-0.32
aa. Engage in hands-on science activities	3.58	0.51	3.78	0.73	-0.32
bb. Follow specific instructions in an activity or investigation	3.89	0.81	3.78	0.73	0.14
cc. Design or implement their own investigation	1.89	0.94	2.28	1.18	-0.37
dd. Work on models of simulations	3.32	0.75	2.56	1.10	0.82*
ee. Work on extended science investigations or projects (a week or more in duration).	3.16	0.96	1.78	1.11	1.33*
ff. Participate in field work.	1.26	0.56	1.39	0.70	-0.21
gg. Write reflections in a notebook or journal	2.37	0.90	1.61	1.04	0.78*
hh. Prepare written science reports	2.11	0.81	2.61	1.38	-0.46
ii. Use computers for modeling and simulations	3.53	0.70	1.78	0.81	2.32*
jj. Use the Internet	3.63	0.76	2.22	1.31	1.36*
kk. Total across 36-item scale (alpha = 0.93)	3.23	0.40	2.88	0.47	0.80*

Notes: On a scale of 1 = never, 2 = rarely (a few times), 3 = sometimes (every other week), 4 = often (once or twice a week), and 5 = every or almost every lesson.
* = statistical significance at p < .05.
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: *NanoLeap* Teacher Survey, 2007–2008.

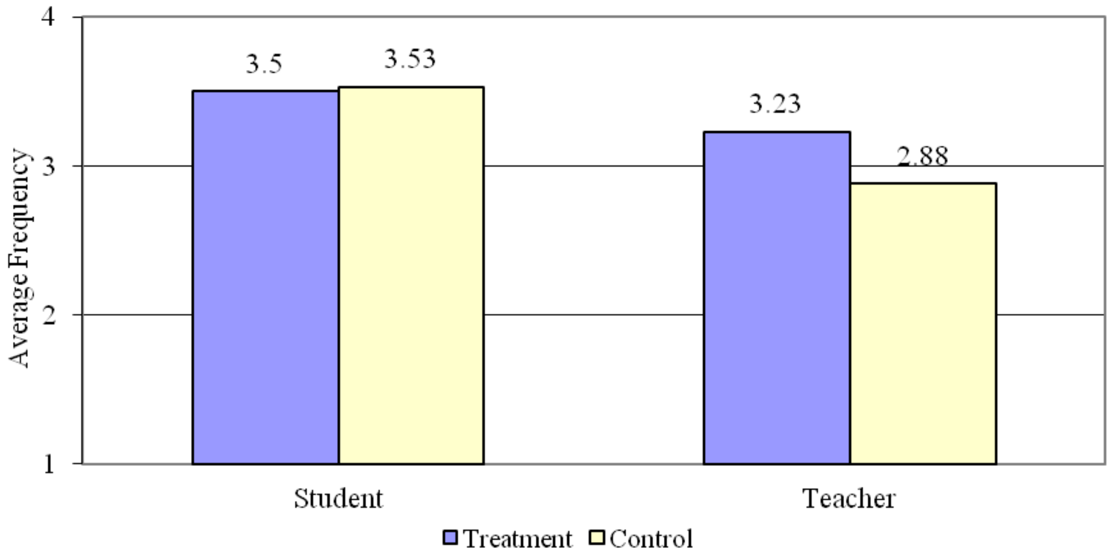
Thus, in both the physical science and chemistry field tests, both students and teachers in the control groups reported that teachers were able to implement the *NanoLeap* modules in an inquiry-based manner (see Figures 1 and 2).

Figure 1: Student and Teacher **Perceptions of Inquiry-Based Classroom Practices in Physical Science Treatment Group, 2007–2008 *NanoLeap* Field Test.**



Note: Average across 14-item scale for students and 36-item scale for teachers where 1 = never, 2 = rarely (a few times), 3 = sometimes (every other week), 4 = often (once or twice a week), and 5 = every or almost every lesson.
Source: *NanoLeap* physical science student and teacher surveys, 2007–2008.

Figure 2: Student and Teacher Perceptions of Inquiry-Based Classroom Practices in Chemistry Treatment Group, 2007–2008 *NanoLeap* Field Test.



Note: Average across 14-item scales for students and 36-item scale for teachers where 1 = never, 2 = rarely (a few times), 3 = sometimes (every other week), 4 = often (once or twice a week), and 5 = every or almost every lesson.
Source: *NanoLeap* chemistry student and teacher surveys, 2007–2008.

STUDENT INTEREST AND ENGAGEMENT

An integral part of developing instructional materials that support inquiry-based teaching and learning is the extent to which the materials engage students in a manner that increases their interest in learning science.

OUTCOME #2:	Students in classrooms where teachers fully implement the *NanoLeap* materials (treatment group) will demonstrate greater levels of interest and engagement in learning science than students in classrooms where the *NanoLeap* materials are not implemented (control group).
FINDING #2:	Participation in the *NanoLeap* physical science and chemistry modules did not increase students' interest and/or engagement in science.

Students participating in the *NanoLeap* physical science and chemistry field tests were asked a series of questions to determine their interest and/or engagement in science just before and just after the period in which the *NanoLeap* modules were being implemented (i.e., when the topics addressed by the modules were being taught in the course).

With two exceptions, students in both the treatment and control groups for the *NanoLeap* physical science and chemistry field tests came into the project expressing an interest in science (see Tables 12 and 13). As a whole, students did not enter the project with an interest in becoming scientists or in obtaining a job in nanoscale science or technology nor did they express one after participating.

Over the course of the project, students in both the treatment and control groups for the physical science and chemistry field tests did not show an increased interest and/or engagement in science as a result of the NanoLeap project (see Table 14). This is likely a reflection of the fact that they came into the project with a high interest in science leaving little room for improvement.

TABLE 12: STUDENT INTEREST / ENGAGEMENT IN PHYSICAL SCIENCE, 2007–2008 *NANOLEAP* FIELD TEST

	Treatment (n=306)				Control (n= 340)			
	Pre	Post	Gain	Effect Size	Pre	Post	Gain	Effect Size
1. Physical Science is a difficult subject.	2.44 (0.77)	2.54 (0.79)	0.10 (0.74)	-0.13	2.43 (0.72)	2.43 (0.81)	0.01 (0.76)	0.00
2. Physical Science is interesting.	2.27 (0.73)	2.27 (0.73)	-0.00 (0.75)	0.00	2.20 (0.75)	2.20 (0.76)	-0.02 (0.69)	0.00
3. Physical Science is easy for me to learn.	2.50 (0.75)	2.54 (0.75)	0.04 (0.68)	-0.05	2.51 (0.76)	2.55 (0.80)	0.04 (0.74)	-0.05
4. Physical Science has opened my eyes to new and exciting jobs.	2.91 (0.71)	2.88 (0.72)	-0.03 (0.81)	0.04	2.82 (0.76)	2.86 (0.76)	0.04 (0.77)	-0.05
5. I like Physical Science better than most other subjects.	2.93 (0.84)	3.01 (0.80)	0.83 (0.74)	-0.10	2.86 (0.90)	2.84 (0.92)	-0.01 (0.83)	0.02
6. I think everybody should learn Physical Science at school.	2.26 (0.79)	2.23 (0.77)	-0.03 (0.77)	0.04	2.15 (0.74)	2.12 (0.75)	-0.03 (0.68)	0.04
7. The things that I learn in Physical Science will be helpful in my everyday life.	2.41 (0.72)	2.51 (0.74)	0.98 (0.79)	-0.14	2.35 (0.72)	2.39 (0.70)	0.05 (0.70)	-0.06
8. I think that the Physical Science I learn at school will improve my career chances.	2.21 (0.75)	2.37 (0.77)	0.15 (0.80)	-0.21	2.34 (0.73)	2.37 (0.80)	0.43 (0.76)	-0.04
9. Physical Science has made me more critical and skeptical.	2.78 (0.66)	2.70 (0.71)	-0.08 (0.79)	0.12	2.71 (0.66)	2.68 (0.73)	-0.03 (0.74)	0.04
10. Physical Science has increased my curiosity about things we cannot yet explain.	2.38 (0.78)	2.35 (0.87)	-0.04 (0.91)	0.04	2.29 (0.81)	2.34 (0.84)	0.04 (0.73)	-0.06

TABLE 12: STUDENT INTEREST / ENGAGEMENT IN PHYSICAL SCIENCE, 2007–2008 *NANOLEAP* FIELD TEST (CONT).

