Argument-Driven Inquiry in PHYSICAL SCIENCE

LAB INVESTIGATIONS for GRADES 6–8

Jonathon Grooms, Patrick J. Enderle,
Todd Hutner, Ashley Murphy, and Victor Sampson

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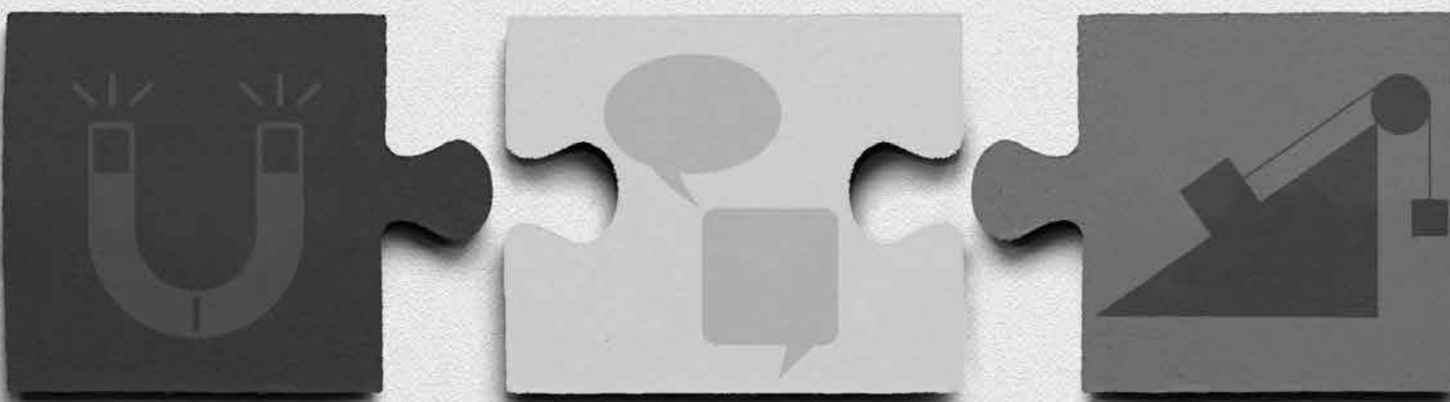

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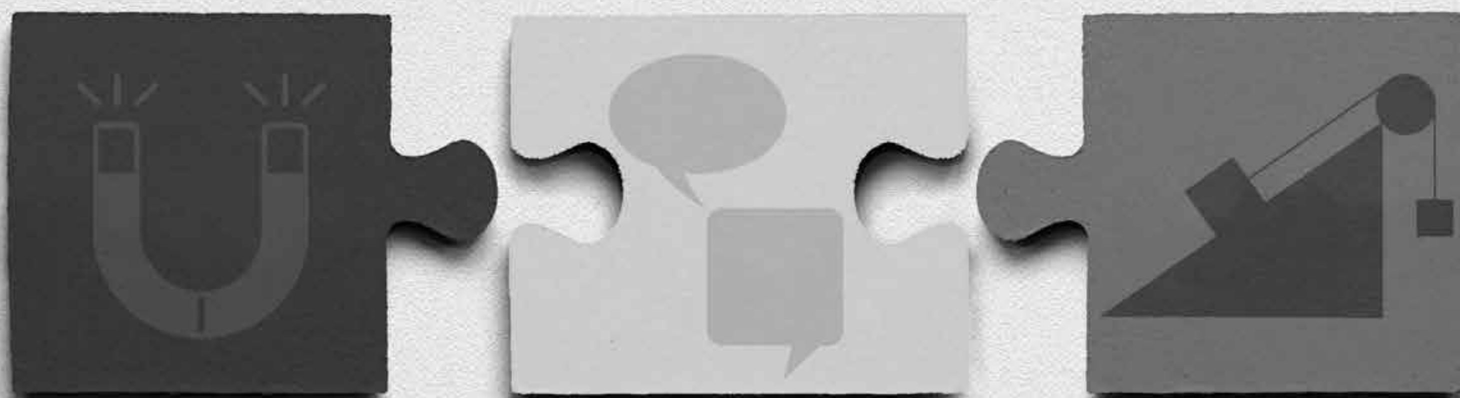

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PREFACE

There is a push to change the way science is taught in the United States, arising from a different idea of what it means to know, understand, and be able to do in science. As described in *A Framework for K–12 Science Education* (National Research Council [NRC] 2012) and the *Next Generation Science Standards* (NGSS Lead States 2013), science education should be structured to emphasize ideas *and* practices to

