Argument-Driven Inquiry in Fifth-Grade Science

Three-Dimensional Investigations

Victor Sampson, Todd L. Hutner, Jonathon Grooms, Jennifer Kaszuba, and Carrie Burt

nsta Press
National Science Teaching Association

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Contents

Contents

Contents

Contents

Preface

There are a number of good reasons for teaching children about science in elementary school: to give students a strong foundation in the basics to prepare them for what they will be expected to know or do in middle and high school; to get students interested in science early so that more people will choose to go into a science or science-related career; and to take advantage of children's natural curiosity about how the world works, using the information included as part of the science curriculum to answer many of their questions. We, however, think that one of the most important reasons to teach children about science in elementary school is that it will be useful for them in everyday life.

Science is useful because it, along with engineering, mathematics, and the technologies that are made possible by these three fields, affects almost every aspect of modern life in one way or another. For example, people need to understand science to be able to think meaningfully about policy issues that affect their communities or to make informed decisions about what food to eat, what medicine to take, or what products to use. People can use their understanding of science to help evaluate the acceptability of different ideas or to convince others about the best course of action to take when faced with a wide range of options. In addition, understanding how science works and all the new scientific findings that are reported each year in the media can be interesting, relevant, and meaningful on a personal level and can open doors to exciting new professional opportunities. The more a person understands science, which includes the theories, models, and laws that scientists have developed over time to explain how and why things happen and how these ideas are developed and refined based on evidence, the easier it is for that person to have a productive and fulfilling life in our technology-based and information-rich society. Science is therefore useful to everyone, not just future scientists.

A Framework for K–12 Science Education (NRC 2012; henceforth referred to as the *Framework*) is based on the idea that all citizens should be able to use scientific ideas to inform both individual choices and collective choices as members of a modern democratic society. It also acknowledges the fact that professional growth and economic opportunity are increasingly tied to the ability to use scientific ideas, processes, and ways of thinking. From the perspective of the *Framework*, it is important for children to learn science because it can help them figure things out or solve problems. It is not enough to remember some facts and terms; people need to be able to use what they have learned while in school. We think this goal for science education is not only important but represents a major shift in what should be valued inside the classroom.

The *Framework* asks all of us, as teachers, to reconsider what we teach in grades K–5 and how we teach it, given this goal for science education. It calls for all students, over multiple years of school, to learn how to use disciplinary core ideas (DCIs), crosscutting concepts (CCs), and scientific and engineering practices (SEPs) to figure things out or solve problems. The DCIs are key organizing principles that have broad explanatory power within a discipline. Scientists use these ideas to explain the natural world. The CCs are ideas that are used across disciplines. These concepts provide a framework or a lens that people can use to explore natural phenomena; thus, these concepts often influence what people focus on or pay attention to when they attempt to understand how something works or why something happens. The SEPs are the different activities that scientists engage in as they attempt to generate new concepts, models, theories, or laws that are both valid and reliable. All three of these dimensions of science are important. Students not only need to know about the DCIs, CCs, and SEPs but also must be able to use all three dimensions at the same time to figure things out or to solve problems. These important DCIs, CCs, and SEPs are summarized in Table P-1.

When we give students an opportunity to learn how to use DCIs, CCs, and SEPs to make sense of the world around them, we also provide an authentic context for students to develop fundamental literacy and mathematic skills. Students are able to develop literacy and mathematics skills in this type of context because doing science requires people to obtain, evaluate, and communicate information. Students, for example, must read and talk to others to learn what others have done and what they are thinking. Students must write and speak to share their ideas about what they have learned or what they still need to learn. Students can use mathematics to make measurements and to discover trends, patterns, or relationships in their observations. They can also use mathematics to make predictions about what will happen in the future. When we give students opportunities to do science, we give students a reason to read, write, speak, and listen. We also create a need for them to use mathematics.

To help students learn how to use DCIs, CCs, and SEPs to figure things out or solve problems while providing a context for them to develop fundamental literacy and mathematical skills, elementary teachers will need to use new instructional approaches. These instructional approaches must give students an opportunity to actually do science. To help teachers who teach elementary school make this instructional shift, we have developed a tool called argument-driven inquiry (ADI). ADI is an innovative approach to instruction that gives students an opportunity to use DCIs, CCs, and SEPs to construct and critique claims about how things work or why things happen. As part of this process, students must talk, listen, read, and write in order to obtain, evaluate, and communicate information. ADI, as a result, creates a rich learning environment for children that enables them to learn science, language, and mathematics at the same time.

TABLE P-1

The three dimensions of *A Framework for K–12 Science Education*

Scientific and engineering practices (SEPs)	Crosscutting concepts (CCs)
• SEP 1: Asking Questions and Defining Problems • SEP 2: Developing and Using Models • SEP 3: Planning and Carrying Out Investigations • SEP 4: Analyzing and Interpreting Data • SEP 5: Using Mathematics and Computational Thinking • SEP 6: Constructing Explanations and Designing Solutions • SEP 7: Engaging in Argument From Evidence • SEP 8: Obtaining, Evaluating, and Communicating Information	• CC 1: Patterns • CC 2: Cause and Effect: Mechanism and Explanation • CC 3: Scale, Proportion, and Quantity • CC 4: Systems and System Models • CC 5: Energy and Matter: Flows, Cycles, and Conservation • CC 6: Structure and Function • CC 7: Stability and Change

Disciplinary core ideas (DCIs)		
Earth and Space Sciences (ESS)	**Life Sciences (LS)**	**Physical Sciences (PS)**
• ESS1: Earth's Place in the Universe • ESS2: Earth's Systems • ESS3: Earth and Human Activity	• LS1: From Molecules to Organisms: Structures and Processes • LS2: Ecosystems: Interactions, Energy, and Dynamics • LS3: Heredity: Inheritance and Variation of Traits • LS4: Biological Evolution: Unity and Diversity	• 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.

This book not only describes how ADI works and why it is important but also provides 16 investigations that can be used in the classroom to help students reach the performance expectations found in the *Next Generation Science Standards* (NGSS Lead States 2013) for fifth grade.[1] The 16 investigations 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* (NGAC and CCSSO 2010)

1 See *Argument-Driven Inquiry in Third-Grade Science* (Sampson and Murphy 2019b) and *Argument-Driven Inquiry in Fourth-Grade Science* (Sampson and Murphy 2019a) for additional investigations for students in elementary school.

because ADI gives students an opportunity to make presentations to their peers; respond to audience questions and critiques; and then write, evaluate, and revise reports as part of each investigation. In addition, these investigations will help students learn many of the mathematical ideas and practices outlined in the *Common Core State Standards for Mathematics* (NGAC and CCSSO 2010) because ADI gives students an opportunity to use mathematics to collect, analyze, and interpret data. Finally, and perhaps most important, ADI can help emerging bilingual students meet the *English Language Proficiency (ELP) Standards* (CCSSO 2014) because it provides a language-rich context where children can use receptive and productive language to communicate and to negotiate meaning with others. Teachers can therefore use these investigations to align how and what they teach with current recommendations for improving science education.

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Introduction

A Vision for Science Education in Elementary School

The current aim of science education in the United States is for *all* students to become proficient in science by the time they finish high school. *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, to be able to use these explanations to solve problems, and to be able to 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 planning and carrying out investigations, analyzing and interpreting data, and arguing from evidence) and communicate in a manner that is consistent with the norms of the scientific community. These four aspects of science proficiency include the knowledge and skills that all people need to have to be able to purse a degree in science, be prepared for a science-related career, and participate in a democracy as an informed citizen.

This view of science proficiency serves as the foundation for *A Framework for K–12 Science Education* (NRC 2012). The *Framework* calls for all students to learn how to use disciplinary core ideas (DCIs), crosscutting concepts (CCs), and scientific and engineering practices (SEPs) to figure things out or solve problems as a way to help them develop the four aspects of science proficiency. The *Framework* was used to guide the development of the *Next Generation Science Standards* (*NGSS;* NGSS Lead States 2013). The goal of the *NGSS*, and other sets of academic standards that are based on the *Framework*, is to describe what *all* students should be able to do at each grade level or at the end of each course as they progress toward the ultimate goal of science proficiency.

The DCIs found in the *Framework* and the *NGSS* are scientific theories, laws, or principles that are central to understanding a variety of natural phenomena. An example of a DCI in Earth and space sciences is that the solar system consists of the Sun and a collection of objects that are held in orbit around the Sun by its gravitational pull on them. This DCI not only can be used to help explain the motion of planets around the Sun but also can be used to explain why we have tides on Earth, why the appearance of the Moon changes over time in a predictable pattern, and why we see eclipses of the Sun and the Moon.

The CCs are ideas that are important across the disciplines of science. The CCs help people think about what to focus on or pay attention to during an investigation. For example, one of the CCs from the *Framework* is Energy and Matter: Flows, Cycles, and Conservation. This CC is important in many different fields of study, including astronomy, geology, and meteorology. This CC is equally important in physics and biology. Physicists use this CC when they study how things move, why things change temperature, and the behavior of circuits or magnets. Biologists use this CC when they study how cells work, the growth and development of plants or animals, and the nature of ecosystems. It is important to help students see the value of the CCs as a tool for developing an understanding of how or why things happen.

The SEPs describe what scientists do as they attempt to make sense of the natural world. Some of the SEPs include familiar aspects of what we typically associate with "doing" science, such as Asking Questions and Defining Problems, Planning and Carrying Out Investigations, and Analyzing and Interpreting Data. More important, however, some of the SEPs focus on activities that are related to developing and sharing new ideas, solutions to problems, or answers to questions. These SEPs include Developing and Using Models, Constructing Explanations and Designing Solutions, Engaging in Argument From Evidence, and Obtaining, Evaluating, and Communicating Information. All these SEPs are important to learn because scientists engage in different practices, at different times, and in different orders depending on what they are studying and what they are trying to accomplish at that point in time.

Few students in fifth grade have an opportunity to learn how to use DCIs, CCs, and SEPs to figure things out or to solve problems. Instead, most students are introduced to facts, concepts, and vocabulary without a real reason to know or use them. This type of focus in fifth grade does little to promote and support the development of science proficiency because it emphasizes "learning about" science rather than learning how to use science to "figure things out." This type of focus also reflects a view of teaching that defines *rigor* as covering more topics and *learning* as the simple acquisition of more information.

We must think about rigor in different ways before we can start teaching science in ways described by the *Framework*. Instead of using the number of different topics covered in a particular grade level as a way to measure rigor in our schools (e.g., "we made fifth grade more challenging by adding more topics for students to learn about"), we must start to measure rigor in terms of the number of opportunities students have to use DCIs, CCs, and SEPs to make sense of different phenomena (e.g., "we made fifth grade more challenging because students have to figure out where plants get the materials they need to grow"). A rigorous class, in other words, should be viewed as one where students are expected to do science, not just learn about science. From this perspective, our goal as teachers should be to help our students learn how to use DCIs and CCs as tools to plan and carry out investigations, construct and evaluate explanations, and question how we know what we know instead of just ensuring that we "cover" all the different DCIs and CCs that are included in the standards by the end of the school year.