	TREATMENT (N=306)				CONTROL (N= 340)			
	PRE	POST	GAIN	EFFECT SIZE	PRE	POST	GAIN	EFFECT SIZE
11. Physical Science has increased my appreciation of nature.	2.45 (0.76)	2.44 (0.80)	-0.01 (0.82)	0.01	2.40 (0.70)	2.42 (0.74)	0.03 (0.73)	-0.03
12. Physical Science has shown me the importance of science for our way of living.	2.27 (0.71)	2.34 (0.68)	0.07 (0.74)	-0.10	2.22 (0.68)	2.24 (0.75)	0.02 (0.80)	-0.03
13. I would like to become a scientist.	3.41 (0.73)	3.36 (0.74)	-0.05 (0.64)	0.07	3.32 (0.78)	3.27 (0.76)	-0.05 (0.71)	0.06
14. I would like to have as much Physical Science as possible at school.	2.98 (0.81)	3.02 (0.79)	0.04 (0.75)	-0.05	2.88 (0.79)	2.86 (0.82)	-0.02 (0.74)	0.02
15. I would like to get a job in nanoscale science or technology.	3.34 (0.71)	3.40 (0.68)	0.59 (0.78)	-0.09	3.16 (0.82)	3.22 (0.81)	0.06 (0.85)	-0.07

Notes: On a scale of 1=strongly disagree, 2 = disagree, 3 = agree, and 4 = strongly agree.
Source: *NanoLeap* Pre/Post Student Assessment, 2007–2008.

TABLE 13: STUDENT INTEREST / ENGAGEMENT IN CHEMISTRY, 2007–2008 *NANOLEAP* FIELD TEST

	TREATMENT (N=306)				CONTROL (N= 340)			
	PRE	POST	GAIN	EFFECT SIZE	PRE	POST	GAIN	EFFECT SIZE
1. Chemistry is a difficult subject.	2.07 (0.80)	2.10 (0.77)	0.03 (0.71)	-0.04	2.03 (0.80)	2.08 (0.87)	0.05 (0.69)	-0.06
2. Chemistry is interesting.	2.09 (0.72)	2.17 (0.77)	0.08 (0.71)	-0.11	2.15 (0.83)	2.20 (0.78)	0.05 (0.61)	-0.06
3. Chemistry is easy for me to learn.	2.65 (0.80)	2.65 (0.79)	-0.00 (0.60)	0.00	2.64 (0.91)	2.61 (0.85)	-0.03 (0.81)	0.03
4. Chemistry has opened my eyes to new and exciting jobs.	2.77 (0.79)	2.67 (0.77)	-0.09 (0.68)	0.13	2.81 (0.76)	2.75 (0.78)	-0.07 (0.70)	0.08
5. I like Chemistry better than most other subjects.	2.88 (0.90)	2.90 (0.85)	0.01 (0.63)	-0.02	2.85 (0.94)	2.83 (0.93)	-0.02 (0.76)	0.02
6. I think everybody should learn Chemistry at school.	2.30 (0.80)	2.32 (0.82)	0.02 (0.69)	-0.02	2.25 (0.81)	2.23 (0.83)	-0.02 (0.78)	0.02
7. The things that I learn in Chemistry will be helpful in my everyday life.	2.60 (0.78)	2.57 (0.72)	-0.02 (0.72)	0.04	2.64 (0.82)	2.56 (0.81)	-0.09 (0.77)	0.10
8. I think that the Chemistry I learn at school will improve my career chances.	2.30 (0.85)	2.33 (0.83)	0.03 (0.69)	-0.04	2.41 (0.87)	2.35 (0.84)	-0.06 (0.74)	0.07
9. Chemistry has made me more critical and skeptical.	2.72 (0.75)	2.63 (0.75)	-0.10 (0.78)	0.12	2.63 (0.78)	2.56 (0.77)	-0.07 (0.78)	0.09
10. Chemistry has increased my curiosity about things we cannot yet explain.	2.27 (0.88)	2.26 (0.80)	-0.02 (0.79)	0.01	2.37 (0.86)	2.38 (0.87)	0.01 (0.76)	-0.01

TABLE 13: STUDENT INTEREST / ENGAGEMENT IN CHEMISTRY, 2007–2008 *NANOLEAP* FIELD TEST (CONT).

	TREATMENT (N=306)				CONTROL (N= 340)			
	PRE	POST	GAIN	EFFECT SIZE	PRE	POST	GAIN	EFFECT SIZE
11. Chemistry has increased my appreciation of nature.	2.52 (0.78)	2.49 (0.76)	-0.03 (0.77)	0.04	2.54 (0.76)	2.51 (0.80)	-0.04 (0.82)	0.04
12. Chemistry has shown me the importance of science for our way of living.	2.22 (0.73)	2.25 (0.70)	0.03 (0.75)	-0.04	2.29 (0.75)	2.31 (0.73)	0.02 (0.77)	-0.03
13. I would like to become a scientist.	3.18 (0.85)	3.13 (0.86)	-0.05 (0.66)	0.06	3.23 (0.86)	3.10 (0.90)	-0.13 (0.76)	0.15
14. I would like to have as much Chemistry as possible at school.	3.02 (0.81)	2.97 (0.85)	-0.05 (0.68)	0.06	3.02 (0.86)	2.90 (0.90)	-0.12 (0.81)	0.14
15. I would like to get a job in nanoscale science or technology.	3.31 (0.71)	3.35 (0.73)	0.04 (0.75)	-0.06	3.32 (0.74)	3.22 (0.82)	-0.10 (0.78)	0.13

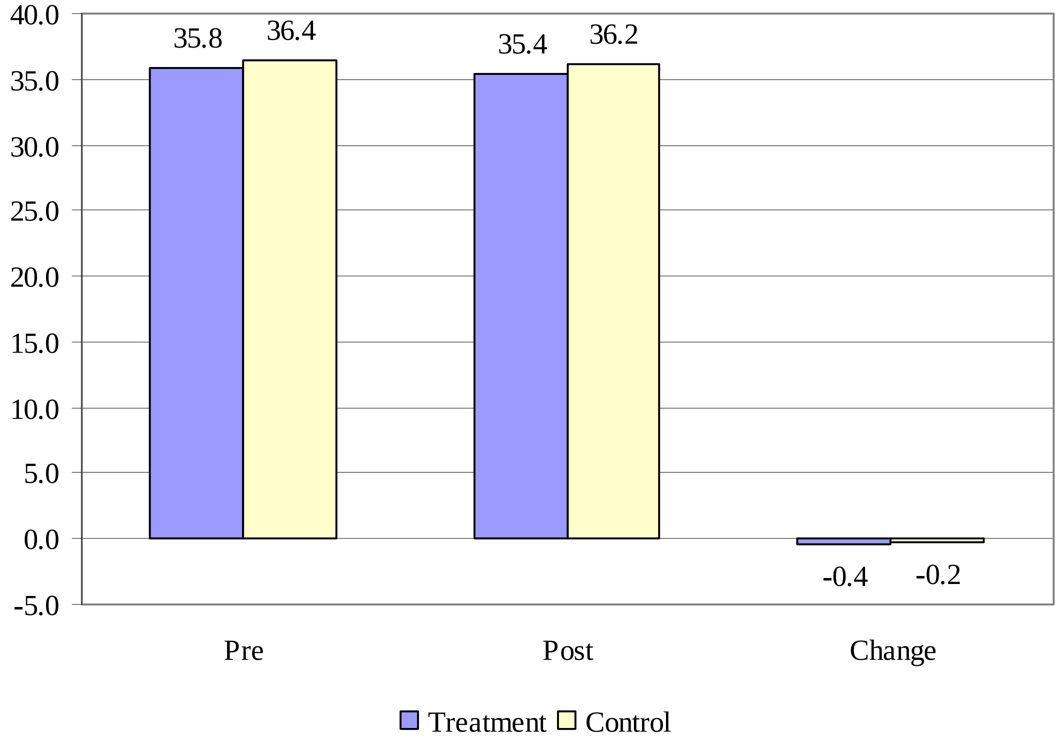
Notes: On a scale of 1=strongly disagree, 2 = disagree, 3 = agree, and 4 = strongly agree.
Source: *NanoLeap* Pre/Post Student Assessment, 2007–2008.

TABLE 14: CHANGE IN OVERALL STUDENT INTEREST / ENGAGEMENT, 2007–2008 *NANOLEAP* FIELD TEST

<table>
<tr><td></td><td colspan="2">RELIABILITY</td><td colspan="3">TREATMENT (N=305)</td><td colspan="3">CONTROL (N=334)</td><td colspan="3">DIFFERENCE TREATMENT - CONTROL</td></tr>
<tr><td>MEAN (S.D.)</td><td>PRE</td><td>POST</td><td>PRE</td><td>POST</td><td>GAIN SCORE</td><td>PRE</td><td>POST</td><td>GAIN SCORE</td><td>PRE</td><td>POST</td><td>GAIN SCORE</td></tr>
<tr><td>PHYSICAL SCIENCE (15 ITEMS)</td><td>.82</td><td>.83</td><td>35.8 (6.1)</td><td>35.4 (6.1)</td><td>-0.4 (4.9)</td><td>36.4 (6.1)</td><td>36.2 (6.7)</td><td>-0.2 (5.2)</td><td>-0.6 (0.5)</td><td>-0.7 (0.5)</td><td>-0.2 (0.4)</td></tr>
<tr><td>Effect Size</td><td colspan="4"></td><td>-0.07</td><td colspan="2"></td><td>-0.03</td><td>-0.10</td><td>-0.13</td><td>-0.04</td></tr>
<tr><td></td><td colspan="2">RELIABILITY</td><td colspan="3">TREATMENT (N=364)</td><td colspan="3">CONTROL (N=290)</td><td colspan="3">DIFFERENCE TREATMENT – CONTROL</td></tr>
<tr><td>CHEMISTRY (15 ITEMS)</td><td>.87</td><td>.86</td><td>35.7 (7.1)</td><td>35.6 (7.0)</td><td>-0.0 (4.4)</td><td>35.1 (7.4)</td><td>35.6 (7.2)</td><td>0.5 (4.8)</td><td>0.6 (0.6)</td><td>0.0 (0.6)</td><td>-0.6 (0.4)</td></tr>
<tr><td>Effect Size</td><td colspan="4"></td><td>0.01</td><td colspan="2"></td><td>-0.07</td><td>0.08</td><td>0.00</td><td>-0.13</td></tr>
<tr><td colspan="12">Notes: The motivation scale included 15 items, each rated as 1 = strongly disagree, 2 = disagree, 3 = agree, and 4 = strongly agree.
* = statistical significance at $p < .05$.
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: NanoLeap Physical Science and Chemistry Student Assessments, 2007–2008.</td></tr>
</table>