> ensure that by the end of 12th grade, *all* students have some appreciation of the beauty and wonder of science; possess sufficient knowledge of science and engineering to engage in public discussions on related issues; are careful consumers of scientific and technological information related to their everyday lives; are able to continue to learn about science outside school; and have the skills to enter careers of their choice, including (but not limited to) careers in science, engineering, and technology. (NRC 2012, p. 1)

Instead of teaching with the goal of helping students learn facts and concepts, science teachers are now charged with helping their students become *proficient* in science by time they graduate from high school. To be considered proficient in science, the NRC (2012) suggests that students need to understand four core ideas in the physical sciences,[1] be aware of seven crosscutting concepts that span the various disciplines of science, and learn how to participate in eight fundamental scientific practices. These important practices, crosscutting concepts, and core ideas are summarized in Figure 1 (p. xii).

As described by the NRC (2012), new instructional approaches will be needed to assist students in developing these proficiencies. In answer to this call, this book provides 22 laboratory investigations designed using an innovative approach to lab instruction called argument-driven inquiry (ADI). This approach and the labs based on it are aligned with the content, crosscutting concepts, and scientific practices outlined in Figure 1. Because the ADI model calls for students to give presentations to their peers, respond to questions, and then write, evaluate, and revise reports as part of each lab, the lab activities described in this book will also enable students to develop the disciplinary-based literacy skills outlined in the *Common Core State Standards* for English language arts (National Governors Association Center for Best Practices and Council of Chief State School Officers 2010). Use of these labs, as a result, can help teachers align their teaching with current recommendations for making physical science more meaningful for students and instruction more effective for teachers.

[1] Throughout this book, we use the term *physical sciences* when referring to the core ideas of the *Framework* (in this context the term refers to a broad collection of scientific fields), but we use the term *physical science* when referring to courses at the middle school level (as in the title of the book).

FIGURE 1

The three dimensions of the framework for the *Next Generation Science Standards*

Scientific Practices	Crosscutting Concepts
1. Asking questions and defining problems 2. Developing and using models 3. Planning and carrying out investigations 4. Analyzing and interpreting data 5. Using mathematics and computational thinking 6. Constructing explanations and designing solutions 7. Engaging in argument from evidence 8. Obtaining, evaluating, and communicating information	1. Patterns 2. Cause and effect: Mechanism and explanation 3. Scale, proportion, and quantity 4. Systems and system models 5. Energy and matter: Flows, cycles, and conservation 6. Structure and function 7. Stability and change
Physical Sciences Core Ideas • PS1: Matter and its interactions • PS2: Motion and stability: Forces and interactions • PS3: Energy • PS4: Waves and their applications in technologies for information transfer	

Source: Adapted from NRC 2012, p. 3.

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INTRODUCTION

The Importance of Helping Students Become Proficient in Science

The new aim of science education in the United States is for all students to become proficient in science by the time they finish high school. It is essential to recognize that science proficiency involves more than an understanding of important concepts, it also involves being able to *do* science. *Science proficiency,* as defined by Duschl, Schweingruber, and Shouse (2007), consists of four interrelated aspects. First, it requires an individual to know important scientific explanations about the natural world, be able to use these explanations to solve problems, and understand new explanations when they are introduced to the individual. Second, it requires an individual to be able to generate and evaluate scientific explanations and scientific arguments. Third, it requires an individual to understand the nature of scientific knowledge and how scientific knowledge develops over time. Finally, and perhaps most important, an individual who is proficient in science should be able to participate in scientific practices (such as designing and carrying out investigations and arguing from evidence) and communicate in a manner that is consistent with the norms of the scientific community.

In the past decade, however, the importance of learning how to participate in scientific practices has not been acknowledged in the standards of many states. Many states have also attempted to make their science standards more rigorous by adding more content to them or lowering the grade level at which content is introduced rather than emphasizing depth of understanding of core ideas and crosscutting concepts, as described by the National Research Council (NRC) in *A Framework for K–12 Science Education* (NRC 2012). The result of the increased number of content standards and the pressure to cover them to prepare students for high-stakes tests that target facts and definitions is that teachers have "alter[ed] their methods of instruction to conform to the assessment" (Owens, 2009, p. 50). Teachers, as a result, tend to move through the science curriculum quickly to ensure that they have introduced all the content found in the standards before the administration of the tests, which leads them to cover many topics in a shallow fashion rather than to delve into a smaller number of core ideas in a way that promotes a coherent and deep understanding. The unintended consequence of this approach has been a focus on content (learning facts) rather than on developing scientific habits of mind or learning how to use core ideas and the practices of science to explain natural phenomena.