To better promote and support the development of science proficiency, we must also rethink what learning is and how it happens. Rather than viewing learning as an individual process where children accumulate more and more information over time, we need to view learning as both a social and an individual process that involves being exposed to new ideas and ways of doing things, trying out these new ideas and practices under the guidance of more experienced people, and then adopting the ideas and practices that are found to be useful for making sense of the world (NRC 1999, 2008, 2012). Learning, from this perspective, requires children to "do science" while in school not because it is fun or interesting (which is true for many) but because doing science gives children a reason to use the ideas and practices of science. When children are given repeated opportunities to use DCIs, CCs, and SEPs as a way to make sense of the world, they will begin to see why these ideas and practices are valuable. Over time, children will then adopt these ideas and practices and start using them on their own. We therefore must give our students an opportunity to experience how scientists figure things out and share ideas so they can become "socialized to a greater or lesser extent into the practices of the scientific community with its particular purposes, ways of seeing, and ways of supporting its knowledge claims" (Driver et al. 1994, p. 8).

It is important to keep in mind that helping children learn how to use the ideas and practices of science to figure things out by giving them an opportunity to do science is not a "hands-off" approach to teaching. The process of learning to use the ideas and practices of science to figure things out requires constant input and guidance about "what counts" from teachers who are familiar with the goals of science, the norms of science, and the ways things are done in science. Thus, learning how to use DCIs, CCs, and SEPs to figure things out or to solve problems is dependent on supportive and informative interactions with teachers. This is important because students must have a supportive and educative learning environment to try out new ideas and practices, make mistakes, and refine what they know and how they do things before they are able to adopt the ideas and practices of science as their own.

The Need for New Ways of Teaching Science in Elementary School

Science in fifth grade has historically been taught through a combination of direct instruction and hands-on activities. A typical lesson often begins with the teacher introducing students to a new concept and related terms through direct instruction. Next, the teacher will often illustrate the concept by giving a demonstration or asking students to complete a hands-on activity. The purpose of including a demonstration or a hands-on activity in the lesson is to provide the students with a memorable experience with the concept. If the memorable experience is a hands-on activity, the teacher will often provide his or her students with a step-by-step procedure to follow to help ensure that no one in the class "gets lost" or "does the wrong thing" and everyone "gets the right results." The teacher will usually assign a set of questions for the students to answer on their own or in groups after the demonstration or the hands-on activity to make sure that everyone in the class "reaches the right conclusion." The lesson usually ends with the teacher reviewing the concept and all related terms to make sure that everyone in the class learned what they were "supposed to have learned." The teacher often accomplishes this last step of the lesson by leading a whole-class discussion, by assigning a worksheet to complete, or by having the students play an educational game.

Classroom-based research, however, suggests that this type of lesson does little to help students learn key concepts (Duschl, Schweingruber, and Shouse 2007; NRC 2008, 2012). This finding is troubling because, as noted earlier, one of the main goals of this type of lesson is to help students understand an important concept by giving them a memorable experience with it. In addition, this type of lesson does little to help students learn how to plan and carry out investigations or analyze and interpret data because students have no voice or choice during the activity. Students are expected to simply follow a set of directions rather than having to think about what data they will collect, how they will collect it, and what they will need to do to analyze it once they have it. These types of activities can also lead to misunderstanding about the nature of scientific knowledge and how this knowledge is developed over time due to the emphasis on following procedure and getting the "right" results. These hand-on activities, as a result, do not reflect how science is done at all.

Many fifth-grade teachers started using more inquiry-based lessons in the late 1990s and early 2000s to help address shortcomings of these typical science lessons. Inquiry-based lessons that are consistent with the definition of *inquiry* found in *Inquiry and the National Science Education Standards* (NRC 2000) share five key features:

1. Students need to answer a scientifically oriented question.
2. Students must collect data or use data collected by someone else.
3. Students formulate an answer to the question based on their analysis of the data.
4. Students connect their answer to some theory, model, or law.
5. Students communicate their answer to the question to someone else.

Many fifth-grade teachers also changed the traditional sequence of science instruction when they started using more inquiry-based lessons. Rather than introducing students to an important concept or principle through direct instruction and then having students do a hands-on activity to demonstrate or confirm it, they used an inquiry-based lesson as a way to give students a firsthand experience with a concept before introducing terms and vocabulary (NRC 2012). Inquiry-based lessons, as a result, are often described as an "activity before content" approach to teaching science (Cavanagh 2007). The focus of these "activity before content" lessons, as the name implies, is to help students understand the core ideas of science. Inquiry-based lessons also give students more opportunities to learn how to plan and carry out investigations, analyze and interpret data, and develop explanations. These lessons also give students more voice and choice so they are more consistent with how science is done.

Although classroom-based research indicates that inquiry-based lessons are effective at helping students understand core ideas and give students more voice and choice than typical science lessons, they do not do as much as they could do to help students develop all four aspects of science proficiency (Duschl, Schweingruber, and Shouse 2007; NRC 2008, 2012). For example, inquiry-based lessons are usually not designed in a way that encourages students to learn how to use DCIs, CCs, and SEPs because they are often used to help students "learn about" important concepts or principles (NRC 2012). These lessons also do not give students an opportunity to participate in the full range of SEPs because these lessons tend to be designed in a way that gives students many opportunities to learn how to ask questions, plan and carry out investigations, and analyze and interpret data but few opportunities to learn how to participate in the practices that focus on how new ideas are developed, shared, refined, and eventually validated within the scientific community. These important sense-making practices include developing and using models; constructing explanations; arguing from evidence; and obtaining, evaluating, and communicating information (NRC 2012). Inquiry-based lessons that do not focus on sense-making also do not provide a context that creates a need for students to read, write, and speak, because these lessons tend to focus on introducing students to new ideas and how to design and carry out investigations instead of how to develop, share, critique, and revise ideas. These types of inquiry-based lessons, as a result, are often not used as a way to help students develop fundamental literacy skills. To help address this problem, teachers will need to start using instructional approaches that give students more opportunities to figure things out.

This emphasis on "figuring things out" instead of "learning about things" represents a big change in the way we have been teaching science in fifth grade. To figure out how things work or why things happen in a way that is consistent with how science is actually done, students must have opportunities to use DCIs, CCs, and SEPs at the same time to make sense of the world around them (NRC 2012). This focus on students using DCIs, CCs, and SEPs at the same time during a lesson is called *three-dimensional instruction* because students have an opportunity to use all three dimensions of the *Framework* to understand how something works, to explain why something happens, or to develop a novel solution to a problem. When teachers use three-dimensional instruction inside their classrooms, they encourage students to develop or use conceptual models, develop explanations, share and critique ideas, and argue from evidence, all of which allow students to develop the knowledge and skills they need to be proficient in science (NRC 2012). A large body of research suggests that all students benefit from three-dimensional instruction because it gives all students more voice and choice during a lesson and it makes the learning process inside the classroom more active and inclusive (NRC 2012).

We think investigations that focus on making sense of how the world works are the perfect way to integrate three-dimensional science instruction into elementary classrooms. Well-designed investigations can provide opportunities for students to not only use one or more DCIs to understand how something works, to explain why something happens, or to develop a novel solution to a problem but also use several different CCs and SEPs during the same lesson. A teacher, for example, can give his or her students an opportunity to figure out if the mass of a substance changes when it melts. The teacher can then encourage them to use what they know about Matter and Its Interactions (a DCI) and their understanding of Scale, Proportion, and Quantity (a CC) to plan and carry out an investigation to figure out how to measure the total weight of a piece of wax, a chunk of ice, and a few milliliters of vegetable shortening before and after they are heated to the point that they melt. In addition to planning and carrying out an investigation, they must also ask questions; analyze and interpret data; use mathematics; construct an explanation; argue from evidence; and obtain, evaluate, and communicate information (seven different SEPs).

Using DCIs, CCs, and SEPs at the same time is important because it creates a classroom experience that parallels how science is done. This, in turn, gives all students who participate in the investigation an opportunity to deepen their understanding of what it means to do science and to develop science-related identities (Carlone, Scott, and Lowder 2014; Tan and Barton 2008, 2010). In the following section, we will describe how to promote and support the development of science proficiency through three-dimensional instruction by using an innovative instructional model called argument-driven inquiry (ADI).

Argument-Driven Inquiry as a Way to Promote Three-Dimensional Instruction While Focusing on Literacy and Mathematics

The ADI instructional model (Sampson and Gleim 2009; Sampson, Grooms, and Walker 2009, 2011) was developed as a way to change how science is taught in our schools. Rather than simply encouraging students to learn about the facts, concepts, and terms of science, ADI gives students an opportunity to use DCIs, CCs, and SEPs to figure out how things work or why things happen. ADI also encourages children to think about "how we know" in addition to "what we have figured out." The ADI instructional model includes eight stages of classroom activity. These eight stages give children an opportunity to *investigate* a phenomenon; *make sense* of that phenomenon; and *evaluate and refine* ideas, explanations, or arguments. These three aspects of doing science help students learn how to figure something out and make it possible for them to develop and refine their understanding of DCIs, CCs, and SEPs over time.

Students will use different SEPs depending on what they are trying to accomplish during an investigation, which changes as they move through the eight stages of ADI. For example, students must learn how to ask questions to design and carry out an investigation in order to investigate a phenomenon, which is the overall goal of the first two stages of ADI. Then during the next stage of ADI, the students must learn how to analyze and interpret data, use mathematics, develop models, and construct explanations to accomplish the goal of making sense of the phenomenon they are studying. Students then need to evaluate and refine ideas, explanations, or arguments during the last five stages of this instructional model. Students therefore must learn how to ask questions; obtain, evaluate, and communicate information; and argue from evidence. These three goals provide coherence to a three-dimensional lesson, create a need for students to learn how to use each of the SEPs (along with one or more DCIs and one or more CCs), and will keep the focus of the lesson on figuring things out. We will provide a more detailed discussion of what students do during each stage of ADI in Chapter 1.

ADI also provides an authentic context for students to develop fundamental literacy and mathematics skills. Students are able to develop these skills during an ADI investigation because the use of DCIs, CCs, and SEPs requires them to gather, analyze, interpret, and communicate information. Students, for example, must read and talk to others to learn to gather information and to find out how others are thinking. Students must also talk and write to share their ideas about what they are doing and what they have found out and to revise an explanation or model. Students, as a result, "are able to fine-tune their literacy skills when they engage in science investigations because so many of the sense-making tools of science are consistent with, if not identical to, those of literacy, thus allowing a setting for additional practice and refinement that can enhance future reading and writing efforts" (Pearson, Moje, and Greenleaf 2010, p. 460). Students must also use mathematics during an ADI investigation to measure what they are studying and to find patterns in their observations, uncover differences between groups, identify a trend over time, or confirm a relationship between two variables. They also use mathematics to make predictions. Teachers can therefore use ADI to help students develop important literacy and mathematics skills as they teach science. We will discuss how to promote and support the development of literacy and mathematics skills during the various stages of ADI in greater detail in Chapter 1. We will also describe ways to promote and support productive talk, reading, and writing during ADI in the Teacher Notes for each investigation.