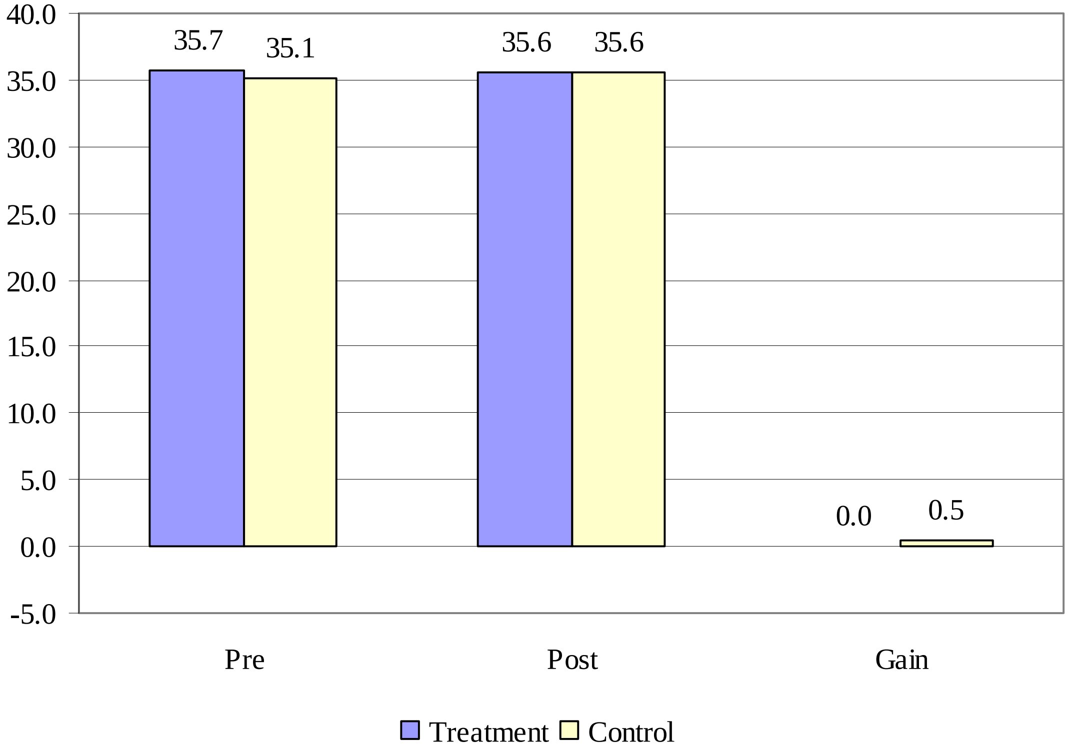
Thus, overall, students did not demonstrate an increased interest and/or engagement in science (see Figures 3 and 4).

Figure 3: Comparison of Treatment and Control Group Student Motivation **in Physical Science, 2007–2008 *NanoLeap* Field Test.**



Note: 15-item motivation scale with each item rated as 1 = strongly disagree, 2 = disagree, 3 = agree, and 4 = strongly agree.
Source: *NanoLeap* physical science student survey, 2007–2008.

Figure 4: Comparison of Treatment and Control Group Student Motivation in Chemistry, 2007–2008 *NanoLeap* Field Test.



Note: 15-item motivation scale with each item rated as 1 = strongly disagree, 2 = disagree, 3 = agree, and 4 = strongly agree.
Source: *NanoLeap* chemistry student survey, 2007–2008.

STUDENT LEARNING

To achieve the goal of integrating nanoscale science into high school physical science and chemistry classes in a manner that supports student learning of core science concepts, the *NanoLeap* project developed instructional materials to support inquiry-based teaching and learning.

OUTCOME #3:	Students in classrooms where teachers fully implement the *NanoLeap* materials (treatment group) will demonstrate a level of understanding of core science concepts that is at least equal to, if not greater than, that of students in classrooms where the *NanoLeap* materials are not implemented (control group).
FINDING #3:	Students in the physical science treatment group significantly outperformed their peers in the control group in terms of the gain in knowledge demonstrated from the pre- to the post-test.

OUTCOME #4:	Students in classrooms where teachers fully implement the *NanoLeap* materials (treatment group) will demonstrate an increased understanding of nanoscale science, technology, engineering, and mathematics concepts, applications, and careers.
FINDING #4:	Students in the chemistry treatment group significantly outperformed their peers in the control group in terms of the gain in knowledge that was demonstrated from the pre- to the post-test. Student understanding of nanoscale applications and careers was not formally assessed.[8]

Students in the physical science and chemistry field tests completed a pre- and post-test to assess their knowledge of core science and nanoscale science concepts within the particular subject area. The questions on these assessments of student knowledge in both the chemistry and physical science modules represented three types of science concepts (see Appendix C for sample items):

- <u>CORE SCIENCE</u> concepts include those items on the assessment that typically <u>are</u> addressed in high school science and measure student understanding of macroscale objects, comparisons, and phenomena.

[8] The *Nanoleap* modules were designed to increase student understanding of nanoscale science, technology, engineering, and mathematics concepts through their application and through exposure to related careers. As such, nanoscale applications and careers were used as pedagogical vehicles to promote greater understanding of nanoscale concepts and were not measured directly.

- TRANSITION TO NANOSCALE SCIENCE concepts include those items on the assessment that typically are not addressed in high school science and measure student understanding of macroscale and nanoscale objects, comparisons, and phenomena.
- NANOSCALE SCIENCE concepts include those items on the assessment that typically are not addressed in high school science and measure student understanding of nanoscale objects, comparisons, and phenomena.

PHYSICAL SCIENCE

In the *NanoLeap* physical science field test, pre- and post-assessment data were available from 306 students in the treatment group and 343 students in the control group. In looking at overall performance on the physical science assessment, an item analysis of the field test data indicated that the test functioned well with high reliability (alphas of 0.77 pre and 0.88 post) and the ability to discriminate between low and high performing students (item discrimination coefficients of 0.98 pre and .099 post) (see Table 15).[9]

TABLE 15: PHYSICAL SCIENCE STUDENT ASSESSMENT – SUMMARY STATISTICS, 2007–2008 FIELD TEST

	PRE-TEST		POST-TEST	
	TREATMENT (N=306)	CONTROL (N=343)	TREATMENT (N=306)	CONTROL (N=343)
MAXIMUM POSSIBLE SCORE	42	42	42	42
HIGHEST OBTAINED SCORE	34	33	40	36
LOWEST OBTAINED SCORE	6	5	7	0
MINIMUM POSSIBLE SCORE	0	0	0	0
MEAN SCORE (S.D.)	19.5 (6.2)	18.7 (6.0)	24.9 (8.0)	19.5 (7.6)
MEAN PERCENT OF MAX POSSIBLE	46.4%	44.5%	59.3%	46.4%
MEDIAN	19	18	26	19
MODE	25	13, 27	24, 31	13, 20
RELIABILITY	.77		.88	
ITEM DISCRIMINATION COEFFICIENT[1]	.98		.99	

Notes: [1] Item discrimination coefficients are based on all available data. All other data are based on cases with both pre- and post-test data.
Source: *NanoLeap* Physical Science Student Assessment, 2007–2008.

[9] A separate item analysis report was prepared for the physical science and chemistry field tests.

GROWTH

As shown in Table 16, the treatment and control group students in the physical science *NanoLeap* field test were comparable (i.e., no significant differences) in their baseline knowledge of all three science concepts: “core science,” “nanoscale science,” and “transition to nanoscale science” concepts.

Overall, students in the physical science treatment group significantly outperformed their peers in the control group in terms of the gain in knowledge demonstrated from the pre- to the post-test (see Table 16 and Figure 5). The differences between the performance of the treatment and the control group, overall, and with regard to “core science” concepts, “nanoscale science” concepts, and “transitional science” concepts was “educationally significant;” that is, likely to represent an improvement in learning that was demonstrated in practice.[10]

With regard to “core science” concepts, students in the physical science treatment group demonstrated greater gains in knowledge than the control group (see Table 16 and Figure 5). The treatment group gains were approaching moderate magnitude with an effect size of .54 and, as such, were at the “educationally significant” level. In contrast, the control group showed no real change in knowledge of “core science” concepts with an effect size of 0.10.