Despite this focus on more content and high-stakes accountability for science learning, students do not seem to be gaining proficiency in science. According to *The Nation's Report Card: Science 2009* (National Center for Education Statistics 2011), only 21% of all 12th-grade students who took the National Assessment of Educational Progress in science scored at the proficient level. The performance of U.S. students on international assessments is even bleaker, as indicated by their scores on the science portion of the Programme for International Student Assessment (PISA). The Organisation for Economic Co-operation and Development (OECD) began administering the PISA in 1997 to assess and compare education systems. Since 1997, students in more than 70 countries have taken the PISA. The test is designed to assess reading, math, and science achievement and is given every three years. The mean score for students in the United States on the science portion of the PISA in 2012 was below the international mean (500), and there has been no significant change in the U.S. mean score since 2000; in fact, the U.S. mean score in 2012 was slightly less than it was in 2000 (OECD 2012; see Table 1). Students in many different countries, including China, Korea, Japan, and Finland, consistently score higher than students in the United States. These results suggest that U.S. students are not learning what they need to be considered proficient in science, even though teachers are covering a great deal of material and being held accountable for it.

TABLE 1

PISA scientific literacy performance for U.S. students

Year	U.S. mean score*	U.S. rank/ Number of countries assessed	Top-performing countries (score)		
			1	2	3
2000	499	14/27	Korea (552)	Japan (550)	Finland (538)
2003	491	22/41	Finland (548)	Japan (548)	Hong Kong–China (539)
2006	489	29/57	Finland (563)	Hong Kong–China (542)	Canada (534)
2009	499	15/43	Japan (552)	Korea (550)	Hong Kong–China (541)
2012	497	36/65	Shanghai-China (580)	Hong Kong–China (555)	Singapore (551)

*The mean score of the PISA is 500 across all years.

Source: OECD 2012.

Additional evidence of the consequences of emphasizing breadth over depth comes from empirical research in science education that supports the notion that broad, shallow coverage neglects the practices of science and hinders the development of science proficiency (Duschl, Schweingruber, and Shouse 2007; NRC 2005, 2008). As noted in the *Framework* (NRC 2012),

> K–12 science education in the United States fails to [promote the development of science proficiency], in part because it is not organized systematically across multiple years of school, emphasizes discrete facts with a focus on breadth over depth, and does not provide students with engaging opportunities to experience how science is actually done. (p. 1)

Based on their review of the available literature, the NRC recommends that science teachers delve more deeply into core ideas to help their students develop improved understanding and retention of science content. The NRC also calls for students to be given more experience participating in the practices of science, with the goal of enabling students to better engage in public discussions about scientific issues related to their everyday lives, be consumers of scientific information, and have the skills and abilities needed to enter science or science-related careers. We think the school science laboratory is the perfect place to focus on core ideas and engage students in the practices of science and, as a result, help them develop the knowledge and abilities needed to be proficient in science.

How School Science Laboratories Can Help Foster the Development of Science Proficiency

Investigators have shown that lab activities[1] have a standard format in U.S. secondary-school classrooms (Hofstein and Lunetta 2004; NRC 2005). This format begins with the teacher introducing students to a concept through direct instruction, usually a lecture and/or reading. Next, students complete a confirmatory laboratory activity, usually following a "cookbook recipe" in which the teacher provides a step-by-step procedure to follow and a data table to fill out. Finally, students are asked to answer a set of focused analysis questions to ensure that the lab has illustrated, confirmed, or otherwise verified the targeted concept(s). This type of approach does little to promote science proficiency because it often fails to help students think critically about the concepts, engage in important scientific practices (such as designing an investigation, constructing explanations, or arguing from evidence), or develop scientific habits of mind (Duschl, Schweingruber, and Shouse 2007; NRC 2005). Further, this approach does not do much to improve science-specific literacy skills.

