NanoLeap

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

Preface

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)[1] 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 will consider throughout the module is: "**What factors affect the strength of the contact forces between interacting surfaces?**"

Why *NanoLeap*?

NanoLeap: 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 to 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, *NanoLeap: Exploring the Mystery of the Gecko* fits easily into the curriculum. The 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.

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

Traditional Sequence	Proposed NanoLeap Placement
1. *Scientific Method/Measurement*	1. *Introduction to Scientific Method, Measurement*
2. Description *of Motion (Velocity/Acceleration)*	2. *NanoLeap: Exploring the Mystery of the Gecko (Observation, Interpretation, Forces [including electrical, atomic] adhesion, size/scale, modeling, experimentation, instrumentation, drawing conclusions)* The *module* **replaces or supplements Scientific Method and Forces (Net Forces/Friction)**
3. ***Forces (Net Forces/Friction)***	3. *Description of Motion (Velocity/Acceleration)*
4. *Forces to Explain Motion (Newton's Laws)*	4. *Forces to Explain Motion (Newton's Laws)*

Learning Cycle and Assessments

The module employs a modified "Five E" learning cycle where observations and questions are developed in the Engage phase. Investigations are based on new understandings of concepts during subsequent learning experiences in the "Explore, Explain, and Elaborate phases." The Evaluate phase is conducted at the conclusion of the module. Student formative assessments, designed to help teachers make effective instructional decisions, are embedded within each lesson (e.g., reflection journals to assess learning and identify questions and misconceptions early). The summative essay assessment is evaluated using rubrics designed to help students and teachers understand expectations and measure performance against specific criteria.

The following table contains the lesson sequence organized by the learning cycle and lesson objectives. This table also includes how each lesson aligns with the *National Science Education Standards*, the NanoLeap Big Ideas and Essential Understandings, and Multiple Choice Summative Assessment Items.

Learning Cycle	Lesson Title	Objectives	NSES Content Standards Addressed	*NanoLeap* Big Ideas/Essential Understandings
Engage	Lesson 1: How Can a Gecko Walk on a Ceiling?	Make observations, predictions, and interpretations of how the gecko's foot interacts with surfaces	**History and Nature of Science**: Nature of Scientific Knowledge	

Learning Cycle	Lesson Title	Objectives	NSES Content Standards Addressed	*NanoLeap* Big Ideas/Essential Understandings
		Formulate questions that might be used for further investigations	**Science as Inquiry**: Abilities necessary to do scientific inquiry Identify questions and concepts that guide scientific investigations	
Explore	Lesson 2: What Do We Mean When We Speak About Surfaces in Contact?	Compare the amount of surface contact (real contact) to total unit area (apparent contact) Understand that different textures of surfaces have different contact ratios	**Science as Inquiry**: Understandings about scientific inquiry Mathematics is essential in scientific inquiry. Mathematics' tools and models guide and improve the posing of questions, gathering data, constructing explanations, and communicating results.	**Forces** Electrical and magnetic forces are the most important of the fundamental forces at the nanoscale level. Adhesion, the attractive force between two unlike materials, is dependent upon the total area of contact between the materials' surfaces.
Explore/ Explain	Lesson 3: What Are Your Ideas About Small Sizes?	Classify and compare objects in different size ranges to have a better understanding of objects at the nanoscale Understand relative size of objects at different scales	**Science as Inquiry**: Understandings about scientific inquiry Mathematics is essential in scientific inquiry. Mathematics' tools and models guide and improve the posing of questions, gathering data, constructing explanations, and communicating results. **Physical Science**: The structure of atoms	**Measurement and Size** Imaging and measurement tools allow for detection, characterization, and manipulation of nanostructures. Nanoscience is the study of the structure of atoms and molecules with at least one dimension roughly between 1 and 100 nanometers. The size of a single atom or small molecule is measured at the nanometer scale.