ADI investigations also provide a rich language-learning environment for emerging bilingual students who are learning how to communicate in English. A rich language-learning environment is important because emerging bilingual students must (1) interact with people who know English well enough to provide both access to this language and help in learning it and (2) be in a social setting that will bring them in contact with these individuals so they have an opportunity to learn (Lee, Quinn, and Valdés 2013). Once these two conditions are met, people are able to learn a new language through meaningful use and interaction (Brown 2007; García 2005; García and Hamayan 2006; Kramsch 1998). ADI, and its focus on giving students opportunities to use DCIs, CCs, and SEPs to figure things out, also provides emerging bilingual students with opportunities to interact with English speakers and opportunities to do things with language inside the classroom (Lee, Quinn, and Valdés 2013). Emerging bilingual students therefore have an opportunity to use receptive and productive language to communicate and to negotiate meaning with others inside the science classroom. Teachers can promote and support the acquisition of a new language by using ADI to give emerging bilingual students an opportunity to *investigate* a phenomenon; *make sense* of that phenomenon; and *evaluate and refine* ideas, explanations, or arguments with others. Teachers can then provide support and guidance as students learn how to communicate in a new language. We will provide a more detailed discussion of how teachers can use ADI to promote language development in Chapter 1. We will also provide advice and recommendations for supporting emerging bilingual students as they learn science and how to communicate in a new language at the same time in Chapter 1 and Appendix 3.

Organization of This Book

This book is divided into seven sections. Section 1 includes two chapters. The first chapter describes the ADI instructional model. The second chapter provides an overview of the information that is associated with each investigation. Sections 2–6 contain the 16 investigations. Each investigation includes three components:

- Teacher Notes, which provides information about the purpose of the investigation and what teachers need to do to guide students through it.
- Investigation Handout, which can be photocopied and given to students at the beginning of the lesson. The handout provides the students with a phenomenon to investigate, an overview of the DCI(s) and CC(s) that students can use during the investigation, and a guiding question to answer.
- Checkout Questions, which can be photocopied and given to students at the conclusion of investigation. The Checkout Questions consist of items that target students' understanding of the DCI(s) and the CC(s) addressed during the investigation.

Section 7 consists of six appendixes:

- Appendix 1 contains several standards alignment matrixes that can be used to assist with curriculum or lesson planning.
- Appendix 2 provides an overview of the CCs and nature of scientific knowledge (NOSK) and nature of scientific inquiry (NOSI) concepts that are a focus of the different investigations.
- Appendix 3 lists some frequently asked questions about ADI.
- Appendix 4 provides a peer-review guide and teacher scoring rubric, which can be photocopied and given to students.
- Appendix 5 provides a safety acknowledgment form, which can also be photocopied and given to students.
- Appendix 6 provides an answer guide for the Checkout Questions.

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Investigation 14

Star Brightness: How Does Distance Affect the Apparent Brightness of a Star?

Purpose

The purpose of this investigation is to give students an opportunity to use two disciplinary core ideas (DCIs), two crosscutting concepts (CCs), and eight scientific and engineering practices (SEPs) to figure out how distance affects the apparent brightness of a star. Students will also learn about the use of models as tools for reasoning about natural phenomena during the reflective discussion.

The DCIs, CCs, and SEPs That Students Use During This Investigation to Figure Things Out

DCIs

- *PS3.B: Conservation of Energy and Energy Transfer:*Light transfers energy from place to place
- *ESS1.A: The Universe and Its Stars:* Stars range greatly in their distance from Earth.

CCs

- *CC2: Cause and Effect*: Cause-and-effect relationships are routinely identified, tested, and used to explain change. Events that occur together with regularity might or might not be a cause-and-effect relationship.
- *CC3: Scale, Proportion, and Quantity*: Standard units are used to measure and describe physical quantities such as weight, time, temperature, and volume.

SEPs

- *SEP 1: Asking Questions and Defining Problems:* Ask questions about what would happen if a variable is changed. Ask questions that can be investigated and predict reasonable outcomes based on patterns such as cause-and-effect relationships.
- *SEP 2: Developing and Using Models:* Develop and/or use models to describe and/or predict phenomena.
- *SEP 3: Planning and Carrying Out Investigations:* Plan and conduct an investigation collaboratively to produce data to serve as the basis for evidence, using fair tests in which variables are controlled and the number of trials considered. Evaluate appropriate methods and/or tools for collecting data.
- *SEP 4: Analyzing and Interpreting Data:* Represent data in tables and/or various graphical displays (bar graphs, pictographs, and/or pie charts) to reveal

patterns that indicate relationships. Analyze and interpret data to make sense of phenomena, using logical reasoning, mathematics, and/or computation. Compare and contrast data collected by different groups in order to discuss similarities and differences in their findings.

- *SEP 5: Using Mathematics and Computational Thinking:* Organize simple data sets to reveal patterns that suggest relationships. Describe, measure, estimate, and/or graph quantities (e.g., area, volume, weight, time) to address scientific and engineering questions and problems.
- *SEP 6: Constructing Explanations and Designing Solutions:* Construct an explanation of observed relationships. Use evidence to construct or support an explanation. Identify the evidence that supports particular points in an explanation.
- *SEP 7: Engaging in Argument From Evidence:* Compare and refine arguments based on an evaluation of the evidence presented. Distinguish among facts, reasoned judgment based on research findings, and speculation in an explanation. Respectfully provide and receive critiques from peers about a proposed procedure, explanation, or model by citing relevant evidence and posing specific questions.
- *SEP 8: Obtaining, Evaluating, and Communicating Information:* Read and comprehend grade-appropriate complex texts and/or other reliable media to summarize and obtain scientific and technical ideas. Combine information in written text with that contained in corresponding tables, diagrams, and/or charts to support the engagement in other scientific and/or engineering practices. Communicate scientific and/or technical information orally and/or in written formats, including various forms of media as well as tables, diagrams, and charts.

Other Concepts That Students May Use During This Investigation

Students might also use some of the following concepts:

- *Luminosity* is the total amount of energy emitted by a star in a unit of time. The luminosity of a star depends on its size and temperature.
- *Apparent brightness* is how bright a star looks to us from Earth.
- *Lux* is a unit of measurement used to describe the amount of light that falls on an object.
- *Lumens* is a unit of measurement used to describe the amount of light produced by a bulb.

What Students Figure Out

Stars that are closer to Earth will appear brighter in the sky than stars that produce more energy but are farther away.

Background Information About This Investigation for the Teacher

There are a vast number of stars in the universe. Astronomers classify stars using different characteristics such as color, size, temperature, and luminosity. Luminosity is the total amount of energy emitted by a star in a unit of time. This energy then transfers from the star to other objects around it by light. Stars that produce more energy in a given amount of time have a greater luminosity and emit more light than stars that produce less energy in the same amount of time. The Sun, for example, has a white-yellow color, a diameter of about 864,000 miles, a surface temperature of about 5500°C, and a luminosity of 3.846 × 1026 watts, an amount equal to 1 *solar luminosity* (Gregersen 2009, NASA 2017). Astronomers use solar luminosity as the baseline for measuring the luminosity of other stars. Rigel is another example of a star that we can see in the sky. Rigel has a blue-white color, a diameter of about 68,250,000 miles, a surface temperature of about 11600°C, and a luminosity that is 120,000 times greater than the Sun (Sessions 2020, Star Facts 2019).

Astronomers use the term *apparent brightness* to describe how bright a star looks to us on Earth. Apparent brightness is not the same as luminosity. Stars that produce the same amount of energy each second may have a different apparent brightness when viewed from Earth, and stars with the same apparent brightness when viewed from Earth may have different luminosities. The Sun is a good example of this phenomenon. The Sun produces less energy per second than many other stars in the universe (such as Rigel). It is also smaller and cooler than many of these stars. The Sun, however, appears much brighter than any of the other stars that we can see in the sky because it is closer to Earth than any other star. The Sun is about 93 million miles away from us, and it takes the light that is produced by the Sun about 8 minutes to travel this distance through space. The next closest star to Earth is called Proxima Centauri. This star is about 25 trillion miles away from Earth, and light from Proxima Centauri takes about 4.24 years to reach Earth (Temming 2014). Rigel is even farther away than Proxima Centauri. It takes 863 years for energy from Rigel to travel through space and reach Earth (Sessions 2020). There are other stars that are even farther away from the Earth.

Timeline

The time needed to complete this investigation is 260 minutes (4 hours and 20 minutes). The amount of instructional time needed for each stage of the investigation is as follows:

- *Stage 1.* Introduce the task and the guiding question: 35 minutes
- *Stage 2.* Design a method and collect data: 40 minutes
- *Stage 3.* Create a draft argument: 45 minutes
- *Stage 4.* Argumentation session: 30 minutes
- *Stage 5.* Reflective discussion: 15 minutes

- *Stage 6*. Write a draft report: 30 minutes
- *Stage 7*. Peer review: 35 minutes
- *Stage 8*. Revise the report: 30 minutes

Materials and Preparation

The materials needed for this investigation are listed in Table 14.1. The items can be purchased from a big-box retail store such as Walmart or Target or through an online retailer such as Amazon. The materials for this investigation can also be purchased as a complete kit (which includes enough materials for 24 students, or six groups of four students) at *www.argumentdriveninquiry.com*.

TABLE 14.1

Materials for Investigation 14

Item	Quantity
Safety goggles	1 per student
Lamp with 40 W bulb	1 per class
Lamp with 60 W bulb	1 per class
Lamp with 100 W bulb	1 per class
Masking tape	1 roll per class
Meterstick or soft tape measure	1 per group
Tablet with a light meter app	1 per group
10 strips (1" × 8.5") of paper stapled together	1 per group
Whiteboard, 2' × 3'*	1 per group
Investigation Handout	1 per student
Peer-review guide and teacher scoring rubric	1 per student
Checkout Questions (optional)	1 per student

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

Students will need to create physical models of stars during this investigation. The 40 W, 60 W, and 100 W bulbs produce different amounts of light, so these bulbs can be used to create a physical model of three different stars with different luminosities. The amount of light produced by a bulb is reported in a unit of measurement called lumens. The amount of light produced by a bulb, in lumens, is labeled on the top of each bulb. Students can measure the apparent brightness of each bulb at different distances using a light meter app loaded onto a tablet with a camera. A light meter app measures the intensity of light using a unit of measurement called lux. There are several free light meter apps that can be used to measure light intensity available to download at the Apple App Store or Google Play. Some examples follow.

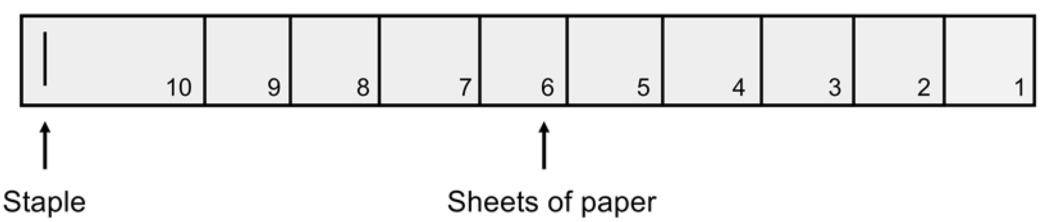
- Lux Light Meter Pro at *https://apps.apple.com/us/app/lux-light-meter-pro/id1292598866*
- Lux Light Meter Free at *https://apps.apple.com/us/app/lux-light-meter-free/id1171685960*
- Lux Light Meter Free at *https://play.google.com/store/apps/details?id=com.doggoapps.luxlight&hl=en_US*

You may need to ask someone from your school or district IT department to load one of these apps on the tablets that the students will use. If you do not have tablets available for students to use in your school or district, set up a meeting with someone from your IT department to discuss other options. You should learn how to use the light meter app that you decide to use before starting the investigation so you can help students when they get stuck.