Changing the focus of lab instruction can help address these challenges. To implement such a change, teachers will have to emphasize "how we know" in the physical sciences (i.e., how new knowledge is generated and validated) equally with "what we know" about behavior of matter on Earth (i.e., the theories, laws, and unifying

[1] We use the NRC's definition of a school science lab activity, which is "an opportunity for students to interact directly with the material world using the tools, data collection techniques, models, and theories of science" (NRC 2005, p. 3).

concepts). Because it is an essential practice of science, the NRC calls for *argumentation* (which we define as a process of proposing, supporting, evaluating, and refining claims on the basis of reason) to play a more central role in the teaching and learning of science. The NRC (2012) provides a good description of the role argumentation plays in science:

> Scientists and engineers use evidence-based argumentation to make the case for their ideas, whether involving new theories or designs, novel ways of collecting data, or interpretations of evidence. They and their peers then attempt to identify weaknesses and limitations in the argument, with the ultimate goal of refining and improving the explanation or design. (p. 46)

This means that the focus of teaching will have to shift more to scientific abilities and habits of mind so that students can learn to construct and support scientific knowledge claims through argument (NRC 2012). Students will also have to learn to evaluate the claims and arguments made by others.

A part of this change in instructional focus will need to be a change in the nature of lab activities (NRC 2012). Students will need to have more experiences engaging in scientific practices so that lab activities can become more authentic. This is a major shift away from labs driven by prescribed worksheets and data tables to be completed. These activities will have to be thoughtfully constructed so as to be educative and help students develop the required knowledge, skills, abilities, and habits of mind. This type of instruction will require that students receive feedback and learn from their mistakes; hence, teachers will need to develop more strategies to help students learn from their mistakes.

The argument-driven inquiry (ADI) instructional model (Sampson and Gleim 2009; Sampson, Grooms, and Walker 2009, 2011) was designed as a way to make lab activities more authentic and educative for students and thus help teachers promote and support the development of science proficiency. This instructional model reflects research about how people learn science (NRC 1999) and is also based on what is known about how to engage students in argumentation and other important scientific practices (Berland and Reiser 2009; Erduran and Jimenez-Aleixandre 2008; McNeill and Krajcik 2008; Osborne, Erduran, and Simon 2004; Sampson and Clark 2008).

Organization of This Book

The remainder of this book is divided into six sections. Section 1 includes two chapters: the first describes the ADI instructional model, and the second describes the development and components of the ADI lab investigations. Sections 2–5 contain the lab investigations, including notes for the teacher, student handouts, and checkout questions for students. Four appendixes contain standards alignment matrixes, timeline and proposal options for the investigations, and a peer-review guide and instructor rubric for assessing the investigation reports.

Safety Practices in the Science Laboratory

It is important for science teachers to make hands-on and inquiry-based lab activities safer for students and teachers. Teachers therefore need to have proper safety equipment in the classroom/laboratory in the form of engineering controls such as ventilation, fume hoods, fire extinguishers, eye wash, and showers. They also need to ensure that students use appropriate personal protective equipment (PPE; e.g., sanitized indirectly vented chemical-splash goggles meeting ANSI/ISEA Z87.1 standard, chemical-resistant aprons and nonlatex gloves) during all components of laboratory activities (i.e., setup, hands-on investigation, and takedown). Teachers also need to adopt legal safety standards and better professional practices and enforce them inside the classroom and/or laboratory. Finally, teachers must review and comply with all safety policies and procedures, including but not limited to appropriate chemical management, that have been established by their school district or school.

Throughout this book, safety precautions are provided for each investigation. Teachers should follow these safety precautions to provide a safer learning experience for students. The safety precautions associated with each activity are based, in part, on the use of the recommended materials and instructions, legal safety standards, and better professional safety practices. We also recommend that students review the National Science Teacher Association's document *Safety in the Science Classroom, Laboratory, or Field Sites* under the direction of the teacher before working in the laboratory for the first time. This document is available online at *www.nsta.org/docs/SafetyInTheScienceClassroomLabAndField.pdf.* The students and their parents or guardians should then sign the document to acknowledge that they understand the safety procedures that must be followed during a lab activity.

As a final note, remember that the lab activity is composed of three sections: the setup, the hands-on investigation, and takedown. PPE and safety procedures apply to all three sections!

Disclaimer: The safety precautions for each activity are based in part on use of the recommended materials and instructions, legal safety standards, and better professional practices. Selection of alternative materials or procedures for these activities may jeopardize the level of safety and therefore is at the user's own risk.

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Teacher Notes

Lab 14. Potential Energy

How Can You Make an Action Figure Jump Higher?

Purpose

The purpose of this lab is to *introduce* students to the types of energy, specifically potential energy. Through this activity, students will have an opportunity to explore the crosscutting concepts of the importance of using and defining models to make sense of phenomena and how scientists focus on tracking the movement of energy through a system. Students will also learn about the difference between laws and theories and how scientists use multiple methods to investigate the natural world.