Learning Cycle	Lesson Title	Objectives	NSES Content Standards Addressed	*NanoLeap* Big Ideas/Essential Understandings
		Describe nanotechnology, some of its applications, and the positive as well as negative impacts of this technology to someone who is not familiar with the subject.	**History and Nature of Science:** Science as a Human Endeavor Scientists have ethical traditions. Scientists value peer review, truthful reporting about the methods and outcomes of investigations, and making public the results of work.	**Interdisciplinary Nature of Nanoscale Science** The nature of nanoscale science, technology, and engineering is interdisciplinary. The understanding of the properties and interactions of atoms and molecules may lead to advances in biology, chemistry, and physics. **Ethical and Social Issues of Nanoscale Science and Technology** Social interactions can occur between scientific and engineering communities and society. It is the responsibility of scientists and practitioners to communicate information necessary for the public to make informed decisions.
Explain/ Elaborate	Lesson 4: What Do We Learn When We Look More Closely?	Explain how size, structure, and scale relate to surface interactions Describe the function of compliant surfaces in regards to adhesion (what happens when a surface of an object is	**Science as Inquiry**: Understandings about scientific inquiry Mathematics is essential in scientific inquiry. Mathematics' tools and models guide and improve the posing of	**Forces** Electrical and magnetic forces are the most important of the fundamental forces at the nanoscale level. Adhesion, the attractive force between two unlike materials, is

Learning Cycle	Lesson Title	Objectives	NSES Content Standards Addressed	*NanoLeap* Big Ideas/Essential Understandings
		applied to the surface of another object)	questions, gathering data, constructing explanations, and communicating results.	dependent upon the total area of contact between the materials' surfaces.
Explore	Lesson 5: What Types of Forces Can Hold Objects Together?	Describe what happens when a surface of an object is applied to the surface of another object Characterize different methods of adhesion Evaluate applicability of different methods to explain gecko adhesion	**Science as Inquiry**: Abilities Necessary to Do Scientific Inquiry Formulate and revise scientific explanations and models using logic and evidence	**Forces** Electrical and magnetic forces are the most important of the fundamental forces at the nanoscale level. Adhesion, the attractive force between two unlike materials, is dependent upon the total area of contact between the materials' surfaces. Adhesion mechanisms include: mechanical interlocking, interdiffusion, surface reaction, capillary action, suction, and intermolecular forces.
Explore/ Explain	Lesson 6: How MUCH Force Is Needed to Make an Object Stick? What Factors Affect the STRENGTH of Force Acting on an Object?	Describe that a net force of zero is necessary for objects to adhere to a surface (wall or ceiling) Identify different variables and the constants that affect adhesive forces Explain how the amount of adhesion changes when the conditions of the surfaces change	**Physical Science:** Motion and Forces Objects change their motion only when a net force is applied. Whenever one object exerts force on another, a force equal in magnitude and opposite in direction is exerted on the first object.	

Learning Cycle	Lesson Title	Objectives	NSES Content Standards Addressed	*NanoLeap* Big Ideas/Essential Understandings
Elaborate	Lesson 7: How Do We Measure Forces at the Nanoscale Level? Why Is Merely Looking not Enough?	Compare and contrast model probe instruments with those that are used to make measurements of electric and magnetic forces at the nanoscale (AFM, MEMS)	**Science as Inquiry**: Understandings about scientific inquiry Scientists rely on technology to enhance the gathering and manipulation of data. New techniques and tools provide new evidence to guide inquiry and new methods to gather data, thereby contributing to the advance of science. **Science and Technology: Abilities of Technical Design** Students should be introduced to the roles of models and simulations in these processes.	**Measurement and Size** Imaging and measurement tools allow for detection, characterization, and manipulation of nanostructures. Scientific instruments can be used to characterize and measure properties of objects, their structure and surfaces, even if the objects cannot be seen. Magnetic and electric forces at the nanoscale level, such as van der Waals forces can be measured experimentally.
		Model how instrument probes can be used to characterize surface interactions		
		Describe how the topography of a surface relates to adhesion		
		Interpret graphs of forces at the nanoscale level		

Learning Cycle	Lesson Title	Objectives	NSES Content Standards Addressed	*NanoLeap* Big Ideas/Essential Understandings
		Consider the new evidence about surface topography and seta adhesive forces to evaluate remaining methods of gecko adhesion	**Science as Inquiry** Abilities necessary to do scientific inquiry Recognize and analyze alternative explanations and models	
Evaluate	Lesson 8: How Can a Gecko Walk on a Ceiling?	Describe the attractive forces between and within molecules that cause the gecko to adhere to a vertical surface	**Physical Science: Motion and Forces** The electric force is a universal force that exists between any two charged objects. Opposite charges attract while like charges repel **Physical Science: Structure of Atoms** Matter is made of minute particles called atoms, and atoms are composed of even smaller components.	**Properties of Matter** Surface interactions can dominate and changes in properties can arise at the nanoscale. Electrical and magnetic forces affect properties of materials, specifically physical and mechanical. At the nanoscale level, a large fraction of an object's atoms or molecules are exposed at its surface; therefore, the object's properties are dominated by surface interactions. **Forces** Electrical and magnetic forces are the most important of the fundamental forces at the nanoscale level. Adhesion mechanisms include: mechanical interlocking, interdiffusion, surface reaction, capillary action, suction, and intermolecular forces.
		Describe how a large number of small forces (van der Waals interactions) at the nanoscale level can add up to macroscopic forces	**Physical Science: Motions and Forces** Most observable forces such as those exerted by a coiled spring or friction may be traced to electric forces acting between atoms and molecules.	

