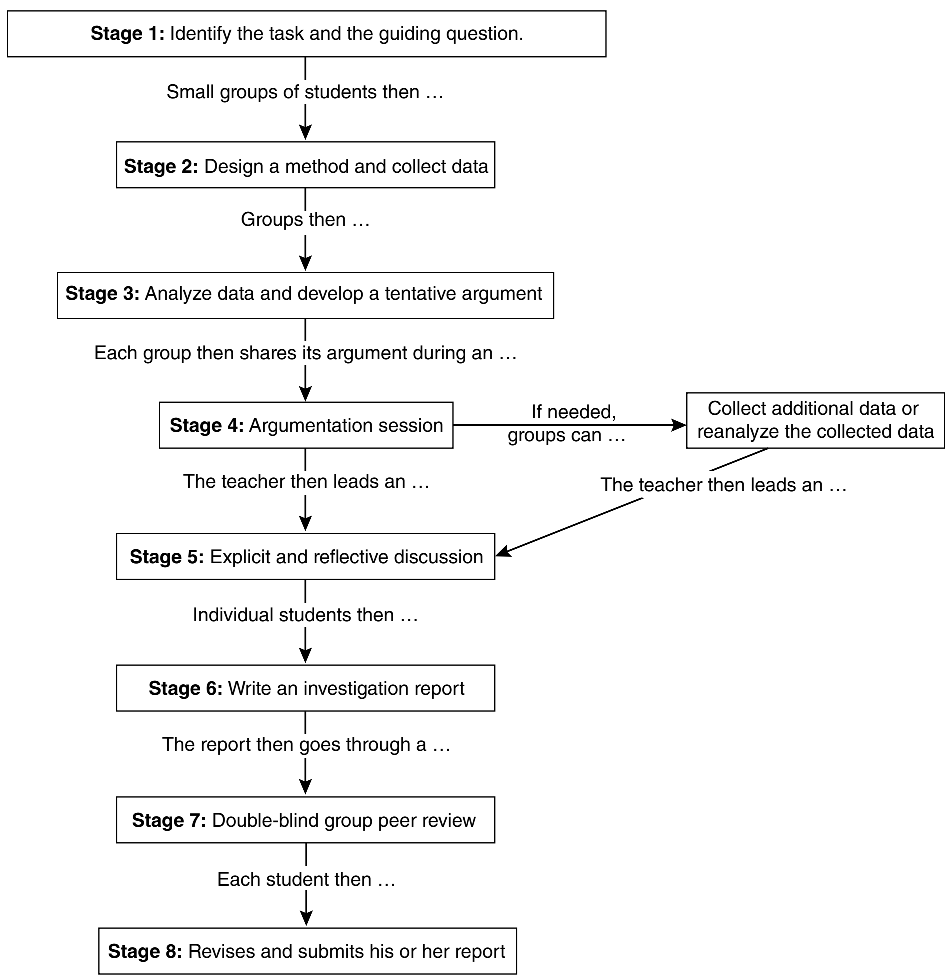
CHAPTER 1
Argument-Driven Inquiry

Stages of Argument-Driven Inquiry

Each of the eight stages in the argument-driven inquiry (ADI) instructional model is designed to ensure that the experience is authentic (students have an opportunity to engage in the practices of science) *and* educative (students receive the feedback and explicit guidance that they need to improve on each aspect of science proficiency). Figure 2 summarizes the eight stages.

FIGURE 2

Stages of the argument-driven inquiry instructional model



Stage 1: Identification of the Task and the Guiding Question; Tool Talk

In the ADI instructional model each lab activity begins with the teacher identifying a phenomenon to investigate and offering a guiding question for the students to answer. The goal of the teacher at this stage of the model is to capture the students' interest and provide them with a reason to complete the investigation. To aid in this, teachers should provide each student with a copy of the Lab Handout. This handout includes a brief introduction that provides a puzzling phenomenon or a problem to solve and a guiding question to answer. This handout also includes information about the nature of the artifact they will need to produce (i.e., an argument on a large whiteboard, a piece of paper, presentation slides, or other medium), some helpful tips on how to get started, and criteria that will be used to judge argument quality (e.g., the sufficiency of the explanation and the quality of the evidence).