The Content

The *law of conservation of energy* states that within a given system the total amount of energy always stays the same. Essentially, this means that energy is neither created nor destroyed, but rather transferred from one type to another. Remember that scientific laws are used to describe specific relationships that exist in the natural world, whereas scientific theories provide broad-based explanations for different phenomena. In a more practical sense, laws tell us how things relate, while theories tell us why they do. In this case, the law of conservation of energy simply describes the relationship that exists among the many different types of energy present in the world.

There are several common forms of energy that exist in the world. Two of the most fundamental types of energy are potential and kinetic energy. When energy is stored in one form or another, it is called *potential energy*. Potential energy can be stored in the chemical bonds between atoms in a molecule and in the nuclei of atoms. Energy can also be stored based on the position of an object. Indeed, potential energy can be referred to as energy of position. The amount of potential energy an object has depends on the system being explored. In this use, a *system* refers to a specified collection of objects and their interactions. A ball on the floor has potential energy with respect to a desk in the same room, which can be called the ball-desk system. However, the potential energy of the ball is different if we are considering the ball-tree system, which includes a tree that exists outside of the room. Similarly, the amount of energy available and the different forms present will depend on the specific system that is being studied.

When potential energy is transformed into motion, it becomes *kinetic energy,* which can be detected when objects move. Kinetic energy is known as energy of motion. Kinetic energy is more obvious to identify, because it is the form of energy that does work on an object in a system. Other basic forms of energy include thermal energy (heat), chemical energy, electromagnetic energy, and nuclear energy. Some of these forms actually represent a mixture of potential and kinetic energies in more specific systems. More recognizable forms of energy, such as light and sound, also represent combinations of kinetic and potential energy.

As an example, think about climbing a hill. When you are at the bottom of a hill, you have low potential energy based on your position in the "hill-person" system. To increase your potential energy, you climb to the top of the hill. As you are climbing, you are moving, so you are using kinetic energy; you are transforming kinetic energy into increased potential energy; and you are changing position. Since you have climbed higher, you have greater potential energy. Now, you may wonder where the kinetic energy to climb the hill came from. That energy ultimately came from the energy stored in molecules that your body used to move your muscles.

Timeline

The instructional time needed to complete this lab investigation is 170–230 minutes. Appendix 2 (p. 411) provides options for implementing this lab investigation over several class periods. Option C (230 minutes) should be used if students are unfamiliar with scientific writing, because this option provides extra instructional time for scaffolding the writing process. You can scaffold the writing process by modeling, providing examples, and providing hints as students write each section of the report. Option D (170 minutes) should be used if students are familiar with scientific writing and have developed the skills needed to write an investigation report on their own. In option D, students complete stage 6 (writing the investigation report) and stage 8 (revising the investigation report) as homework.

Materials and Preparation

The materials needed to implement this investigation are listed in Table 14.1 (p. 252). The equipment can be purchased from a science supply company such as Carolina, Flinn Scientific, or Ward's Science. The clay and the action figures can be purchased at a toy store or general retail store.

We recommend that you use a set routine for distributing and collecting the materials during the lab investigation. For example, the equipment for each group can be set up at each group's lab station before class begins, or one member from each group can collect them from a table or a cart when needed during class.

TABLE 14.1

Materials list for Lab 14

Item	Quantity
Safety glasses or goggles	1 per student
Ruler	1 per group
Meterstick	1 per group
Electronic or triple beam balance	1 per group
Pencil	1 per group
Clay	100 g per group
Action figures	2–3 per group
Investigation Proposal C (optional)	1 per group
Whiteboard, 2' × 3'*	1 per group
Lab Handout	1 per student
Peer-review guide	1 per student
Checkout Questions	1 per student

*As an alternative, students can use computer and presentation software, such as Microsoft PowerPoint or Apple Keynote, to create their arguments.

Safety Precautions and Laboratory Waste Disposal

Follow all normal lab safety rules. In addition, tell students to take the following safety precautions:

1. Wear sanitized safety glasses or goggles during lab setup, hands-on activity, and take down.
2. Sweep clay up off the floor to avoid a slip or fall hazard.
3. Do not allow the action figures to jump too far from the work area.
4. Remove any fragile items from the work area.
5. Wash hands with soap and water after completing the lab activity.

There is no laboratory waste associated with this activity. The materials for this laboratory investigation can be stored and reused.