With regard to “nanoscale science” and “transition to nanoscale science” concepts, the physical science treatment group demonstrated much greater gains than the control group (see Table 16 and Figure 5). The treatment group gains were “educationally significant” with regard to “nanoscale science,” as noted by a large effect size of 0.85, and with regard to “transition to nanoscale science,” as noted by a moderate effect size of 0.63. In contrast, the control group demonstrated a small gain in knowledge of “nanoscale science,” which approached but was not “educationally significant” (effect size of 0.24), and no gain in knowledge of “transition to nanoscale science” concepts.

Overall, the physical science treatment group also performed better than the control group with regard to the two “essential understandings” most representative of the *NanoLeap* physical science module: “measurement and size” and “forces” (see Table 16 and Figure 5). The differences between the treatment and control group gains were “educationally significant.” Both the treatment and control groups, however, demonstrated generally poor understanding of measurement and size. This may be due to the nature of the assessment which tested students’ knowledge of material that students struggled to grasp in class (e.g., questions that required

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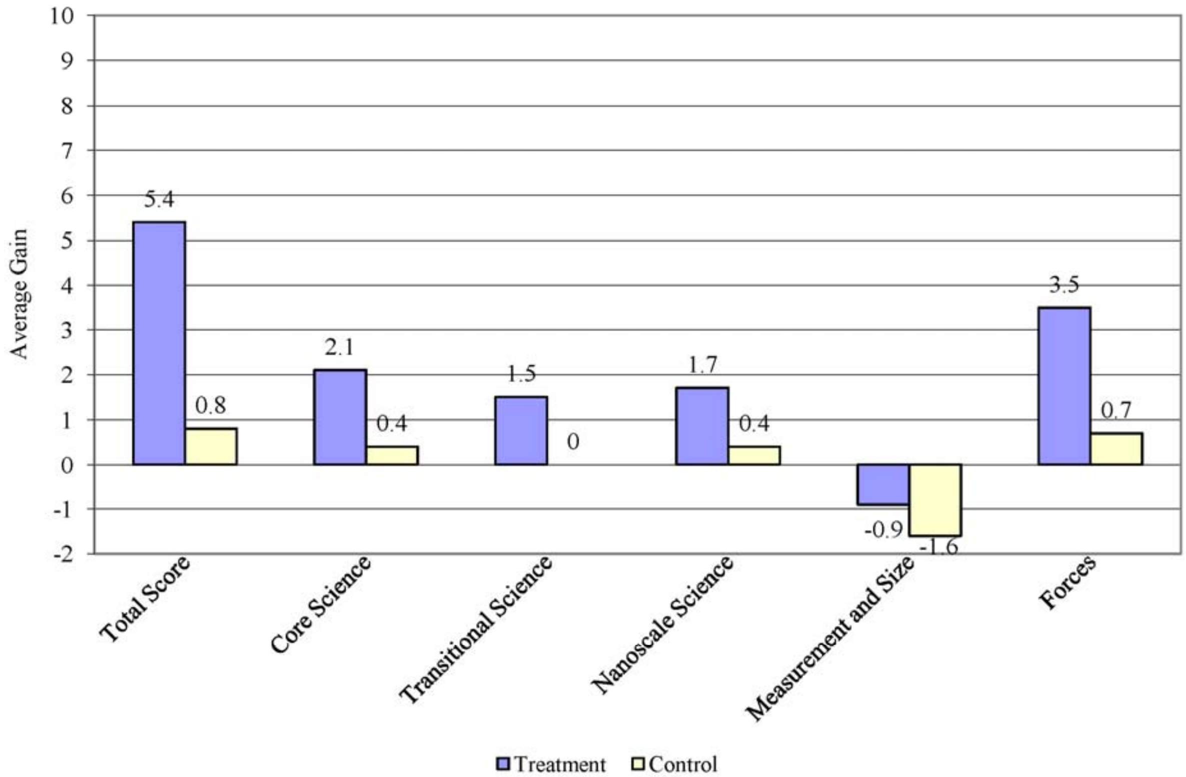
[10] “Statistical” significance refers to a statistical measure of the extent to which we can be certain that the difference is not due to chance; in this case, we are 95 percent certain that the results are not due to chance. As such, statistically significant results will highlight changes of any magnitude from those that are very small to very large. “Practical” significance examines the magnitude of a statistically significant change to determine whether the magnitude of the change is large enough to produce effects that will result in difference that it is noticed in “practice” as determined by prior research in a particular area. “Educational significance” refers to an effect size of at least .25 and represents the average effect size across a variety of educational interventions that would be needed to see a change in educational outcomes, such as student achievement.

students to rank the size of objects that were visible to the naked eye and objects that were not visible, and questions regarding exponents).

Figure 5: Comparison of Treatment and Control Group Performance on Physical Science Student Assessment, 2007–2008 *NanoLeap* Field Test.



Source: *NanoLeap* physical science student assessment, 2007–2008.

FACTORS RELATED TO GROWTH

Prior research indicates that many factors are related to student achievement, including student characteristics, student engagement, and instructional practices.

The students in the physical science treatment group most likely to show the greatest gains in knowledge said that they:[11]

- speak English in the home (*student characteristics*),
- find physical science interesting (*student characteristics*),
- find physical science is easy for them to learn (*student characteristics*), and
- have a teacher who emphasizes learning basic science in class (*instructional practices*).

[11] Results are based on bivariate correlations that are statistically significant at $p < .05$. The magnitude of correlations was 0.20 or less.

Other factors that were examined for their relationship to student performance on the physical science assessment, but were not significant, included gender, ethnicity, (student) hours working at a job each week, and other inquiry-based instructional practices that differed between the treatment and control groups.

In addition, the relationship between student interest / engagement in science and student performance on the physical science assessment was examined. Students in the physical science control group who had a greater interest coming into the project were more likely to show significant gains in their knowledge of core science concepts; there was no relationship between student interest in science and student performance in the treatment group.

IMPLEMENTATION FIDELITY

In addition to the standard data collection, teachers in the treatment group also provided data on the extent to which they implemented each of the *NanoLeap* physical science lessons. Almost every teacher made minor modifications to the module to better accommodate their students and/or the time available. Most teachers, however, completed the physical science lessons in their entirety.[12] When teachers did not complete a portion of a *NanoLeap* lesson, typically, they did not cover the two end-of-lesson activities designed to support metacognition in students (e.g., the "Making Connections" discussion questions and review of the Flow Chart designed to remind students where they were in the overall module). With regard to content, some teachers also did not fully implement all activities related to the examination of variables related to adhesion. Still, the results of the physical science assessment demonstrate that altering the implementation of the *NanoLeap* module in this way did not adversely affect students' understanding of key science concepts.

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[12] Three treatment group teachers were unable to complete the final lesson in the physical science module due to a lack of time. Of these, one teacher was unable to complete the last three lessons in the physical science module. The final analysis of assessment data presented in this report includes this classroom as it represented less than 5 percent of the final sample of treatment group students. Excluding this class from the analysis did not significantly alter the results when compared to the control group.

TABLE 16: PHYSICAL SCIENCE STUDENT ASSESSMENT - OVERALL AND BY SCIENCE CONTENT, 2007–2008 FIELD TEST

		TREATMENT (N=306)			CONTROL (N=343)			DIFFERENCE TREATMENT - CONTROL		
MEAN (S.D.)	ITEMS	PRE	POST	GAIN SCORE	PRE	POST	GAIN SCORE	PRE	POST	GAIN SCORE
TOTAL SCORE (42 ITEMS)	1-42	19.5 (6.2)	24.9 (8.0)	5.4 (7.1)	18.7 (6.0)	19.5 (7.6)	0.8 (6.8)	0.8 (6.1)	5.4 (7.8)	4.6 (7.0)
Effect Size				**0.76***			0.12	0.13	**0.69***	**0.65***
CORE SCIENCE (21 ITEMS)	1-3, 7, 9-13, 17, 20, 23, 24, 32-37, 41, 42	10.3 (3.5)	12.4 (4.2)	2.1 (3.9)	9.9 (3.7)	10.3 (4.4)	0.4 (4.1)	0.4 (3.6)	2.1 (4.3)	1.7 (3.9)
Effect Size				**0.54***			0.10*	0.11	**0.49***	**0.44***
TRANSITION TO NANOSCALE SCIENCE (11 ITEMS)	4-6, 8, 14, 15, 21-22, 25, 29, 30, 38	5.9 (2.2)	7.4 (2.6)	1.5 (2.4)	5.7 (2.3)	5.7 (2.6)	0.0 (2.5)	0.2 (2.3)	1.7 (2.6)	1.5 (2.5)
Effect Size				**0.63***			0.00	0.09	**0.65***	**0.60***
NANOSCALE SCIENCE (10 ITEMS)	16, 18, 19, 26-28, 31, 39, 40	3.4 (1.7)	5.1 (2.2)	1.7 (2.0)	3.1 (1.5)	3.5 (1.8)	0.4 (1.7)	0.3 (1.6)	1.7 (2.0)	1.4 (2.1)
Effect Size				**0.87***			0.24*	0.19*	**0.80***	**0.62***

Notes: * = statistical significance at p < .05.
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: *NanoLeap* Chemistry Student Assessment, 2007–2008.