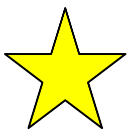
Learning Cycle	Lesson Title	Objectives	NSES Content Standards Addressed	*NanoLeap* Big Ideas/Essential Understandings
				Intermolecular forces act at the nanoscale. Van der Waals forces are the only attractive intermolecular forces between two nonpolar, neutral objects. **Interdisciplinary Nature of Nanoscale Science** The nature of nanoscale science, technology, and engineering is interdisciplinary. The understanding of the properties and interactions of atoms and molecules may lead to advances in biology, chemistry, and physics. **Measurement and Size** Imaging and measurement tools allow for detection, characterization, and manipulation of nanostructures. Magnetic and electric forces at the nanoscale level, such as van der Waals forces, can be measured experimentally.

NanoLeap

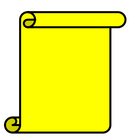
Overview of Instructional Materials

Teacher Guides
The teacher guides contain background information, suggested procedures, instructional strategies, guiding questions, and connections to previous and subsequent lessons. The teacher guides are formatted in a landscape view. This allows the teacher to correlate between the teacher guide, the PowerPoint slide, and student journal. Each lesson contains the student objectives, a preview of highlights—"At a Glance for the Teacher", vocabulary, estimated teaching time, materials for activities, demonstrations, and Web site URL addresses. The text of the guide is structured such that background information and pedagogy are in italics and suggested teacher script is in bold. Some questions from the student journal are embedded in the script and are underlined to note formative assessment checkpoints to check for students' understanding of lesson objectives. These questions are mapped to the student learning objectives.

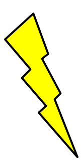
Additionally, the teacher guides use icons to draw attention to specific items.



Important: A star notes special content or pedagogy that can significantly enhance student understanding based on pilot-teacher input.



Vocabulary: A scroll notes vocabulary terms. Please see the end of each lesson in the teacher guide for definitions.



Time Savers: A lightning bolt notes a suggestion for a time saver. If you are running short on time, use these suggestions to optimize your time.

Student PowerPoint Slides

This module uses PowerPoint slides to guide instruction. In addition to the slides that frame the lesson's content, additional slides for each lesson include a flowchart so that students can be reminded of previous lessons as well as a slide entitled "Making Connections." The "Making Connections" slides include questions that assist teachers in formatively assessing student understanding.

Student Journals

The student journal functions as an archive of the students' written response to activities, probing questions, graphing, and diagramming. Therefore, students will find their journals useful as study guides. It is suggested that the teacher regularly collect the student journal for formative assessment and for grading. Some questions are underlined to note formative assessment checkpoints to check for students' understanding of lesson objectives.

Direct Vocabulary Instruction Strategy

When introducing new vocabulary to students, teachers can help students learn the meaning by following the steps below.

1. Present learners with a brief explanation or description of a new term. For example: "Adhesive: A substance that can stick to another object."

2. Then, present learners with a nonlinguistic representation of the new term or phrase. This could be a drawing, an artifact, or even acting out the meaning of a word.

3. Ask learners to generate their own verbal description of "adhesive."

4. Ask learners to create their own nonlinguistic representation of "adhesive."

5. Periodically ask learners to review the accuracy of their explanations and representations.

Adopted from: Marzano, R. J., Pickering, D. J., & Pollock, J. E. (2001). *Classroom instruction that works: Research-based strategies for increasing student achievement.* Alexandria, VA: Association for Supervision and Curriculum Development.

Resources for Definitions

The module's definitions are adopted/adapted from one or more of the following sources:

Bellairs, A. (1970). *The life of reptiles.* Universe Books: New York, NY.

Mathematics in Nanoscale Science and Engineering. (2002). Institute for Pure and Applied Mathematics. Retrieved August 23, 2006, from www.ipam.ucla.edu/programs/nano2002/

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Ramig, J.E., Bailer, J., & Ramsey, J. M. (1995). *Teaching science process skills*. Good Apple: Torrance, CA.

Ratner, M. & Ratner, D. (2003). *NanoTechnology: A gentle introduction to the next big idea*. Pearson Education, Inc.: New Jersey.