Topics for the Explicit and Reflective Discussion

Concepts That Can Be Used to Justify the Evidence

To provide an adequate justification of their evidence, students must explain why they included the evidence in their arguments and make the assumptions underlying their analysis and interpretation of the data explicit. In this investigation, students can use the following concepts to help justify their evidence:

- Law of conservation of energy
- Potential energy
- Kinetic energy
- Transformation of energy

We recommend that you review these concepts during the explicit and reflective discussion to help students make this connection.

How to Design Better Investigations

It is important for students to reflect on the strengths and weaknesses of the investigation they designed during the explicit and reflective discussion. Students should therefore be encouraged to discuss ways to eliminate potential flaws, measurement errors, or sources of bias in their investigations. To help students be more reflective about the design of their investigation, you can ask the following questions:

1. What were some of the strengths of your investigation? What made it scientific?
2. What were some of the weaknesses of your investigation? What made it less scientific?
3. If you were to do this investigation again, what would you do to address the weaknesses in your investigation? What could you do to make it more scientific?

Crosscutting Concepts

This investigation is well aligned with two crosscutting concepts found in *A Framework for K–12 Science Education*, and you should review these concepts during the explicit and reflective discussion.

- *System and system models:* Defining a system under study and making a model of it are tools for developing a better understanding of natural phenomena in science. In this lab students will investigate a system that can be used to convert potential energy to kinetic energy.

- *Energy and matter: Flows, cycles, and conservation:* In science it is important to track how energy and matter move into, out of, and within systems. In this lab students will investigate the conversion of energy from one type to another.

The Nature of Science and the Nature of Scientific Inquiry

This investigation is well aligned with two important concepts related to the *nature of science* (NOS) and the *nature of scientific inquiry* (NOSI), and you should review these concepts during the explicit and reflective discussion.

- *The difference between laws and theories in science:* A scientific law describes the behavior of a natural phenomenon or a generalized relationship under certain conditions; a scientific theory is a well-substantiated explanation of some aspect of the natural world. Theories do not become laws even with additional evidence; they explain laws. However, not all scientific laws have an accompanying explanatory theory. It is also important for students to understand that scientists do not discover laws or theories; the scientific community develops them over time.
- *Methods used in scientific investigations*: Examples of methods include experiments, systematic observations of a phenomenon, literature reviews, and analysis of existing data sets; the choice of method depends on the objectives of the research. There is no universal step-by step scientific method that all scientists follow; rather, different scientific disciplines (e.g., chemistry vs. physics) and fields within a discipline (e.g., organic vs. physical chemistry) use different types of methods, use different core theories, and rely on different standards to develop scientific knowledge.

Hints for Implementing the Lab

- Allowing students to design their own procedures for collecting data gives students an opportunity to try, to fail, and to learn from their mistakes. However, you can scaffold students as they develop their procedure by having them fill out an investigation proposal. These proposals provide a way for you to offer students hints and suggestions without telling them how to do it. You can also check the proposals quickly during a class period. For this lab we suggest you use Investigation Proposal C.
- Suggest that students use a small amount of clay to stick the pencil to the ruler when they construct their teeterboard.
- Have students focus on changing one characteristic of the system at a time. They should not change the mass of the dropped clay while also changing the height they drop it from.

- Encourage students to think of a way they could mathematically represent the relationships they find in this investigation.
- Action figures should not be too large, so that they can actually be launched using the ruler apparatus. We have had success using small, plastic army action figures that can be purchased in large quantities. Be sure to test your action figures with the equipment to determine if they are appropriate.

Topic Connections

Table 14.2 provides an overview of the scientific practices, crosscutting concepts, disciplinary core ideas, and supporting ideas at the heart of this lab investigation. In addition, it lists the NOS and NOSI concepts for the explicit and reflective discussion. Finally, it lists literacy and mathematics skills (*CCSS ELA* and *CCSS Mathematics*) that are addressed during the investigation.