One engaging way to begin each lab includes selecting a different student to read each section of the handout out loud. After each section is read, the teacher should pause to clarify expectations, answer questions, and provide additional information as needed.

It is also important for the teacher to hold a "tool talk" during this stage, taking a few minutes to explain how to use specific lab equipment, how to use a computer simulation, or even how to use software to analyze data. Teachers need to hold a tool talk because students are often unfamiliar with lab equipment; even if they are familiar with the equipment, they will often use it incorrectly or in an unsafe manner. A tool talk can also be productive during this stage because students often find it difficult to design a method to collect the data needed to answer the guiding question (the task of stage 2) when they do not understand how to use the available materials. The teacher should also review specific safety protocols and precautions as part of the tool talk.

Once all the students understand the goal of the activity and how to use the available materials, the teacher should divide the students into small groups (we recommend three students per group) and move on to the second stage of the model.

Stage 2: Design a Method and Collect Data

In stage 2, small groups of students develop a method to gather the data they need to answer the guiding question and carry out that method. How students complete this stage depends on the nature of the investigation. Some investigations call for groups to answer the guiding question by designing a controlled experiment, whereas others require students to analyze an existing data set (e.g., a database or information sheets). If students need assistance in designing their method, teachers can have students complete an investigation proposal. These proposals guide students through the process of developing a method by encouraging them to think about what type of data they will need to collect, how to collect it, and how to analyze it. We have included three different investigation proposals in Appendix 3 (p. 415) of this book that students can use to design their investigations. Teachers can direct students to use Investigation Proposal A or Investigation Proposal B when they need to test alternative explanations or claims as part of their investigation and Investigation Proposal C when they need to collect systematic observations for a descriptive investigation.

The overall intent of this stage is to provide students with an opportunity to interact directly with the natural world (or, in some cases, with data drawn from the natural world) using appropriate tools and data collection techniques and to learn how to deal with the ambiguities of empirical work. This stage of the model also gives students a chance to learn why some approaches to data collection or analysis work better than others and how the method used during a scientific investigation is based on the nature of the question and the phenomenon under investigation. At the end of this stage, students should have collected all the data they need to answer the guiding question.