Students can also measure the apparent brightness of the bulbs at different distances by counting the number of pieces of paper that the light shines through. Figure 14.1 shows how you can make a basic tool for measuring apparent brightness by stapling 10 strips of paper together and labeling the number of strips with a pen or pencil. Brighter or more intense lights will shine through more pieces of paper than dimmer lights.

FIGURE 14.1

How to make a tool to measure light intensity with 10 strips of paper



Safety Precautions

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

- Wear sanitized safety goggles during setup, investigation activity, and cleanup.
- Lightbulbs can get very hot. Do not touch a lightbulb when it is on or for several minutes after turning it off.
- Keep electrical equipment away from water sources to prevent shock.
- Make sure all materials are put away after completing the activity.
- Wash their hands with soap and water when they are done cleaning up.

Lesson Plan by Stage

Stage 1: Introduce the Task and the Guiding Question (35 minutes)

1. Ask the students to sit in six groups, with three or four students in each group.
2. Ask the students to clear off their desks except for a pencil (and their *Student Workbook for Argument-Driven Inquiry in Fifth-Grade Science* if they have one).
3. Pass out an Investigation Handout to each student (or ask students to turn to the Investigation Log for Investigation 14 in their workbook).
4. Read the first paragraph of the "Introduction" aloud to the class. Ask the students to follow along as you read.
5. Show the following video: *www.youtube.com/watch?v=0FXJUP6_O1w.*
6. Tell the students to record their observations and questions about what they see in the video on the "NOTICED/WONDER" chart in the "Introduction."
7. Ask the students to share what they observed.
8. Ask the students to share what questions they have.
9. Tell the students, "Some of your questions might be answered by reading the rest of the 'Introduction.'"
10. Ask the students to read the rest of the "Introduction" on their own *or* ask them to follow along as you read it aloud.
11. Once the students have read the rest of the "Introduction," ask them to fill out the "Things we KNOW" chart on their Investigation Handout (or in their Investigation Log) as a group.
12. Ask the students to share what they learned from the reading. Add these ideas to a class "Things we KNOW" chart.
13. Tell the students, "Let's see what we will need to figure out during our investigation."
14. Read the task and the guiding question aloud.
15. Tell the students, "I have lots of materials here that you can use."
16. Introduce the students to the materials available for them to use during the investigation by holding each one up and then asking how it might be used to collect data. We also recommend that you show the students how to use the light meter app or the strips of paper to measure light intensity and then give them a chance to play with the app or the strips of paper so they can see how they work before moving on to stage 2.

Stage 2: Design a Method and Collect Data (40 minutes)

1. Tell the students, "I am now going to give you and the other members of your group about 15 minutes to plan your investigation. Before you begin, I want you all to take a couple of minutes to discuss the following questions with the rest of your group."
2. Show the following questions on the screen or board:
   - What information do we need to find a relationship between a *cause* and an *effect?*
   - What measurement *scale* and *units* might we use as we collect data?
3. Tell the students, "Please take a few minutes to come up with an answer to these questions."
4. Give the students two or three minutes to discuss these two questions.
5. Ask two or three different groups to share their answers. Highlight or write down any important ideas on the board so students can refer to them later.
6. If possible, use a document camera to project an image of the graphic organizer for this investigation on a screen or board (or take a picture of it and project the picture on a screen or board). Tell the groups of students, "I now want you all to plan out your investigation. To do that, you will need to fill out this proposal."
7. Point to the box labeled "Our guiding question:" and tell the students, "You can put the question we are trying to answer in this box." Then ask, "Where can we find the guiding question?"
8. Wait for a student to answer.
9. Point to the box labeled "This is a picture of how we will set up the equipment:" and tell the students, "You can draw a picture in this box of how you will set up the equipment in order to carry out this investigation."
10. Point to the box labeled "We will collect the following data:" and tell the students, "You can list the measurements or observations that you will need to collect during the investigation in this box."
11. Point to the box labeled "These are the steps we will follow to collect data:" and tell the students, "You can list what you are going to do to collect the data you need and what you will do with your data once you have it. Be sure to give enough detail that I could do your investigation for you."
12. Ask the students, "Do you have any questions about what you need to do?"
13. Wait for questions. Answer any questions that come up.
14. Tell the students, "Once you are done, raise your hand and let me know. I'll then come by and look over your proposal and give you some feedback. You may not begin collecting data until I have approved your proposal by signing it. You need to have your proposal done in the next 15 minutes."

15. Give the students 15 minutes to work in their groups on their investigation proposal. As they work, move from group to group to check in, ask probing questions, and offer a suggestion if a group gets stuck.
16. As each group finishes its investigation proposal, read it over and determine if it will be productive or not. If you feel the investigation will be productive (not necessarily what you would do or what the other groups are doing), sign your name on the proposal and let the group start collecting data. If the plan needs to be changed, offer some suggestions or ask some probing questions, and have the group make the changes before you approve it.

What should a student-designed investigation look like?

There are a number of different investigations that students can design to answer the question "How does distance affect the apparent brightness of a star?" For example, one method might include the following steps:

1. Go to the lamp with the 40 W lightbulb and turn it on.
2. Use the light meter app to measure the apparent brightness of the bulb (in lux) when the tablet is positioned 100 cm, 200 cm, 300 cm, 400 cm, and 500 cm from the bulb.
3. Go to the lamp with the 60 W lightbulb and turn it on.
4. Repeat step 2.
5. Go to the lamp with a 100 W lightbulb and turn it on.
6. Repeat step 2.

If students use this method, they will need to collect data on (1) distance from the light source and (2) apparent brightness of the light in lux.

17. Pass out the materials, or have one student from each group collect the materials they need from a central supply table or cart for the groups that have an approved proposal.
18. Remind students of the safety rules and precautions for this investigation.
19. Tell the students to collect their data and record their observations or measurements in the "Collect Your Data" box in their Investigation Handout (or the Investigation Log in their workbook).
20. Give the students 30 minutes to collect their data. Collect the materials from each group before asking them to analyze their data.

Stage 3: Create a Draft Argument (45 minutes)

1. Tell the students, "Now that we have all this data, we need to analyze the data so we can figure out an answer to the guiding question."
2. If possible, project an image of the "Analyze Your Data" section for this investigation on a screen or board using a document camera (or take a picture of it and project the picture on a screen or board). Point to the section and tell the students, "You can create a graph as a way to analyze your data. You can make your graph in this section."
3. Ask the students, "What information do we need to include in a graph?"
4. Tell the students, "Please take a few minutes to discuss this question with your group and be ready to share."
5. Give the students five minutes to discuss.
6. Ask two or three different groups to share their answers. Highlight or write down any important ideas on the board so students can refer to them later.
7. Tell the students, "I am now going to give you and the other members of your group about 10 minutes to create your graph." The graph they create should include the distance from the lightbulb and the amount of light falling on the tablet. If the students are having trouble making a graph, you can take a few minutes to provide a mini-lesson about how to create a graph from a bunch of measurements (this strategy is called just-in-time instruction because it is offered only when students get stuck).
8. Give the students 10 minutes to analyze their data by creating a graph. As they work, move from group to group to check in, ask probing questions, and offer suggestions.

What should the graph for this investigation look like?

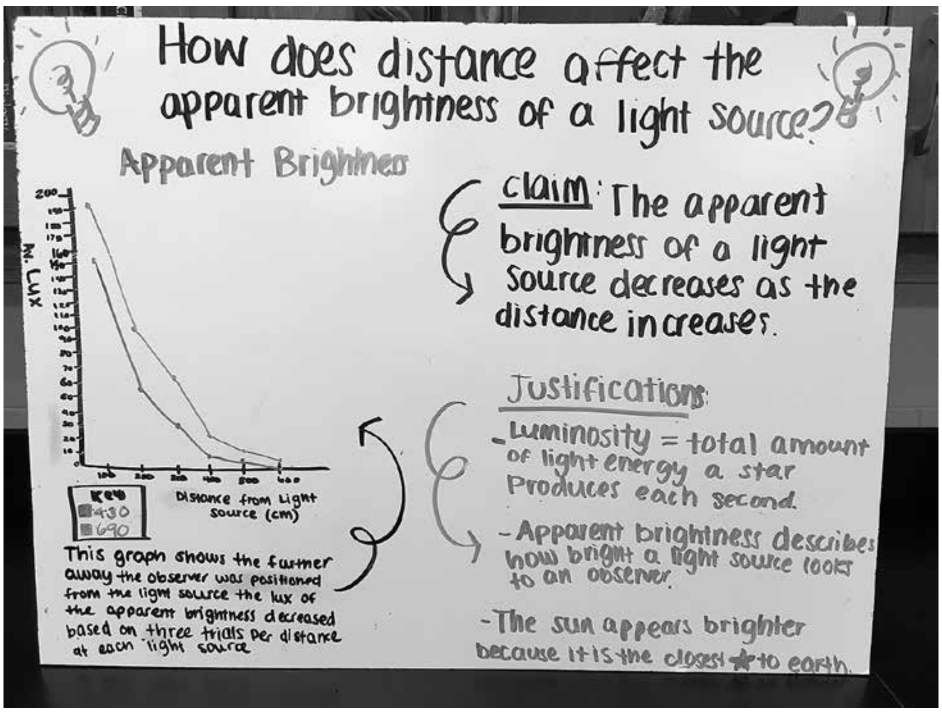
There are a number of different ways that students can analyze the measurements they collect during this investigation. One of the most straightforward ways is to create a grouped bar graph with the distance from the bulb on the horizontal axis, or *x*-axis, and the amount of light falling on the tablet on the vertical axis, or *y*-axis. The groups of bars can be labeled by type of bulb (40 W, 60 W, or 100 W). There are other options for analyzing the collected data. Students often come up with some unique ways of analyzing their data, so be sure to give them some voice and choice during this stage.

9. Tell the students, "I am now going to give you and the other members of your group about 15 minutes to create an argument to share what you have learned and convince others that they should believe you. Before you do that, we need to take a few minutes to discuss what you need to include in your argument."
10. If possible, use a document camera to project the "Argument Presentation on a Whiteboard" image from the "Draft Argument" section of the Investigation Handout (or the Investigation Log in their workbook) on a screen or board (or take a picture of it and project the picture on a screen or board).
11. Point to the box labeled "The Guiding Question:" and tell the students, "You can put the question we are trying to answer here on your whiteboard."
12. Point to the box labeled "Our Claim:" and tell the students, "You can put your claim here on your whiteboard. The claim is your answer to the guiding question."
13. Point to the box labeled "Our Evidence:" and tell the students, "You can put the evidence that you are using to support your claim here on your whiteboard. Your evidence will need to include the analysis you just did and an explanation of what your analysis means or shows. Scientists always need to support their claims with evidence."
14. Point to the box labeled "Our Justification of the Evidence:" and tell the students, "You can put your justification of your evidence here on your whiteboard. Your justification needs to explain why your evidence is important. Scientists often use core ideas to explain why the evidence they are using matters. Core ideas are important concepts that scientists use to help them make sense of what happens during an investigation."
15. Ask the students, "What are some core ideas that we read about earlier that might help us explain why the evidence we are using is important?"
16. Ask the students to share some of the core ideas from the "Introduction" section of the Investigation Handout (or the Investigation Log in the workbook). List these core ideas on the board.
17. Tell the students, "That is great. I would like to see everyone try to include these core ideas in your justification of the evidence. Your goal is to use these core ideas to help explain why your evidence matters and why the rest of us should pay attention to it."
18. Ask the students, "Do you have any questions about what you need to do?"
19. Answer any questions that come up.
20. Tell the students, "Okay, go ahead and start working on your arguments. You need to have your argument done in the next 15 minutes. It doesn't need to be perfect. We just need something down on the whiteboards so we can share our ideas."