TABLE 14.2

Lab 14 alignment with standards

Scientific practices	• Asking questions and defining problems • Planning and carrying out investigations • Analyzing and interpreting data • Using mathematics and computational thinking • Constructing explanations and designing solutions • Engaging in argument from evidence • Obtaining, evaluating, and communicating information
Crosscutting concepts	• Systems and system models • Energy and matter
Core ideas	• PS3.A: Definitions of energy • PS3.B: Conservation of energy and energy transfer
Supporting ideas	• Law of conservation of energy • Potential energy • Kinetic energy • Transformation of energy
NOS and NOSI concepts	• Scientific laws and theories • Methods used in scientific investigations
Literacy connections (*CCSS ELA*)	• *Reading*: Key ideas and details, craft and structure, integration of knowledge and ideas • *Writing*: Text types and purposes, production and distribution of writing, research to build and present knowledge, range of writing • *Speaking and listening*: Comprehension and collaboration, presentation of knowledge and ideas
Mathematics connections (*CCSS Mathematics*)	• Reason abstractly and quantitatively • Construct viable arguments and critique the reasoning of others • Use appropriate tools strategically • Attend to precision

LAB 14

Lab Handout

Lab 14. Potential Energy

How Can You Make an Action Figure Jump Higher?

Introduction

Teeterboards are typical pieces of equipment found on many playgrounds around the country. They are often used in shows that focus on gymnastic tricks. The picture in Figure L14.1 shows a circus act involving a performer launching another performer high into the air. It is easy to observe how the activity of a teeterboard involves objects' motion. However, that activity also involves energy shifting between forms.

FIGURE L14.1

Circus performers on a teeterboard

The law of conservation of energy states that within a given system the total amount of energy always stays the same—it is neither created nor destroyed; instead, energy is transformed from one form to another. When energy is stored in one form or another, it is called potential energy. Potential energy can be stored in the chemical bonds between atoms in a molecule and in the nuclei of atoms. Energy can also be stored based on the position of an object. Indeed, potential energy can be referred to as energy of position. When potential energy is transformed into motion, it becomes kinetic energy. Kinetic energy can be detected when objects move. Kinetic energy is known as energy of motion.

For an example, think about climbing a hill. When you are at the bottom of a hill, you have low potential energy based on your position. To increase your potential energy, you climb to the top of the hill. As you are climbing, you are moving, so you are using kinetic energy; you are transforming kinetic energy into increased potential energy; and you are changing position. Since you have climbed higher, you have greater potential energy. In this investigation you will explore the relationship between potential energy and kinetic energy as you try to make an action figure jump using a teeterboard.

The Task

Use what you know about the conservation of energy and models to design and carry out an investigation that will allow you to develop a rule that explains how an action figure can be made to jump lower or higher on a teeterboard.

The guiding question of this investigation is, **How can you make an action figure jump higher?**

Materials

You may use any of the following materials during your investigation:

- Ruler
- Meterstick
- Electronic or triple beam balance
- Pencil
- Clay (100 g)
- Action figures
- Safety glasses or goggles

Safety Precautions

Follow all normal lab safety rules. In addition, take the following safety precautions:

1. Wear sanitized safety glasses or goggles during lab setup, hands-on activity, and takedown.
2. Sweep clay up off the floor to avoid a slip or fall hazard.
3. Do not allow the action figure to jump too far from your work area.
4. Remove any fragile items from the work area.
5. Wash hands with soap and water after completing the lab activity.

Investigation Proposal Required? ☐ Yes ☐ No

Getting Started

To answer the guiding question, you will need to design and conduct an investigation that explores changing the potential energy of an action figure. To accomplish this task, you must determine what type of data you need to collect, how you will collect it, and how you will analyze it.

To determine *what type of data you need to collect*, think about the following questions:

- How will you test the ability to make the action figure jump higher?
- How will you measure the height of the jump?
- What type of measurements or observations will you need to record during your investigation?

To determine *how you will collect your data*, think about the following questions:

- How often will you collect data and when will you do it?

- How will you make sure that your data are of high quality (i.e., how will you reduce error)?
- How will you keep track of the data you collect and how will you organize it?

To determine *how you will analyze your data,* think about the following questions:

- What type of calculations will you need to make?
- What type of graph could you create to help make sense of your data?

Connections to Crosscutting Concepts, the Nature of Science, and the Nature of Scientific Inquiry

As you work through your investigation, be sure to think about

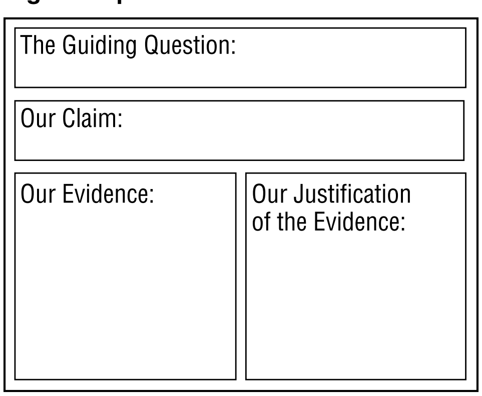
- how defining systems and models provides tools for understanding and testing of ideas;
- why it is important to track how energy and matter flows into, out of, and within a system;
- the difference between laws and theories in science; and
- the different forms of scientific investigation, including experiments, systematic observations, and analysis of data sets.