TABLE 16: PHYSICAL SCIENCE STUDENT ASSESSMENT - OVERALL AND BY SCIENCE CONTENT, 2007–2008 FIELD TEST (CONT).

		TREATMENT (N=306)			CONTROL (N=343)			DIFFERENCE TREATMENT - CONTROL		
MEAN (S.D.)	ITEMS	PRE	POST	GAIN SCORE	PRE	POST	GAIN SCORE	PRE	POST	GAIN SCORE
ESSENTIAL UNDERSTANDING: MEASUREMENT AND SIZE (13 ITEMS)	17-28, 31	5.9 (2.5)	5.0 (1.9)	-0.9 (2.2)	5.3 (2.2)	3.7 (1.6)	-1.6 (1.9)	0.6 (2.4)	1.3 (1.8)	0.7 (2.1)
Effect Size				**-0.41***			**-0.84***	**0.26***	**0.74***	**0.33***
ESSENTIAL UNDERSTANDING: FORCES (17 ITEMS)	3-15, 29, 30, 38, 39	12.0 (4.5)	15.5 (5.2)	3.5 (4.9)	11.5 (4.2)	12.2 (5.3)	0.7 (4.8)	0.5 (4.4)	3.3 (5.3)	2.8 (4.9)
Effect Size				**0.71***			0.15*	0.11	**0.62***	**0.57***

Notes: * = statistical significance at p < .05.
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: *NanoLeap* Chemistry Student Assessment, 2007–2008.

CHEMISTRY

In the *NanoLeap* chemistry field test, pre- and post-assessment data were available from 365 students in the treatment group and 290 students in the control group. In looking at overall performance on the chemistry assessment, the test was not as reliable as a pre-test (alpha of 0.55) but functioned well as a post-test with high reliability (alpha of 0.83) and the ability to discriminate between low and high performing students (item discrimination coefficients of 0.96 pre and 0.98 post) (see Table 17).[13] However, the chemistry assessment was hard for most students, as indicated by the fact that students in the intervention group, on average, answered only 50 percent of the questions correctly at the end of the module.

TABLE 17: CHEMISTRY STUDENT ASSESSMENT – SUMMARY STATISTICS, 2007–2008 FIELD TEST

	PRE-TEST		POST-TEST	
	TREATMENT (N=365)	CONTROL (N=290)	TREATMENT (N=365)	CONTROL (N=290)
MAXIMUM POSSIBLE SCORE	40	40	40	40
HIGHEST OBTAINED SCORE	34	36	39	37
LOWEST OBTAINED SCORE	7	0	0	0
MINIMUM POSSIBLE SCORE	0	0	0	0
MEAN SCORE (S.D.)	15.9 (4.2)	14.7 (4.4)	19.9 (7.3)	13.7 (4.6)
MEAN PERCENT OF MAX POSSIBLE	39.8%	36.8%	49.8%	34.3%
MEDIAN	16	15	20	13
MODE	16	15	13	12
RELIABILITY	.55		.83	
ITEM DISCRIMINATION COEFFICIENT[1]	.96		.98	

Notes: [1] Item discrimination coefficients are based on all available data. All other data are based on cases with both pre- and post-test data.
Source: *NanoLeap* Chemistry Student Assessment, 2007–2008.

[13] A separate item analysis report was prepared for the physical science and chemistry field tests.

GROWTH

As shown in Table 18, the treatment and control group students in the chemistry *NanoLeap* field test were comparable (i.e., no significant differences) in their baseline knowledge of two of the three science concepts: “core science” and “transition to nanoscale science” concepts. At baseline, students in the treatment group had somewhat greater knowledge of “nanoscale science” concepts than their counterpoints in the control group prior to participating in the *NanoLeap* project.

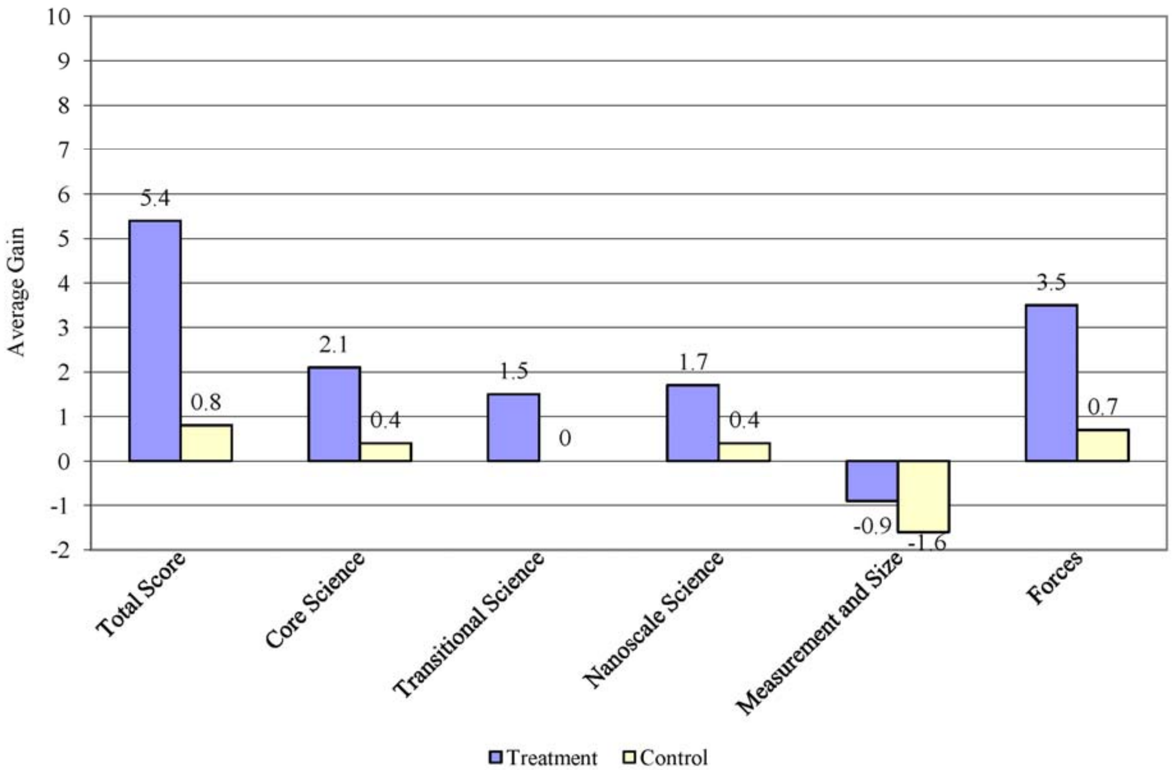
Students in the chemistry treatment group significantly outperformed their peers in the control group in terms of the gain in knowledge that was demonstrated from the pre- to the post-test (see Table 18 and Figure 6). The differences between the performance of the treatment and the control group, overall, and with regard to “core science” concepts, “nanoscale science” concepts, and “transitional science” concepts was “educationally significant.”

With regard to “core science” concepts, students in the chemistry treatment group demonstrated greater gains in knowledge than the control group (see Table 18 and Figure 6). Although small (effect size of .22), the treatment group gains were approaching an “educationally significant” level. In contrast, the control group showed no real change in knowledge of “core science” concepts with an effect size of -0.12.

With regard to “nanoscale science” and “transition to nanoscale science” concepts, the chemistry treatment group demonstrated much greater gains than the control group (see Table 18 and Figure 6). The treatment group gains were “educationally significant” with moderate effect sizes of 0.79 and 0.71, respectively. In contrast, the control group demonstrated no real gains in knowledge of “nanoscale science” and “transition to nanoscale science” concepts (effect sizes of -0.18 and -0.20, respectively).

The chemistry treatment group also demonstrated greater gains than the control group with regard to the two “essential understandings” most representative of the *NanoLeap* chemistry module: “measurement and size” and “properties of matter” (see Table 18 and Figure 6). The differences between the treatment and control group gains were “educationally significant” with moderate effect sizes of 0.56 and 0.68, respectively. In contrast, the control group demonstrated no real gains in knowledge of “measurement and size” (effect size of -0.06) and a small decrease in understanding of “properties of matter” over time (effect size of -0.23).

Figure 6: Comparison of Treatment and Control Group Performance on Chemistry Student Assessment, 2007–2008 *NanoLeap* Field Test.



Source: *NanoLeap* chemistry student assessment, 2007–2008.

FACTORS RELATED TO GROWTH

Prior research indicates that many factors are related to student achievement, including student characteristics, student engagement, and instructional practices.