21. Give the students 15 minutes to work in their groups on their arguments. As they work, move from group to group to check in, ask probing questions, and offer a suggestion if a group gets stuck. Figure 14.2 shows an example of an argument created by students for this investigation.

FIGURE 14.2

Example of an argument



Stage 4: Argumentation Session (30 minutes)

The argumentation session can be conducted in a whole-class presentation format, a gallery walk format, or a modified gallery walk format. We recommend using a whole-class presentation format for the first investigation, but try to transition to either the gallery walk or modified gallery walk format as soon as possible because that will maximize student voice and choice inside the classroom. The following list shows the steps for the three formats; unless otherwise noted, the steps are the same for all three formats.

1. Begin by introducing the use of the whiteboard.
   - *If using the whole-class presentation format,* tell the students, "We are now going to share our arguments. Please set up your whiteboards so everyone can see them."

- *If using the gallery walk or modified gallery walk format,* tell the students, "We are now going to share our arguments. Please set up your whiteboards so they are facing the walls."

2. Allow the students to set up their whiteboards.
   - *If using the whole-class presentation format,* the whiteboards should be set up on stands or chairs so they are facing toward the center of the room.
   - *If using the gallery walk or modified gallery walk format,* the whiteboards should be set up on stands or chairs so they are facing toward the outside of the room.
3. Give the following instructions to the students:
   - *If using the whole-class presentation format,* tell the students, "Okay, before we get started I want to explain what we are going to do next. Your group will have an opportunity to share your argument with the rest of the class. After you are done, everyone else in the class will have a chance to ask questions and offer some suggestions about ways to make your group's argument better. After we have a chance to listen to each other and learn something new, I'm going to give you some time to revise your arguments and make them better."
   - *If using the gallery walk format,* tell the students, "Okay, before we get started I want to explain what we are going to do next. You are going to read the arguments that were created by other groups. When I say 'go,' your group will go to a different group's station so you can see their argument. Once you are there, I'll give your group a few minutes to read and review their argument. Your job is to offer them some suggestions about ways to make their argument better. You can use sticky notes to give them suggestions. Please be specific about what you want to change and how you think they should change it. After we have a chance to learn from each other, I'm going to give you some time to revise your arguments and make them better."
   - *If using the modified gallery walk format,* tell the students, "Okay, before we get started I want to explain what we are going to do next. I'm going to ask some of you to present your arguments to your classmates. If you are presenting your argument, your job is to share your group's claim, evidence, and justification of the evidence. The rest of you will be travelers. If you are a traveler, your job is to listen to the presenters, ask the presenters questions if you do not understand something, and then offer them some suggestions about ways to make their argument better. After we have a chance to learn from each other, I'm going to give you some time to revise your arguments and make them better."
4. Use a document camera to project the "Ways to IMPROVE our argument …" box from the Investigation Handout (or the Investigation Log in their workbook) on a screen or board (or take a picture of it and project the picture on a screen or board).

- *If using the whole-class presentation format,* point to the box and tell the students, "After your group presents your argument, you can write down the suggestions you get from your classmates here. If you are listening to a presentation and you see a good idea from another group, you can write down that idea here as well. Once we are done with the presentations, I will give you a chance to use these suggestions or ideas to improve your arguments."
- *If using the gallery walk format,* point to the box and tell the students, "If you see a good idea from another group, you can write it down here. Once we are done reviewing the different arguments, I will give you a chance to use these ideas to improve your own arguments. It is important to share ideas like this."
- *If using the modified gallery walk format,* point to the box and tell the students, "If you are a presenter, you can write down the suggestions you get from the travelers here. If you are a traveler and you see a good idea from another group, you can write down that idea here. Once we are done with the presentations, I will give you a chance to use these suggestions or ideas to improve your arguments."

5. Ask the students, "Do you have any questions about what you need to do?"
6. Answer any questions that come up.
7. Give the following instructions:
    - *If using the whole-class presentation format,* tell the students, "Okay. Let's get started."
    - *If using the gallery walk format,* tell the students, "Okay, I'm now going to tell you which argument to go to and review."
    - *If using the modified gallery walk format,* tell the students, "Okay, I'm now going to assign you to be a presenter or a traveler." Assign one or two students from each group to be presenters and one or two students from each group to be travelers.
8. Give the students an opportunity to review the arguments.
    - *If using the whole-class presentation format,* have each group present their argument one at a time. Give each group only two to three minutes to present their argument. Then give the class two to three minutes to ask them questions and offer suggestions. Encourage as much participation from the students as possible.
    - *If using the gallery walk format,* tell the students, "Okay. Let's get started. Each group, move one argument to the left. Don't move to the next argument until I tell you to move. Once you get there, read the argument and then offer suggestions about how to make it better. I will put some sticky notes next to each argument. You can use the sticky notes to leave your suggestions." Give each group about three to four minutes to read the arguments, talk, and offer suggestions.

a. After three to four minutes, tell the students, "Okay. Let's move on to the next argument. Please move one group to the left."

b. Again, give each group three to four minutes to read, talk, and offer suggestions.

c. Repeat this process until each group has had their argument read and critiqued three times.

- *If using the modified gallery walk format,* tell the students, "Okay. Let's get started. Reviewers, move one group to the left. Don't move to the next group until I tell you to move. Presenters, go ahead and share your argument with the travelers when they get there." Give each group of presenters and travelers about three to four minutes to talk.

a. Tell the students, "Okay. Let's move on to the next argument. Travelers, move one group to the left."

b. Again, give each group of presenters and travelers about three to four minutes to talk.

c. Repeat this process until each group has had their argument read and critiqued three times.

9. Tell the students to return to their workstations.
10. Give the following instructions about revising the argument:
    - *If using the whole-class presentation format,* tell the students, "I'm now going to give you all about 10 minutes to revise your argument. Take a few minutes to talk in your groups and determine what you want to change to make your argument better. Once you have decided what to change, go ahead and make the changes to your whiteboard."
    - *If using the gallery walk format,* tell the students, "I'm now going to give you all about 10 minutes to revise your argument. Take a few minutes to read the suggestions that were left at your argument. Then talk in your groups and determine what you want to change to make your argument better. Once you have decided what to change, go ahead and make the changes to your whiteboard."
    - *If using the modified gallery walk format,* tell the students, "I'm now going to give you all about 10 minutes to revise your argument. Please return to your original groups." Wait for the students to move back into their original groups and then tell the students, "Okay, take a few minutes to talk in your groups and determine what you want to change to make your argument better. Once you have decided what to change, go ahead and make the changes to your whiteboard."
11. Ask the students, "Do you have any questions about what you need to do?"
12. Answer any questions that come up.
13. Tell the students, "Okay. Let's get started."

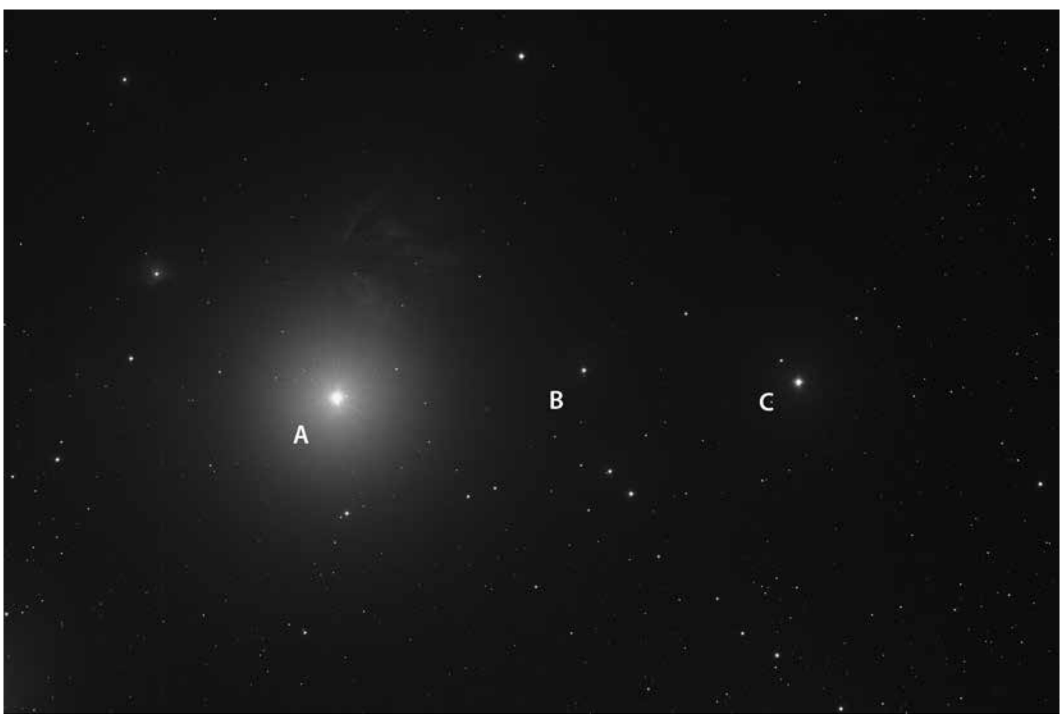
14. Give the students 10 minutes to work in their groups on their arguments. As they work, move from group to group to check in, ask probing questions, and offer a suggestion if a group gets stuck.

Stage 5: Reflective Discussion (15 minutes)

1. Tell the students, "We are now going to take a minute to talk about some of the core ideas and crosscutting concepts that we have used during our investigation."
2. Show Figure 14.3 (without the caption) on the screen.
3. Ask the students, "What do you notice?"
4. Allow the students to share their ideas.

FIGURE 14.3

Stars of different apparent brightness



5. Ask the students, "What are some different properties or characteristics of stars that we can use to help us describe or classify all these stars?"
6. Allow the students to share their ideas. As they share their ideas, encourage them to build off each contribution and keep asking inviting questions (e.g.,

"Would anyone else like to add to that idea?") and probing questions (e.g., "Could you tell me more about that?") until students bring up the characteristics of color, size, temperature, and luminosity.