Initial Argument

Once your group has finished collecting and analyzing your data, your group will need to develop an initial argument. Your initial argument needs to include a *claim, evidence* to support your claim, and a *justification* of the evidence. The claim is your group's answer to the guiding question. The evidence is an analysis and interpretation of your data. Finally, the justification of the evidence is why your group thinks the evidence matters. The justification of the evidence is important because scientists can use different kinds of evidence to support their claims. Your group will create your initial argument on a whiteboard. Your whiteboard should include all the information shown in Figure L14.2.

FIGURE L14.2

Argument presentation on a whiteboard



Argumentation Session

The argumentation session allows all of the groups to share their arguments. One member of each group will stay at the lab station to share that group's argument, while the other members of the group go to the other lab stations to listen to and critique the arguments developed by their classmates. This is similar to how scientists present their arguments to other scientists at conferences. If you are responsible for critiquing your classmates' arguments, your goal is to look for mistakes so these mistakes can be fixed and they can make their argument better. The argumentation session is also a good time to think about ways you can make your initial argument better. Scientists must share and critique arguments like this to develop new ideas.

To critique an argument, you might need more information than what is included on the whiteboard. You will therefore need to ask the presenter lots of questions. Here are some good questions to ask:

- How did you collect your data? Why did you use that method? Why did you collect those data?
- What did you do to make sure the data you collected are reliable? What did you do to decrease measurement error?
- How did your group analyze the data? Why did you decide to do it that way? Did you check your calculations?
- Is that the only way to interpret the results of your analysis? How do you know that your interpretation of your analysis is appropriate?
- Why did your group decide to present your evidence in that way?
- What other claims did your group discuss before you decided on that one? Why did your group abandon those alternative ideas?
- How confident are you that your claim is valid? What could you do to increase your confidence?

Once the argumentation session is complete, you will have a chance to meet with your group and revise your initial argument. Your group might need to gather more data or design a way to test one or more alternative claims as part of this process. Remember, your goal at this stage of the investigation is to develop the most acceptable and valid answer to the research question!

Report

Once you have completed your research, you will need to prepare an *investigation report* that consists of three sections. Each section should provide an answer to the following questions:

1. What question were you trying to answer and why?
2. What did you do to answer your question and why?
3. What is your argument?

Your report should answer these questions in two pages or less. This report must be typed, and any diagrams, figures, or tables should be embedded into the document. Be sure to write in a persuasive style; you are trying to convince others that your claim is acceptable and valid!

Checkout Questions

Lab 14. Potential Energy

How Can You Make an Action Figure Jump Higher?

1. What is potential energy?

2. What is kinetic energy?

3. A student is trying to get a cart to reach the wall at the end of the system pictured below. He uses a ramp to get the cart some energy to cover that distance. However, as shown below, using the ramp as constructed, he was not able to reach the wall.

   a. What can the student change to get the cart to reach the wall?

   b. How do you know?

4. The law of conservation of energy describes how energy exists in physical systems but not why it acts in certain ways.

    a. I agree with this statement.

    b. I disagree with this statement.

    Explain your answer, using an example from your investigation about potential energy.

5. Science only relies on experiments to understand the physical world.

    a. I agree with this statement.

    b. I disagree with this statement.

    Explain your answer, using an example from your investigation about potential energy.

6. Scientists often have to define the boundaries of physical systems and use them to create models to test ideas. Explain why defining systems and models is important in science, using an example from your investigation about potential energy.

7. It is important to track how energy flows into, out of, and within a system during an investigation. Explain why it is important to keep track of energy when studying a system, using an example from your investigation about potential energy.

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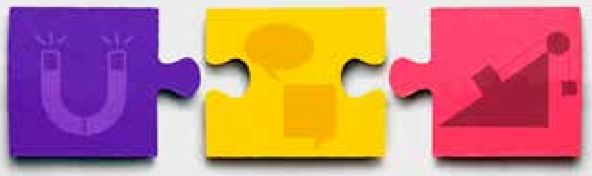
Page numbers printed in **boldface** *type refer to figures or tables.*

Argument-Driven Inquiry in PHYSICAL SCIENCE



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