The students in the chemistry treatment group most likely to show the greatest gains in knowledge said that they:[14]

- feel comfortable in science class (*student characteristics*),
- find chemistry is easy for them to learn (*student engagement*),
- completed all of their assignments (*student engagement*),
- have a teacher who emphasizes learning basic science in class (*instructional practices*), and
- have a teacher that asks them to consider alternative explanations (*instructional practices*).

[14] Results are based on bivariate correlations that are statistically significant at $p < .05$. The magnitude of correlations was 0.20 or less.

Other factors that were examined for their relationship to student performance, but were not significant, included gender, ethnicity, (student) hours working at a job each week, and other inquiry-based instructional practices that differed between the treatment and control groups.

In addition, the relationship between student interest / engagement in science and student performance on the chemistry assessment was examined. No relationship was found between student interest and performance for the treatment or control groups.

IMPLEMENTATION FIDELITY

In addition to the standard data collection, teachers in the treatment group also provided data on the extent to which they implemented each of the *NanoLeap* chemistry lessons. Almost every teacher made minor modifications to the module to better accommodate their students and/or the time available. Almost all teachers, however, completed the chemistry lessons in their entirety.[15] When teachers did not complete a portion of a *NanoLeap* lesson, typically, they did not cover the two end-of-lesson activities designed to support metacognition in students (e.g., the “Making Connections” discussion questions and review of the Flow Chart designed to remind students where they were in the overall module). Many teachers also needed to exclude the peer review and revision activities included with the poster assignment due to time constraints.

With regard to content, only one-third of the teachers fully implemented all activities related to the introduction of variations in electron orbitals and only two-thirds fully reviewed VSEPR three-dimensional shapes. Still, the results of the chemistry assessment demonstrate that altering the implementation of the *NanoLeap* module in this way did not adversely affect students’ understanding of key science concepts.

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[15] Two treatment group teachers were unable to complete the final lesson in the chemistry module due to a lack of time. Of these, one teacher was unable to complete the last four lessons in the chemistry module. The final analysis of assessment data presented in this report includes this classroom as it represented less than 5 percent of the final sample of treatment group students. Excluding this class from the analysis did not significantly alter the results when compared to the control group.

TABLE 18: CHEMISTRY STUDENT ASSESSMENT - OVERALL AND BY SCIENCE CONTENT, 2007–2008 FIELD TEST

		TREATMENT (N=365)			CONTROL (N=290)			DIFFERENCE TREATMENT - CONTROL		
MEAN (S.D.)	ITEMS	PRE	POST	GAIN SCORE	PRE	POST	GAIN SCORE	PRE	POST	GAIN SCORE
TOTAL SCORE (40 ITEMS)	1-40	15.9 (4.2)	19.9 (7.3)	4.0 (5.8)	14.7 (4.4)	13.7 (4.6)	-1.0 (4.5)	1.2 (4.3)	6.2 (6.0)	5.0 (5.2)
Effect Size				**0.69***			-0.22*	**0.28***	**1.03***	**0.96***
CORE SCIENCE (16 ITEMS)	2, 4, 6-12, 14-18, 23, 32	6.9 (2.4)	7.5 (2.9)	0.6 (2.7)	6.4 (2.5)	6.1 (2.5)	-0.3 (2.5)	0.5 (2.5)	1.4 (2.7)	0.9 (2.6)
Effect Size				0.22*			-0.12*	0.20*	**0.52***	**0.35***
TRANSITION TO NANOSCALE SCIENCE (8 ITEMS)	5, 13, 19-22, 26, 31	2.8 (1.4)	4.0 (2.0)	1.2 (1.7)	2.7 (1.5)	2.4 (1.5)	-0.3 (1.5)	0.1 (1.5)	1.6 (1.8)	1.5 (1.6)
Effect Size				**0.71***			-0.20*	0.07	**0.89***	**0.94***
NANOSCALE SCIENCE (16 ITEMS)	1, 3, 24. 25, 27-30, 33-40	6.2 (2.2)	8.5 (3.6)	2.3 (2.9)	5.5 (2.2)	5.1 (2.1)	-0.4 (2.2)	0.7 (2.2)	3.4 (2.9)	2.7 (2.6)
Effect Size				**0.79***			-0.18*	**0.32***	**1.19***	**1.05***

Notes: * = statistical significance at $p < .05$.
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: *NanoLeap* Chemistry Student Assessment, 2007–2008.

TABLE 18: CHEMISTRY STUDENT ASSESSMENT - OVERALL AND BY SCIENCE CONTENT, 2007–2008 FIELD TEST (CONT).

		TREATMENT (N=365)			CONTROL (N=290)			DIFFERENCE TREATMENT - CONTROL		
MEAN (S.D.)	ITEMS	PRE	POST	GAIN SCORE	PRE	POST	GAIN SCORE	PRE	POST	GAIN SCORE
ESSENTIAL UNDERSTANDING: MEASUREMENT AND SIZE (9 ITEMS)	1-4, 5, 7, 24, 38, 39	4.0 (1.5)	5.0 (2.0)	1.0 (1.8)	3.6 (1.6)	3.5 (1.8)	-0.1 (1.7)	0.4 (1.6)	1.5 (1.9)	1.1 (1.8)
Effect Size				**0.56***			-0.06	**0.25***	**0.79***	**0.61***
ESSENTIAL UNDERSTANDING: PROPERTIES OF MATTER (12 ITEMS)	9, 10, 11, 13-23, 25-33, 35, 36	9.4 (2.8)	12.0 (4.8)	2.6 (3.8)	8.9 (2.9)	8.2 (3.0)	-0.7 (3.0)	0.5 (2.9)	3.8 (3.9)	3.3 (3.9)
Effect Size				**0.68***			-0.23*	0.17*	**0.97***	**0.85***

Notes: * = statistical significance at p < .05.
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: *NanoLeap* Chemistry Student Assessment, 2007–2008.

VIABILITY OF THE DESIGN APPROACH

From the very beginning, the *NanoLeap* project engaged in a design process that kept the end in mind. The project partners focused on creating standards- and inquiry-based instructional materials that could bring nanoscale science into high school science courses in a manner that supported student learning of core science concepts. As noted above, the *NanoLeap* project demonstrated through the achievement of its intended outcomes related to teaching and learning that it was indeed based on a viable model for instructional materials development.

The viability of the instructional materials development process utilized by *NanoLeap* reflected *early* and *ongoing* attention to the following design elements:

- inclusion of project partners from a variety of sectors within education who provided expertise in nanoscale science content and pedagogy, instructional materials design, and evaluation;
- relationship- and network-building to engender trust in working relationships and leverage resources;
- planning, review, and refinement of project outcomes and development process to monitor feasibility and promote clarity of purpose and role expectations among project partners;
- needs assessment to verify assumptions about classroom practices, teacher preparedness, and general feasibility of proposed activities against current and emerging realities;
- opportunities for professional learning about nanoscale science concepts, content, tools, and resources that could be utilized in direct instruction or in providing background information for teachers; and
- project coordination and management to monitor progress and ensure enough flexibility in the development process to remain open to unanticipated opportunities.

TAPPING EXPERTISE

The project partners assembled for the *NanoLeap* project included representatives from various sectors within education that provided expertise in nanoscale science content and pedagogy, instructional materials design, and evaluation. The project team included university faculty, an applied research and development organization in education that served as the coordinating agency, classroom teachers from across the United States, and a team of external evaluators. Faculty consulted on nanoscale science content, applied researchers and developers provided project coordination and took the lead on the pedagogical and design framework, teachers put it all to the test in their “real-life” classrooms, and evaluators provided feedback along the way to inform the development process. All were engaged within their assigned roles and committed to a multi-year project. As one partner noted, despite different levels of involvement, “everyone brought something [essential] to the table.”

BUILDING RELATIONSHIPS AND NETWORKS

The *NanoLeap* project was intentional about building relationships to engender trust in its working relationships, promote continued engagement, and leverage resources. Initially, this included in-person meetings with project partners for team-building, planning, and professional development. Later on, the partners convened regularly by telephone, e-mail, and on eCampus[16]. The partners came together again when it was time to revise the modules. As one teacher noted, "Getting to know people [face-to-face] in the beginning made it easier to interact by phone." It also made the editing process easier because "if you don't know people there is less trust."

Conference calls and eCampus gave the project coordinators an opportunity to check in and see where the group wanted to go. To effectively facilitate communication through these venues meant having agendas and specific questions to address. This was effective in that it allowed participants to think about the issues and concerns ahead of time in order to discuss them within a reasonable amount of time. However, teachers on the development team commented that having more opportunities to have concentrated time together or to simply talk with one another would help participants stay motivated over the course of the project.

Finally, as the *NanoLeap* project progressed, it expanded its network of individuals and organizations as more and more connections were made through the project partners with others working on related topics. This expanded network was significant for leveraging resources that included instructional materials, multi-media, and other related tools and content.