7. Ask the students, "How can we use what we know about the characteristics of stars to help explain what we see in this picture?"
8. Allow students to share their ideas. As they share their ideas, ask different questions to encourage them to expand on their thinking (e.g., "Can you tell me more about that?"), clarify a contribution (e.g., "Can you say that in another way?"), support an idea (e.g., "Why do you think that?"), add to an idea mentioned by a classmate (e.g., "Would anyone like to add to the idea?"), re-voice an idea offered by a classmate (e.g., "Who can explain that to me in another way?"), or critique an idea during the discussion (e.g., "Do you agree or disagree with that idea and why?") until students are able to generate an adequate explanation.
9. Tell the students, "We also needed to think about cause and effect during our investigations." Then ask, "Can anyone tell me why it is important to think about cause-and-effect relationships during an investigation?"
10. Allow the students to share their ideas.
11. Tell the students, "I think cause-and-effect relationships are really important in science because they can be used to explain things we see happening."
12. Ask the students, "What cause-and-effect relationship was important to keep in mind during this investigation?"
13. Allow the students to share their ideas.
14. Tell the students, "Scientists often need to think about scales during an investigation." Then ask, "Can anyone tell me why this is important?"
15. Allow the students to share their ideas.
16. Tell the students, "I think natural objects exist from the very small, such as atoms, to the immensely large, such as stars, and from very short to very long distances. Scientists therefore need to think about what measurement scales to use when collecting data."
17. Ask the students, "How did you need to think about measurement scales today?"
18. Show an image of the question "What do you think are the most important core ideas or crosscutting concepts that we used during this investigation to help us make sense of what we observed?" Tell the students, "Okay, let's make sure we are all on the same page. Please take a moment to discuss this question with the other people in your group." Give them a few minutes to discuss the question.
19. Ask the students, "What do you all think? Who would like to share?"

20. Allow the students to share their ideas.
21. Tell the students, "We are now going to take a minute to talk about what went well and what didn't go so well during our investigation. We need to talk about this because you all are going to be planning and carrying out your own investigations like this a lot this year, and I want to help you all get better at it."
22. Show an image of the question "What made your investigation scientific?" on the screen. Tell the students, "Take a few minutes to talk about how you would answer this question with the other people in your group. Be ready to share with the rest of the class." Give the students two to three minutes to talk in their group.
23. Ask the students, "What do you all think? Who would like to share an idea?"
24. Allow the students to share their ideas. Be sure to expand on their ideas about what makes an investigation scientific.
25. Show an image of the question "What made your investigation not so scientific?" on the screen. Tell the students, "Take a few minutes to talk about how you would answer this question with the other people in your group. Be ready to share with the rest of the class." Give the students two to three minutes to talk in their group.
26. Ask the students, "What do you all think? Who would like to share an idea?"
27. Allow the students to share their ideas. Be sure to expand on their ideas about what makes an investigation less scientific.
28. Show an image of the question "What rules can we put into place to help us make sure our next investigation is more scientific?" on the screen. Tell the students, "Take a few minutes to talk about how you would answer this question with the other people in your group. Be ready to share with the rest of the class." Give the students two to three minutes to talk in their group.
29. Ask the students, "What do you all think? Who would like to share an idea?"
30. Allow the students to share their ideas. Once they have shared their ideas, offer a suggestion for a possible class rule.
31. Ask the students, "What do you all think? Should we make this a rule?"
32. If the students agree, write the rule on the board or on a class "Rules for Scientific Investigation" chart so you can refer to it during the next investigation.

Stage 6: Write a Draft Report (30 minutes)

Your students will use either the Investigation Handout or the Investigation Log in the student workbook when writing the draft report. When you give the directions shown in quotes in the following steps, substitute "Investigation Log in your workbook" or just "Investigation Log" (as shown in brackets) for "handout" if they are using the workbook.

1. Tell the students, "You are now going to write an investigation report to share what you have learned. Please take out a pencil and turn to the 'Draft Report' section of your handout [Investigation Log in your workbook]."
2. If possible, use a document camera to project the "Introduction" section of the draft report from the Investigation Handout (or the Investigation Log in their workbook) on a screen or board (or take a picture of it and project the picture on a screen or board).
3. Tell the students, "The first part of the report is called the 'Introduction.' In this section of the report you want to explain to the reader what you were investigating, why you were investigating it, and what question you were trying to answer. All this information can be found in the text at the beginning of your handout [Investigation Log]." Point to the image. "Here are some sentence starters to help you begin writing."
4. Ask the students, "Do you have any questions about what you need to do?"
5. Answer any questions that come up.
6. Tell the students, "Okay, let's write."
7. Give the students 10 minutes to write the "Introduction" section of the report. As they work, move from student to student to check in, ask probing questions, and offer a suggestion if a student gets stuck.
8. If possible, use a document camera to project the "Method" section of the draft report from the Investigation Handout (or the Investigation Log in their workbook) on a screen or board (or take a picture of it and project the picture on a screen or board).
9. Tell the students, "The second part of the report is called the 'Method.' In this section of the report you want to explain to the reader what you did during the investigation, what data you collected and why, and how you went about analyzing your data. All this information can be found in the 'Plan Your Investigation' section of the handout [Investigation Log]. Remember that you all planned and carried out different investigations, so do not assume that the reader will know what you did." Point to the image. "Here are some sentence starters to help you begin writing."
10. Ask the students, "Do you have any questions about what you need to do?"
11. Answer any questions that come up.
12. Tell the students, "Okay, let's write."
13. Give the students 10 minutes to write the "Method" section of the report. As they work, move from student to student to check in, ask probing questions, and offer a suggestion if a student gets stuck.
14. If possible, use a document camera to project the "Argument" section of the draft report from the Investigation Handout (or the Investigation Log in their

workbook) on a screen or board (or take a picture of it and project the picture on a screen or board).

15. Tell the students, "The last part of the report is called the 'Argument.' In this section of the report you want to share your claim, evidence, and justification of the evidence with the reader. All this information can be found on your whiteboard." Point to the image. "Here are some sentence starters to help you begin writing."
16. Ask the students, "Do you have any questions about what you need to do?"
17. Answer any questions that come up.
18. Tell the students, "Okay, let's write."
19. Give the students 10 minutes to write the "Argument" section of the report. As they work, move from student to student to check in, ask probing questions, and offer a suggestion if a student gets stuck.

Stage 7: Peer Review (35 minutes)

Your students will use either the Investigation Handout or their workbook when doing the peer review. Except where noted below, the directions are the same whether using the handout or the workbook.

1. Tell the students, "We are now going to review our reports to find ways to make them better. I'm going to come around and collect your draft reports. While I do that, please take out a pencil."
2. Collect the handouts or the workbooks with the draft reports from the students.
3. If possible, use a document camera to project the peer-review guide (see Appendix 4) on a screen or board (or take a picture of it and project the picture on a screen or board).
4. Tell the students, "We are going to use this peer-review guide to give each other feedback." Point to the image.
5. Tell the students, "I'm going to ask you to work with a partner to do this. I'm going to give you and your partner a draft report to read. You two will then read the report together. Once you are done reading the report, I want you to answer each of the questions on the peer-review guide." Point to the review questions on the image of the peer-review guide.
6. Tell the students, "You can check 'no,' 'almost,' or 'yes' after each question." Point to the checkboxes on the image of the peer-review guide.
7. Tell the students, "This will be your rating for this part of the report. Make sure you agree on the rating you give the author. If you mark 'no' or 'almost,' then you need to tell the author what he or she needs to do to get a 'yes.'" Point to the space for the reviewer feedback on the image of the peer-review guide.

8. Tell the students, "It is really important for you to give the authors feedback that is helpful. That means you need to tell them exactly what they need to do to make their report better."
9. Ask the students, "Do you have any questions about what you need to do?"
10. Answer any questions that come up.
11. Tell the students, "Please sit with a partner who is not in your current group." Allow the students time to sit with a partner.
12. Tell the students, "Okay, I'm now going to give you one report to read." Pass out one Investigation Handout with a draft report or one workbook to each pair. Make sure that the report you give a pair was not written by one of the students in that pair. Give each pair one peer-review guide to fill out. If the students are using workbooks, the peer-review guide is included right after the draft report so you do not need to pass out copies of the peer-review guide.
13. Tell the students, "Okay, I'm going to give you 15 minutes to read the report I gave you and to fill out the peer-review guide. Go ahead and get started."
14. Give the students 15 minutes to work. As they work, move around from pair to pair to check in and see how things are going, answer questions, and offer advice.
15. After 15 minutes pass, tell the students, "Okay, time is up. Please give me the report and the peer-review guide that you filled out."
16. Collect the Investigation Handouts and the peer-review guides, or collect the workbooks if students are using them. If the students are using the Investigation Handouts and separate peer-review guides, be sure you keep each handout with its corresponding peer-review guide.
17. Tell the students, "Okay, I am now going to give you a different report to read and a new peer-review guide to fill out." Pass out one more report to each pair. Make sure that the report you give a pair was not written by one of the students in that pair. Give each pair a new peer-review guide to fill out as a group.
18. Tell the students, "Okay, I'm going to give you 15 minutes to read this new report and to fill out the peer-review guide. Go ahead and get started."
19. Give the students 15 minutes to work. As they work, move around from pair to pair to check in and see how things are going, answer questions, and offer advice.
20. After 15 minutes pass, tell the students, "Okay, time is up. Please give me the report and the peer-review guide that you filled out."
21. Collect the Investigation Handouts and the peer-review guides, or collect the workbooks if students are using them. If the students are using the Investigation Handouts and separate peer-review guides, be sure you keep each handout with its corresponding peer-review guide.

Stage 8: Revise the Report (30 minutes)

Your students will use either the Investigation Handout or their workbook when revising the report. Except where noted below, the directions are the same whether using the handout or the workbook.

1. Tell the students, "You are now going to revise your draft report based on the feedback you get from your classmates. Please take out a pencil."
2. Return the reports to the students.
   - *If the students used the Investigation Handout and a copy of the peer-review guide,* pass back the handout and the peer-review guide to each student.
   - *If the students used the workbook,* pass that back to each student.
3. Tell the students, "Please take a few minutes to read over the peer-review guide. You should use it to figure out what you need to change in your report and how you will change it."
4. Allow the students to read the peer-review guide.
5. *If the students used the workbook,* if possible use a document camera to project the "Write Your Final Report" section from the Investigation Log on a screen or board (or take a picture of it and project the picture on a screen or board).
6. Give the following directions about how to revise their reports:
   - *If the students used the Investigation Handout and a copy of the peer-review guide,* tell them, "Okay, let's revise our reports. Please take out a piece of paper. I would like you to rewrite your report. You can use your draft report as a starting point, but you also need to change it to make it better. Use the feedback on the peer-review guide to make it better."
   - *If the students used the workbook,* tell them, "Okay, let's revise our reports. I would like you to rewrite your report in the section of the Investigation Log called "Write Your Final Report." You can use your draft report as a starting point, but you also need to change it to make it better. Use the feedback on the peer-review guide to make it better."
7. Ask the students, "Do you have any questions about what you need to do?"
8. Answer any questions that come up.
9. Tell the students, "Okay, let's write." Allow about 20 minutes for the students to revise their reports.
10. After about 20 minutes, give the following directions:
    - *If the students used the Investigation Handout,* tell them, "Okay, time's up. I will now come around and collect your Investigation Handout, the peer-review guide, and your final report."
    - *If the students used the workbook,* tell them, "Okay, time's up. I will now come around and collect your workbooks."

11. *If the students used the Investigation Handout,* collect all the Investigation Handouts, peer-review guides, and final reports. *If the students used the workbook,* collect all the workbooks.
12. *If the students used the Investigation Handout,* use the "Teacher Score" column in the peer-review guide to grade the final report. *If the students used the workbook,* use the "Investigation Report Grading Rubric" in the Investigation Log to grade the final report. Whether you are using the handout or the log, you can give the students feedback about their writing in the "Teacher Comments" section.