Stage 3: Data Analysis and Development of a Tentative Argument

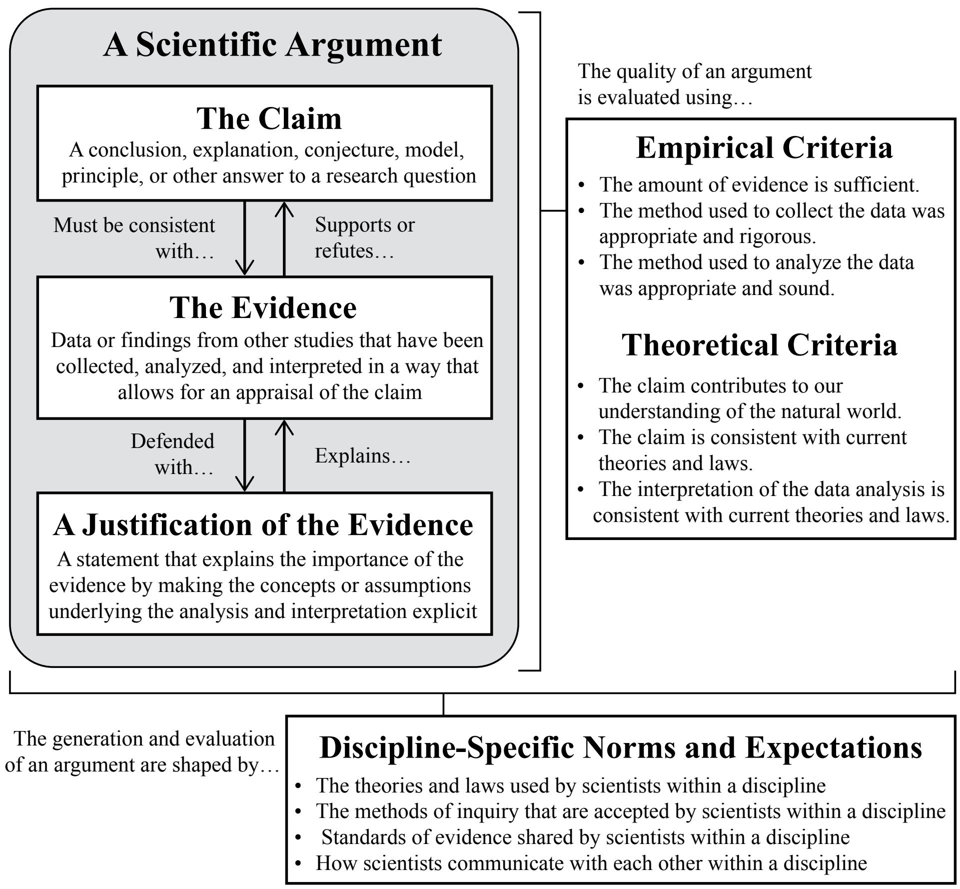
The next stage of the instructional model calls for students to develop a tentative argument in response to the guiding question. To do this, each group needs to be encouraged to first make sense of the measurements (e.g., temperature and mass) and/or observations (e.g., appearance and location) they collected during stage 2 of the model. Once the groups have analyzed and interpreted their data, they can create a tentative argument (the "initial argument" in the Lab Handout). The argument consists of a claim, the evidence they are using to support their claim, and a justification of their evidence. The *claim* is their answer to the guiding question. The *evidence* consists of the data (measurements or observations) they collected, an analysis of the data, and an interpretation of the analysis. The *justification of the evidence* is a statement that defends their choice of evidence by explaining why it is important and relevant and makes the concepts or assumptions underlying the analysis and interpretation explicit. The components of a scientific argument are illustrated in Figure 3 (p. 6).

To illustrate each of the three structural components of a scientific argument, consider the following example. This argument was made in response to the guiding question, "What type of metal are objects A, B, and C?"

> *Claim*: Objects A and B are tin. Object C is lead.
>
> *Evidence*: The density of object A is 7.44 g/cm^3, and the density of object B is 7.34 g/cm^3. These objects have almost the same density as the known density of tin, which is 7.36 g/cm^3. The density of object C is 11.12 g/cm^3. This object has almost the same density as the known density of lead, which is 11.34 g/cm^3.
>
> *Justification of the evidence*: Density is a physical property of matter and remains constant, regardless of the amount of the object present. Therefore, density can be used to identify the substance that makes up an unknown object. The difference in the calculated densities and the known densities is likely due to measurement error.

FIGURE 3

Framework for the components of a scientific argument and criteria for evaluating the merits of the argument



The claim in this argument provides an answer to the guiding question. The author then uses genuine evidence to support the claim by providing an analysis of the data collected (density of each substance) and an interpretation of the analysis (an inference based on known and unknown density values). Finally, the author provides a justification of the evidence in the argument by making explicit the underlying concept and assumptions (density as an inherent physical property and the likelihood that the difference between the calculated and known values is due to measurement error) guiding the analysis of the data and the interpretation of the analysis.

It is important for students to understand that, in science, some arguments are better than others. An important aspect of science and scientific argumentation involves the evaluation of the various components of the arguments put forward by others. Therefore, the framework provided in Figure 3 also highlights two types of criteria that students can and should use to evaluate an argument in science: empirical criteria and theoretical criteria. *Empirical criteria* include

- how well the claim fits with all available evidence,
- the sufficiency of the evidence,
- the quality of the evidence,
- the appropriateness of the method used to collect the data, and
- the appropriateness of the method used to analyze the data.