PLANNING, REVIEW, AND REFINEMENT

Ongoing attention to and review of the project outcomes and the development process helped the *NanoLeap* project monitor feasibility and promote clarity of expectations and purpose among project partners. This commitment to reflection and refinement, which occurred during face-to-face meetings, conference calls, and online and was informed by the evaluation, allowed the project to be responsive to unanticipated opportunities while staying on task. As a result, the development team was able to take advantage of an opportunity to conduct a "pre-pilot" test with students attending a summer upward bound program at the University of Northern Colorado prior to the year three pilot test with the NanoLeap A-Team and opportunities to test other resources that were recommended by project partners and the project's expanding network (e.g., a Van der Waals simulation from the Concord Consortium and the Nanoreisen web site).

[16] eCampus is a Moodle driven online content management system used for communication and document sharing for both the development team and for the NanoLeap A-Team. Communication by online discussion forums was used for NanoLeap A-Team members. We modified eCampus for use during field testing for the NanoLeap B-Team.

Needs Assessment

Throughout the project, the development team made it a point to verify its assumptions about classroom practices, teacher preparedness, and overall feasibility of proposed activities against reality. This included an initial survey of teachers to gauge interest in the project and gather syllabi to assess the potential for placement of the modules within the curriculum. The importance of monitoring trends in education over time became evident as the team began recruitment for the field test and became aware of changes to high school science curriculums since the start of the project, which had the potential to affect the placement of the modules (e.g., significant course changes with regard to the placement of science standards). Finally, the development team learned the importance of sharing the conclusions of these needs sensing activities with external reviewers who could comment on the viability early in and throughout the development process. Tapping these outside perspectives ensured that in its concentrated focus on the many tasks at hand, the development team did not lose sight of other related and/or emerging issues.

Opportunities for Professional Learning

Another essential element of the *NanoLeap* development process was the opportunity for project partners to enhance their knowledge in a manner that supported the project goals. In this case, partners came together at the beginning to learn about the nanoscale science concepts, content, and tools and resources that could be utilized in direct instruction or to provide background information for teachers new to the subject. Having a shared understanding of the core concepts and essential ideas being represented in the instructional modules helped ensure a common vision. Throughout the project, partners continued to come together to informally learn more about nanoscale science from one another, from the identified content and pedagogical experts participating in the project, and from the larger Nanoscale Science and Engineering Education community. In the case of the latter, project staff participated in working groups and professional development workshops sponsored by other nanoscale science projects and the National Science Foundation.

Project Coordination and Management

The *NanoLeap* project directors coordinated activities and monitored progress in a manner that still provided enough flexibility in the development process to allow the team to remain open to unanticipated opportunities. A clear management plan was prepared at the start to communicate tasks, timelines, and responsibilities for each of the partners. And, communications were regularly scheduled and included both synchronous and asynchronous methods (conference calls, eCampus, face-to-face meetings).

In the *NanoLeap* project, it became clear that the assigned roles and responsibilities made the most of the assembled expertise. Typically, the co-project directors would take the lead in the development of a first draft, then bring it to content experts to review, and then to the teachers to try out. Based on this reflection and feedback, the project directors would make the initial revisions and begin the cycle of development, review, and revision again. This cycle, which continued throughout the project, also ensured that when unanticipated changes in personnel occurred as they naturally do in multi-year projects, that the momentum was not lost.

SUMMARY

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

1. CURRICULUM FIT: To explore where nanoscale science, technology, engineering, and mathematics concepts can fit into high school physical science and chemistry classes in a manner that supports students in learning core science concepts.

2. MATERIALS DEVELOPMENT PROCESS: To determine a viable approach for instructional materials development in the areas of nanoscale science, technology, engineering, and mathematics.

With regard to the curriculum fit, during the development process, it was determined that the physical science module would be best implemented in a 9th-grade physical science class as a replacement unit for the following concepts: scientific investigation, measurement, and static forces. Likewise, the chemistry module was viewed as an end-of-year cumulative unit for use in general chemistry classes in which students apply concepts they learned throughout the school year but at the nanoscale level. The fact that teachers were able to implement both the physical science and chemistry modules in a manner that supported inquiry-based learning and that student learning was enhanced, confirms that this placement within the curriculum was indeed a good "fit."

In the achievement of key outcomes – promoting inquiry-based practices and student learning of core science concepts – the *NanoLeap* project also demonstrated viability in its instructional materials design process. Throughout the project, the project partners had an opportunity to stand back and reflect on the development process as they prepared for next steps. In doing so, they were able to continually refine the process to ensure feasibility while being open to unanticipated opportunities.

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APPENDICES

APPENDIX A: NANOLEAP *DEVELOPMENT PROCESS*

The McREL *NanoLeap* development team collaborated with the Stanford Nanofabrication Facility (SNF) team to develop the two NanoLeap modules. Each module is intended to be a three-week unit of instruction for high school physical science or chemistry classes. Project teams used an adapted model that emphasizes aligning instruction and assessment to the student learning goals. This "backwards design" model (Wiggins & McTighe, 1998), emphasizes "looking back" at the original student goals to ensure that instructional strategies, learning activities, and evidence of student learning all relate to the concepts and skills that we want students to learn. Four questions guided the materials development:

1) What content and skills will students learn?

2) What will we do to help students acquire and integrate knowledge?

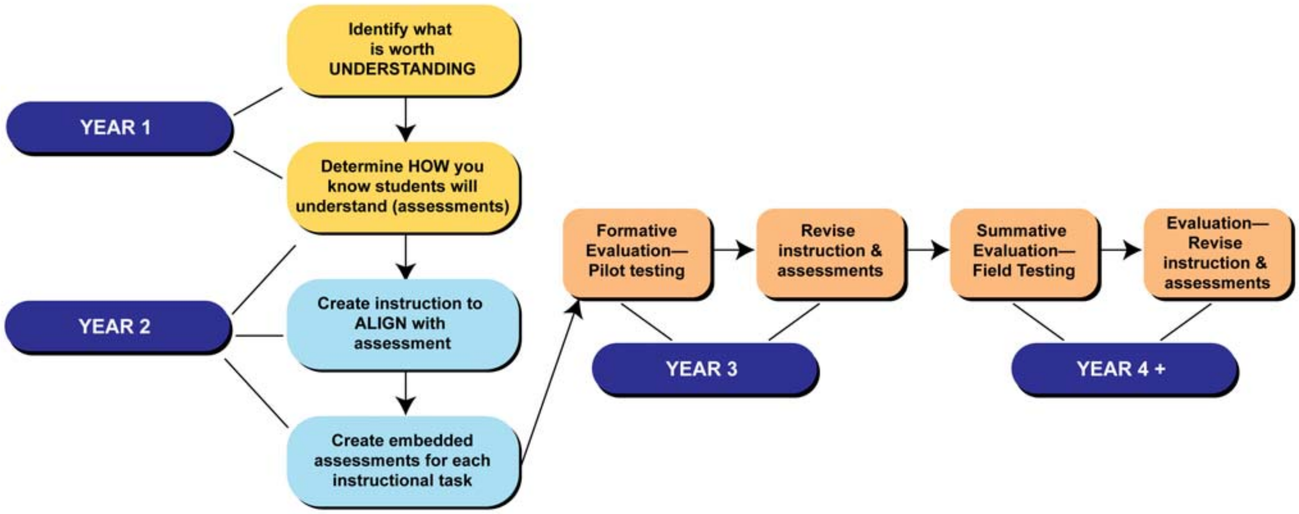
3) What will we do to help students practice, review, and apply knowledge?

4) How will we know if students have learned the content and skills?

The "Big Ideas" in nanoscale science are organizing categories for more specific content for student learning. When considering how to teach a broad content benchmark or "Big Idea," the development team identified the additional supporting knowledge (transitional concepts) that students need to learn to serve as a bridge from core concepts (taught in most high school curricula) to nano concepts (rarely taught in high school curricula). This supporting knowledge includes skills and/or concepts included within, but not mentioned specifically in the benchmark.

As shown in Appendix B, when we developed concepts for nanoscience activities, we "unpacked" the big ideas to elicit "essential understandings" that describe critical elements of each big idea. Multiple essential understandings were derived from each Big Idea. In addition, essential understandings can map to more than one big idea. Then the overarching nanoscale Big Ideas and supporting essential understandings were aligned to appropriate national science and mathematics standards. Finally, we identified specific "learning objectives" for each lesson to serve as stepping stones for students as they progress toward essential understandings.

The following flow chart contains a general overview for each step in our design and development process. Further details about each step are available from the principal investigators.



Identify what is worth UNDERSTANDING
YEAR 1
Determine HOW you know students will understand (assessments)
YEAR 2
Create instruction to ALIGN with assessment
Create embedded assessments for each instructional task
Formative Evaluation—Pilot testing
Revise instruction & assessments
YEAR 3
Summative Evaluation—Field Testing
Evaluation—Revise instruction & assessments
YEAR 4 +

APPENDIX B: NANOLEAP *MODULES*

Investigating Static Forces in Nature: The Mystery of the Gecko
Physical Science Module

http://www.mcrel.org/nanoleap/ps/index.asp

What Is the* NanoLeap *Physical Science Module?