How to Use the Checkout Questions

The Checkout Questions are an optional assessment. We recommend giving them to students at the start of the next class period after the students finish stage 8 of the investigation. You can then look over the student answers to determine if you need to reteach the core idea from the investigation. Appendix 6 gives the answers to the Checkout Questions that should be given by a student who can apply the core idea correctly in all cases and can explain the cause-and-effect relationship.

Alignment With Standards

Table 14.2 highlights how the investigation can be used to address specific performance expectations from the *Next Generation Science Standards, Common Core State Standards for English Language Arts* (*CCSS ELA*) and *Common Core State Standards for Mathematics* (*CCSS Mathematics*), and *English Language Proficiency (ELP) Standards.*

TABLE 14.2

Investigation 14 alignment with standards

***NGSS* performance expectation**	5-ESS1-1: Support an argument that differences in the apparent brightness of the Sun compared to other stars is due to their relative distances from the Earth.
***CCSS ELA*—Reading: Informational Text**	Key ideas and details • CCSS.ELA-LITERACY.RI.5.1: Quote accurately from a text when explaining what the text says explicitly and when drawing inferences from the text. • CCSS.ELA-LITERACY.RI.5.2: Determine two or more main ideas of a text and explain how they are supported by key details; summarize the text. • CCSS.ELA-LITERACY.RI.5.3: Explain the relationships or interactions between two or more individuals, events, ideas, or concepts in a historical, scientific, or technical text based on specific information in the text.

Continued

Table 14.2 (*continued*)

***CCSS ELA*—Reading: Informational Text** (*continued*)	Craft and structure • CCSS.ELA-LITERACY.RI.5.4: Determine the meaning of general academic and domain-specific words and phrases in a text relevant to a *grade 5 topic or subject area*. • CCSS.ELA-LITERACY.RI.5.5: Compare and contrast the overall structure (e.g., chronology, comparison, cause/effect, problem/solution) of events, ideas, concepts, or information in two or more texts. • CCSS.ELA-LITERACY.RI.5.6: Analyze multiple accounts of the same event or topic, noting important similarities and differences in the point of view they represent. Integration of knowledge and ideas • CCSS.ELA-LITERACY.RI.5.7: Draw on information from multiple print or digital sources, demonstrating the ability to locate an answer to a question quickly or to solve a problem efficiently. • CCSS.ELA-LITERACY.RI.5.8: Explain how an author uses reasons and evidence to support particular points in a text, identifying which reasons and evidence support which point(s). Range of reading and level of text complexity • CCSS.ELA-LITERACY.RI.5.10: By the end of the year, read and comprehend informational texts, including history/social studies, science, and technical texts, at the high end of the grades 4–5 text complexity band independently and proficiently.
***CCSS ELA*—Writing**	Text types and purposes • CCSS.ELA-LITERACY.W.5.1: Write opinion pieces on topics or texts, supporting a point of view with reasons. ○ CCSS.ELA-LITERACY.W.5.1.A: Introduce a topic or text clearly, state an opinion, and create an organizational structure in which ideas are logically grouped to support the writer's purpose. ○ CCSS.ELA-LITERACY.W.5.1.B: Provide logically ordered reasons that are supported by facts and details. ○ CCSS.ELA-LITERACY.W.5.1.C: Link opinion and reasons using words, phrases, and clauses (e.g., *consequently*, *specifically*). ○ CCSS.ELA-LITERACY.W.5.1.D: Provide a concluding statement or section related to the opinion presented. • CCSS.ELA-LITERACY.W.5.2: Write informative or explanatory texts to examine a topic and convey ideas and information clearly. ○ CCSS.ELA-LITERACY.W.5.2.A: Introduce a topic clearly, provide a general observation and focus, and group related information logically; include formatting (e.g., headings), illustrations, and multimedia when useful to aiding comprehension. ○ CCSS.ELA-LITERACY.W.5.2.B: Develop the topic with facts, definitions, concrete details, quotations, or other information and examples related to the topic. ○ CCSS.ELA-LITERACY.W.5.2.C: Link ideas within and across categories of information using words, phrases, and clauses (e.g., *in contrast*, *especially*).

Continued

Table 14.2 (*continued*)

***CCSS ELA*—Writing** (*continued*)	○ CCSS.ELA-LITERACY.W.5.2.D: Use precise language and domain-specific vocabulary to inform about or explain the topic. ○ CCSS.ELA-LITERACY.W.5.2.E: Provide a concluding statement or section related to the information or explanation presented. Production and distribution of writing • CCSS.ELA-LITERACY.W.5.4: Produce clear and coherent writing in which the development and organization are appropriate to task, purpose, and audience. • CCSS.ELA-LITERACY.W.5.5: With guidance and support from peers and adults, develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach. • CCSS.ELA-LITERACY.W.5.6: With some guidance and support from adults, use technology, including the internet, to produce and publish writing as well as to interact and collaborate with others; demonstrate sufficient command of keyboarding skills to type a minimum of two pages in a single sitting. Research to build and present knowledge • CCSS.ELA-LITERACY.W.5.8: Recall relevant information from experiences or gather relevant information from print and digital sources; summarize or paraphrase information in notes and finished work, and provide a list of sources. • CCSS.ELA-LITERACY.W.5.9: Draw evidence from literary or informational texts to support analysis, reflection, and research. Range of writing • CCSS.ELA-LITERACY.W.5.10: Write routinely over extended time frames (time for research, reflection, and revision) and shorter time frames (a single sitting or a day or two) for a range of discipline-specific tasks, purposes, and audiences.
***CCSS ELA*—Speaking and Listening**	Comprehension and collaboration • CCSS.ELA-LITERACY.SL.5.1: Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on *grade 5 topics and texts,* building on others' ideas and expressing their own clearly. ○ CCSS.ELA-LITERACY.SL.5.1.A: Come to discussions prepared, having read or studied required material; explicitly draw on that preparation and other information known about the topic to explore ideas under discussion. ○ CCSS.ELA-LITERACY.SL.5.1.B: Follow agreed-upon rules for discussions and carry out assigned roles. ○ CCSS.ELA-LITERACY.SL.5.1.C: Pose and respond to specific questions by making comments that contribute to the discussion and elaborate on the remarks of others. ○ CCSS.ELA-LITERACY.SL.5.1.D: Review the key ideas expressed and draw conclusions in light of information and knowledge gained from the discussions.

Continued

Table 14.2 (*continued*)

***CCSS ELA*—Speaking and Listening** (*continued*)	• CCSS.ELA-LITERACY.SL.5.2: Summarize a written text read aloud or information presented in diverse media and formats, including visually, quantitatively, and orally. • CCSS.ELA-LITERACY.SL.5.3: Summarize the points a speaker makes and explain how each claim is supported by reasons and evidence. Presentation of knowledge and ideas • CCSS.ELA-LITERACY.SL.5.4: Report on a topic or text or present an opinion, sequencing ideas logically and using appropriate facts and relevant, descriptive details to support main ideas or themes; speak clearly at an understandable pace. • CCSS.ELA-LITERACY.SL.5.5: Include multimedia components (e.g., graphics, sound) and visual displays in presentations when appropriate to enhance the development of main ideas or themes. • CCSS.ELA-LITERACY.SL.5.6: Adapt speech to a variety of contexts and tasks, using formal English when appropriate to task and situation.
***CCSS Mathematics*—Numbers and Operations in Base Ten**	Perform operations with multi-digit whole numbers and with decimals to hundredths. • CCSS.MATH.CONTENT.5.NBT.B.7: Add, subtract, multiply, and divide decimals to hundredths.
***CCSS Mathematics*—Measurement and Data**	Convert like measurement units within a given measurement system. • CCSS.MATH.CONTENT.5.MD.A.1: Convert among different-sized standard measurement units within a given measurement system (e.g., convert 5 cm to 0.05 m), and use these conversions in solving multi-step, real-world problems.
ELP Standards (*continued*)	Receptive modalities • ELP 1: Construct meaning from oral presentations and literary and informational text through grade-appropriate listening, reading, and viewing. • ELP 8: Determine the meaning of words and phrases in oral presentations and literary and informational text. Productive modalities • ELP 3: Speak and write about grade-appropriate complex literary and informational texts and topics. • ELP 4: Construct grade-appropriate oral and written claims and support them with reasoning and evidence. • ELP 7: Adapt language choices to purpose, task, and audience when speaking and writing.

Continued

Table 14.2 (*continued*)

ELP Standards (*continued*)	Interactive modalities • ELP 2: Participate in grade-appropriate oral and written exchanges of information, ideas, and analyses, responding to peer, audience, or reader comments and questions. • ELP 5: Conduct research and evaluate and communicate findings to answer questions or solve problems. • ELP 6: Analyze and critique the arguments of others orally and in writing. Linguistic structures of English • ELP 9: Create clear and coherent grade-appropriate speech and text. • ELP 10: Make accurate use of standard English to communicate in grade-appropriate speech and writing.

References

Gregersen, E. 2009. Luminosity. Encyclopaedia Brittanica. *www.britannica.com/science/luminosity.*

NASA. 2017. The Sun. *www.nasa.gov/sun.*

Sessions, L. 2020. Rigel in Orion is blue-white. EarthSky. *https://earthsky.org/brightest-stars/blue-white-rigel-is-orions-brightest-star.*

Star Facts. 2019. Rigel. *www.star-facts.com/rigel.*

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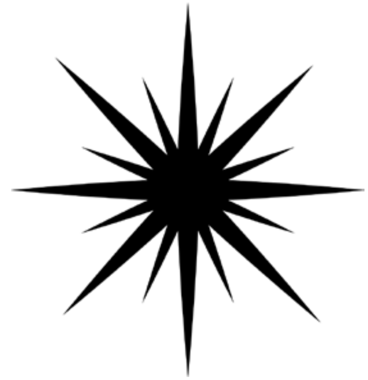
Investigation 14

Star Brightness: How Does Distance Affect the Apparent Brightness of a Star?



Introduction

We can see many different objects in the night sky. Take a few minutes to watch a video of the night sky that was taken from different locations in California and Oregon. As you watch the video, keep track of things you notice and things you wonder about in the boxes below.

Things I NOTICED …	Things I WONDER about …

We can see many different objects in the night sky because these objects either produce light or reflect light. A star is an example of an object that produces light. Stars produce light because they are very hot. The light that a star produces travels through space and transfers energy from the star to other objects around it. Stars, like the Sun, are therefore an important source of energy.

There are a vast number of stars in the universe. Stars differ in color, size, temperature, and luminosity. *Luminosity* is the total amount of energy that a star produces in a unit of time. The luminosity of a star depends on its size and temperature. Stars that are large and hot have a greater luminosity than stars that are small and cool. Astronomers use the color, size, temperature, and luminosity of a star to describe it or to compare it with other stars. The Sun, for example, has a white-yellow color, a diameter of about 864,000 miles, a surface temperature of about 5500°C, and a luminosity of 384.6 septillion watts per second (Gregersen 2009, NASA 2017). Rigel is another example of a star that we can see. Rigel has a blue-white color, a diameter of about 68,250,000 miles, a surface temperature of about 11600°C, and a luminosity that is 120,000 times greater than the Sun (Sessions 2020, Star Facts 2019).