The *NanoLeap* project represents an approach for teachers to introduce the exciting world of nanoscale science and technology to their classes by integrating interdisciplinary research with traditional science concepts. *Investigating Static Forces in Nature: The Mystery of the Gecko* is a three-week module that replaces and supplements part of a unit that is normally taught at the beginning of a physical science course. It addresses *National Science Education Standards* (NSES)[17] in Science as Inquiry, the Nature of Science, and Physical Science including the topics of static forces, measurement, size and scale, and adhesion. It also extends some of the basics of atomic structure.

While considering the question of adhesion, students learn about the properties of surfaces and the measurement of force interactions. They then apply these concepts at the nanoscale level. Through studying a curious natural phenomenon (how a gecko adheres to a ceiling), students gain an understanding of forces, adhesion, surface contact, small size and scale, surfaces close-up, instrumentation, and weak atomic interactions. The central question that students consider throughout the module is: "**What factors affect the strength of the contact forces between interacting surfaces?**"

Why *NanoLeap*?

Investigating Static Forces in Nature: Exploring the Mystery of the Gecko models the way scientists think as they study a real-life phenomenon by asking the same types of questions that biologists, chemists, and engineers have been asking for years. This *NanoLeap* module is intended to motivate students to study a real-world phenomenon and at the same time give them a better understanding of the role that nanoscale science and technology plays in an ever-changing world. The module provides students with opportunities to develop skills in experimental design that are often a major emphasis in state science assessments.

Curriculum Fit

Whether a physical science course begins with chemistry topics or physics topics, *Investigating Static Forces in Nature: Exploring the Mystery of the Gecko* fits easily into the curriculum. The

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[17] National Research Council (1996). *National science education standards*. Washington, DC: National Academy Press.

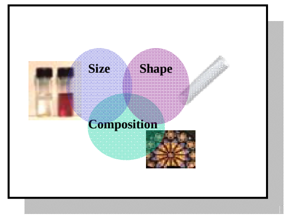
module engages students actively in the processes of experimental design, utilizing metric measurements and conversions, and exploring properties of matter. Pilot-test teachers suggested that it would be beneficial for students to have prerequisite knowledge about scientific notation and basic atomic structure prior to beginning this module. Lessons developed for this module include:

- Lesson 1: How Can a Gecko Walk on the Ceiling?
- Lesson 2: What Do We Mean When We Speak About Surfaces in Contact?
- Lesson 3: What Are Your Ideas About Small Sizes?
- Lesson 4: What Do We Learn When We Look More Closely?
- Lesson 5: What Types of Forces Can Hold Objects Together?
- Lesson 6: How MUCH Force Is Needed to Make an Object Stick?
- Lesson 7: How Do We Measure Forces at the Nanoscale Level?
- Lesson 8: How Can a Gecko Walk on a Ceiling?

NanoLeap Chemistry Module

Nanoscale Materials and Their Properties

http://www.mcrel.org/nanoleap/chemistry/index.asp



Overview

The *NanoLeap* Chemistry Module is designed to be a three-week *culminating unit* in a high school chemistry course. The module asks students to *apply* concepts and skills learned throughout the year in a traditional curriculum and can serve as an *extension* of those concepts that are of particular relevance in nanoscale science.

Nanoscience and nanotechnology are rapidly expanding fields of science and many of the techniques and scientific concepts involved in the research and development of applications and products require a graduate level background in chemistry, physics, materials science, and technology. Therefore, a deliberate decision was made to include in these *NanoLeap* materials only those properties and changes in physical and chemical properties observed at the nanoscale that can be explained in terms understood by most first-year secondary chemistry students.

The essential question that students will consider throughout the module is, "**How and why do the chemical and physical properties of nanosamples differ from those of macrosamples of the same substance?**" The following list describes the units and suggested sequence of the module.

- Unit 1: *Nanoscience: What is it?*
- Poster Assessment introduction
- Unit 2: *Metallic and Ionic Nanoparticles: Extendable Structures*
- Unit 3: *Neat and Discrete Nanoparticles*
- Poster Assessment student preparation, research, and peer reviews of drafts
- Poster Assessment Fair

APPENDIX C: NANOLEAP *ASSESSMENTS*

Overview
For each *NanoLeap* module, an assessment team guided the development of formative and summative assessments to determine the extent to which treatment students in the pilot and field test understood the lesson objectives compared with the control group students. Multiple choice assessment items were developed to align with lesson objectives, essential understandings, Big Ideas, and national science standards. Essay and poster assessments were designed for the physical science and chemistry modules respectively, but were used by teachers as they assessed student learning and not for the *NanoLeap* research study.

Multiple Choice
For the physical science module, the development team designed, conducted item analyses, and revised forty-two multiple choice items that assess student understanding of:

- Science Processes
- Adhesion
- Surfaces
- Forces
- Size and Scale
- Instrumentation
- Interactions and Applications

As the development team reviewed how the test functioned, the average scores on both the pre and post-test were hard for students, with students averaging 44 percent correct on the pre-test and 49 percent on the post-test. However, students in the treatment group did score higher on the post-test with 58 percent correct. The distribution of item difficulty indicated proportionally more "hard" items on the pre-test, indicating that the post-test, overall, was not as hard as the pre-test (i.e., suggesting student learning).

For the chemistry module, the development team designed, conducted item analyses, and revised forty multiple choice items that assess student understanding of:

- Size and Scale
- Electrons and Electron Movement
- Molecular Bonding
- Physical Properties and Reactions
- Physical and Chemical Properties of Nanoparticles
- Applications of Nanoscience

The average scores on both the pre- and post-test were hard for students, with students averaging 38 percent correct on the pre-test and 42 percent on the post-test. Students in the treatment group scored higher than students in the control group on both the pre- and the post-test. In addition, students in the treatment group showed an increase in the percent correct from pre-test (40%) to the post-test (50%). The distribution of item difficulty indicated proportionally more "hard" items on the pre-test, indicating that the post-test, overall, was not as hard as the pre-test (i.e., suggesting student learning).

Essay Assessments

Physical Science

Students drafted written responses as homework and then participated in a peer-review activity during class time. Incorporating peer review transformed the "assessment" into a writing-to-learn opportunity that engaged students in critical thinking with a more in-depth exploration of the content. Since students were able to focus on a range of nanoapplications, the peer-review process enabled students to increase their awareness of the various applications and products for nanotechnology. Students were asked to explain the term "nanotechnology" to someone who has heard of it only on T.V. Then, they explained how scientists and the general public should react to the latest research and applications in nanotechnology. The following guidance was provided to students:

- Define Nanotechnology.
- Give examples of specific nanoapplications to help illustrate nanotechnology. These should come from the Internet resources you read as well as from what you have learned in this unit.
- Describe nanotechnology's impact on science and how the application involves research from many different science subjects (e.g., biology, chemistry, physics, engineering).
- Explain why it is important for scientists to discuss the technology's positive and negative impacts with each other and with the general public.
- Include an explanation for why the general public should stay informed about the progress of nanotechnology.

Chemistry

Students investigated the essential question that they have considered throughout the module: **How and why do the chemical and physical properties of nanosamples differ from those of macrosamples?** Working with a partner, students designed and created an informational poster that they exhibited during a Poster Fair. The text and images in the posters answered the following guiding questions:

- What are the uses of this particular product?
- What are the physical and chemical characteristics of the product?
- How do the characteristics and uses of the nanoproduct differ from those of macro-scale samples? What are the underlying reasons for these differences?
- To help raise public awareness, what are the safety, social, and/or ethical issues resulting from the production or use of this product?

For both modules, essays and posters were peer reviewed. Feedback received through the peer-review process helped students to refine their writing before the final essay or poster was submitted. Through this process, students became familiar with the scoring rubric and expectations for the writing, thereby encouraging them take responsibility for evaluating their own work.

APPENDIX D: RECRUITMENT PROCESS

During the fall of 2006 and spring of 2007, the *NanoLeap* team conducted a nation-wide teacher recruitment for the field testing of both modules. The development and evaluation teams recruited public high school science teachers using list services such as those associated with the National Science Teachers Association (NSTA). Interested teachers completed an application including a letter of support from an administrator. The completed applications were submitted for consideration by the *NanoLeap* team.

The application elicited information such as:

- Contact information
- School demographics
- Teacher professional experiences
- Curriculum information

APPENDIX E: IMPLEMENTATION FIDELITY

Developers used the *Implementation Fidelity Checklist* to determine the extent to which the teacher taught the module lessons as written. We requested teachers to describe adaptations and/or omissions along with their explanations for the changes made. The fidelity checklist included topics found in the *NanoLeap* modules and questions pertaining to the extent to which the teacher addressed the topic and implemented the activities, multimedia, assessments, and suggested pedagogy in each lesson. Additional questions included if and how the lesson was modified including a rationale for each modification. Finally, we queried teachers about additional support materials and access to technology that enhanced or impeded implementation.

We used the data collected from the fidelity checklists submitted by field test treatment teachers to make final revisions to the instructional materials (teacher guides, student journal/handbook, formative and essay assessments, and related multimedia).