Not all stars are the same distance from Earth. The Sun is the closest star to us. It is about 93 million miles away from Earth. It takes the light that is produced by the Sun about 8 minutes to travel this distance through space. The next closest star to Earth is called Proxima Centauri. This star is about 25 trillion miles away from Earth, and light from Proxima Centauri takes about 4.24 years to reach Earth (Temming 2014). Rigel is even farther away. It takes 863 years for light from Rigel to travel though space and reach us (Sessions 2020). There are other stars that are even farther away from Earth.

Astronomers use the term *apparent brightness* to describe how bright a star looks to us on Earth. Apparent brightness is not the same as luminosity. Stars that produce the same amount of energy each second may have a different apparent brightness when viewed from Earth, and stars with the same apparent brightness when viewed from Earth may have different luminosities. In this investigation, you will have a chance to explore how distance affects the apparent brightness of a star. Unfortunately, you cannot change how much energy a star produces or the distance between Earth and a star, so you will need to create a *physical model* to collect the data you need.

Things we KNOW from what we read …

Your Task

Use what you know about stars, light, physical models, scale, and quantity to carry out an investigation to figure out how changing the distance between a light source and an observer (a cause) affects its apparent brightness (the effect). Your teacher will also show you how to measure the apparent brightness of the bulb using a light meter or 10 strips of paper that are stapled together. The light meter measures apparent brightness in a unit of measurement called lux. The unit of measurement for the strips of paper will be number of pieces of paper.

The *guiding question* of this investigation is, ***How does distance affect the apparent brightness of a star?***

Materials

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

- Safety goggles (required)
- Tablet with a light meter app
- 10 strips of paper stapled together.
- Meterstick or soft tape measure
- Lamp with a 40 W bulb
- Lamp with a 60 W bulb
- Lamp with a 100 W bulb

Safety Rules

Follow all normal lab safety rules. In addition, be sure to follow these rules:

- Wear sanitized safety goggles during setup, investigation activity, and cleanup.
- Lightbulbs can get very hot. Do not touch a lightbulb when it is on or for several minutes after turning it off.
- Keep electrical equipment away from water sources to prevent shock.
- Wash your hands with soap and water when you are done cleaning up.

Plan Your Investigation

Prepare a plan for your investigation by filling out the chart on the next page; this plan is called an *investigation proposal.* Before you start developing your plan, be sure to discuss the following questions with the other members of your group:

- What information do we need to find a relationship between a **cause** and an **effect?**
- What measurement **scale** and **units** might we use as we collect data?

Our guiding question:

This is a picture of how we will set up the equipment:

We will collect the following data:

These are the steps we will follow to collect data:

I approve of this investigation proposal.

Teacher's signature

Date

Collect Your Data

Keep a record of what you measure or observe during your investigation in the space below.

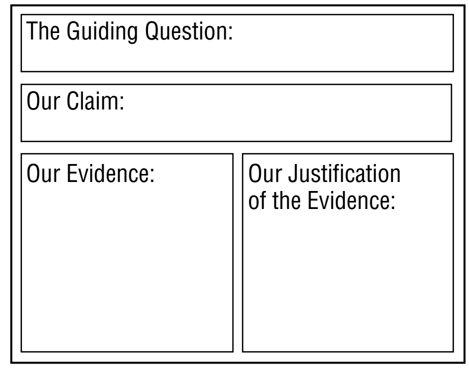
Analyze Your Data

You will need to analyze the data you collected before you can develop an answer to the guiding question. To analyze the data you collected, create a graph that shows the relationship between the cause and the effect.

Draft Argument

Develop an argument on a whiteboard. It should include the following:

1. A *claim*: Your answer to the guiding question.
2. *Evidence*: An analysis of the data and an explanation of what the analysis means.
3. A *justification of the evidence*: Why your group thinks the evidence is important.



Argumentation Session

Share your argument with your classmates. Be sure to ask them how to make your draft argument better. Keep track of their suggestions in the space below.

Ways to IMPROVE our argument …

Draft Report

Prepare an *investigation report* to share what you have learned. Use the information in this handout and your group's final argument to write a *draft* of your investigation report.

Introduction

We have been studying ______________________________ in class.

Before we started this investigation, we explored ______________________________

____

____

We noticed ______________________________

____

____

My goal for this investigation was to figure out ______________________________

____

____

The guiding question was ______________________________

____

____

Method

To gather the data I needed to answer this question, I ______________________________

____

____

____

____

____

I then analyzed the data I collected by ____

____

____

____

Argument

My claim is ____

____

____

____

The graph below shows ____

____

____

____

____

____

This analysis of the data I collected suggests ______________________________________

____

____

____

____

This evidence is based on several important scientific concepts. The first one is ____________

____

____

____

____

____

Review

Your classmates need your help! Review the draft of their investigation reports and give them ideas about how to improve. Use the *peer-review guide* when doing your review.

Submit Your Final Report

Once you have received feedback from your classmates about your draft report, create your final investigation report and hand it in to your teacher.

References

Gregersen, E. 2009. Luminosity. Encyclopaedia Brittanica. *www.britannica.com/science/luminosity.*

NASA. 2017. The Sun. *www.nasa.gov/sun.*

Sessions, L. 2020. Rigel in Orion is blue-white. EarthSky. *https://earthsky.org/brightest-stars/blue-white-rigel-is-orions-brightest-star.*

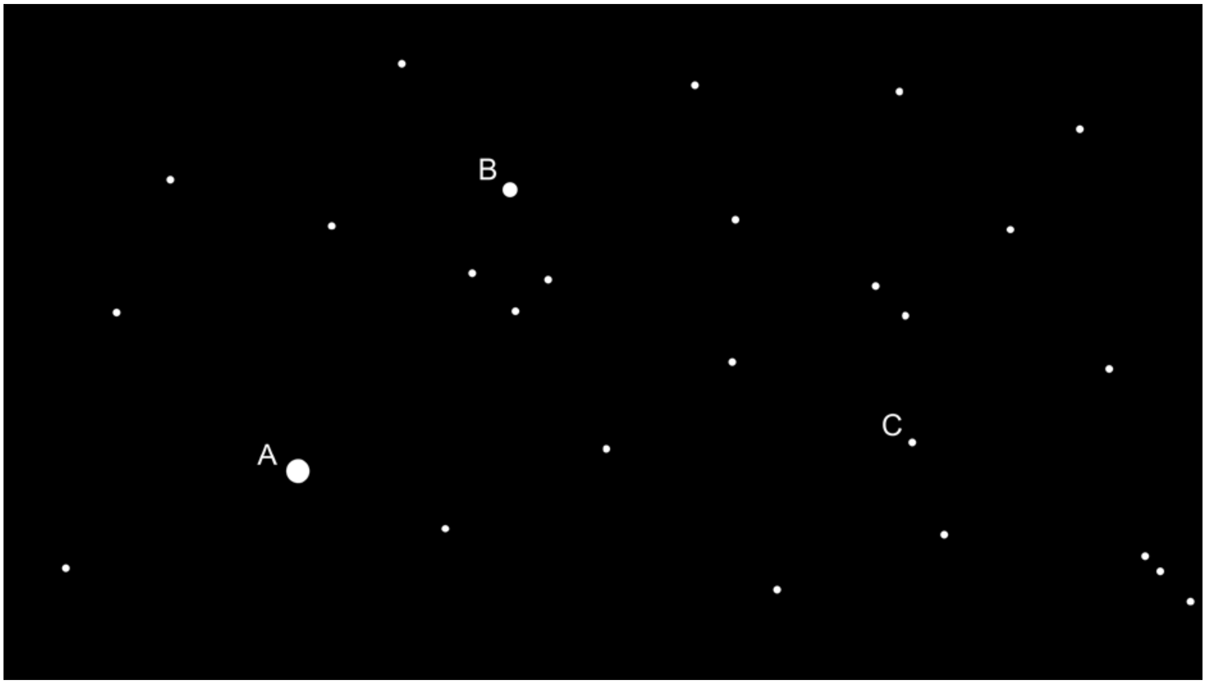
Star Facts. 2019. Rigel. *www.star-facts.com/rigel.*

Temming, M. 2014. How far is the closest star? Sky & Telescope. *https://skyandtelescope.org/astronomy-resources/far-closest-star.*

Checkout Questions

Investigation 14. Star Brightness

The picture below shows a night sky. Use this picture to answer questions 1–4.



1. Which star in the picture appears to be the *brightest?*
    a. Star A
    b. Star B
    c. Star C
    d. Unable to tell
2. Which star in the picture is the *largest?*
    a. Star A
    b. Star B
    c. Star C
    d. Unable to tell
3. Which star in the picture produces the most energy in a hour?
    a. Star A
    b. Star B
    c. Star C
    d. Unable to tell

4. Explain your thinking. What cause-and-effect relationship did you use to answer questions 1–3?

Teacher Scoring Rubric for the Checkout Questions

Level	Description
3	The student can apply the core idea correctly in all cases and can explain the cause-and-effect relationship.
2	The student can apply the core idea correctly in all cases but cannot explain the cause-and-effect relationship.
1	The student cannot apply the core idea correctly in all cases but can explain the cause-and-effect relationship.
0	The student cannot apply the core idea correctly and cannot explain the cause-and-effect relationship.

INDEX

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

Index

Index

Argument-Driven Inquiry in Fifth-Grade Science

Three-Dimensional Investigations

Are you interested in helping your elementary students learn the practices of science, including constructing explanations and engaging in argument from evidence? *Argument-Driven Inquiry in Fifth-Grade Science* will provide you with both the information and instructional materials you need to get started right away. The book is a one-stop source of expertise, advice, and investigations. It's designed to help your fifth graders work the way scientists do while integrating literacy and math at the same time.

Argument-Driven Inquiry in Fifth-Grade Science is divided into two basic parts:

1. **An introduction to the stages of ADI**—from question identification, data analysis, and argument development to evaluating and revising ideas.
2. **A well-organized series of 16 field-tested investigations** designed to be much more authentic for instruction than traditional activities. The focus is on making sense of how the world works. Investigations cover matter and its interactions; motion and stability; ecosystems and their interactions, energy, and dynamics; Earth's place in the universe; and Earth's systems. Using the *Student Workbook,* your students will explore important content and discover scientific practices. They'll investigate questions such as: What happens to a substance's weight when transforming from a solid to a liquid? Where does the matter that plants need to grow come from? Why do days change length in different locations on Earth? And why do people use hot water instead of cold when making tea?

This book is part of NSTA's bestselling series about ADI in elementary, middle, and high school science. Like its predecessors, this collection is designed to be easy to use, with teacher notes, investigation handouts, and checkout questions. The lessons support the *Next Generation Science Standards* and the *Common Core State Standards* for English language arts and mathematics. The book can also help emerging bilingual students meet the *English Language Proficiency Standards* with its tips for teaching English language learners.

Many of today's elementary school teachers—like you—want new ways to engage students in scientific practices and help students learn more from classroom activities. *Argument-Driven Inquiry in Fifth-Grade Science* does all of this while giving students the chance to practice reading, writing, speaking, and using mathematics in the context of science.

GRADE 5

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