Theoretical criteria, on the other hand, refer to standards that are important in science but are not empirical in nature; examples of these criteria are

- the sufficiency of the claim (i.e., Does it include everything needed?);
- the usefulness of the claim (i.e., Does it allow us to engage in new inquiries or understand a phenomenon?);
- the consistency of the claim and the reasoning in terms of other accepted theories, laws, or models; and
- the manner in which the data analysis was conducted.

What counts as quality within these different components, however, varies from discipline to discipline (e.g., physics, chemistry, geology, biology) and within the specific fields of each discipline (e.g., astrophysics, biophysics, nuclear physics, optics, thermodynamics). This variation is due to differences in the types of phenomena investigated, what counts as an accepted mode of inquiry (e.g., descriptive studies, experimentation, computer modeling), and the theory-laden nature of scientific inquiry. It is important to keep in mind that what counts as a quality argument in science is discipline- and field-dependent.

To allow for the critique and refinement of the tentative argument during the next stage of ADI, each group of students should create their tentative argument in a medium that can easily be viewed by the other groups. We recommend using a 2' x 3' whiteboard or large piece of butcher paper. Students should lay out each component of the argument on the board or paper. Figure 4 shows the general layout for a presentation of an argument, and Figure 5 (p. 8) provides an example of argument crafted by students. Students can also create their tentative arguments using presentation software such as Microsoft's PowerPoint or Apple's

FIGURE 4

The components of an argument that should be included on a whiteboard (outline)

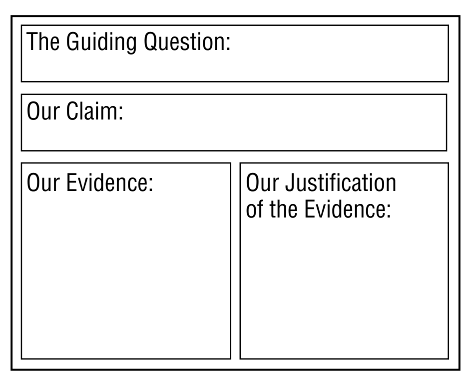
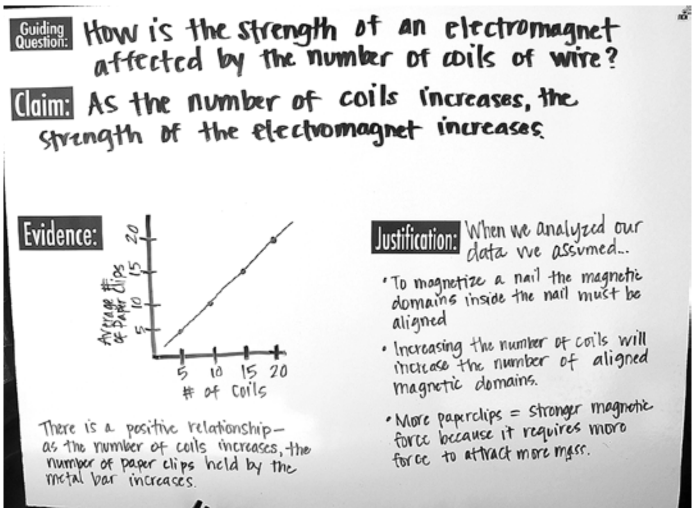


FIGURE 5

An example of a student-generated argument on a whiteboard



Keynote and devote one slide to each component of an argument. The choice of medium is not important, as long as students are able to easily modify the content of their argument as they work and it enables others to easily view their argument.

The intention of this stage of the model is to provide the student groups with an opportunity to make sense of what they are seeing or doing during the investigation. As students work together to create a tentative argument, they must talk with each other and determine how to analyze the data and how to best interpret the trends, differences, or relationships that they identify. They must also decide if the evidence (data that have been analyzed and interpreted) that they chose to include in their argument is relevant, sufficient, and convincing enough to support their claim. This process, in turn, enables the groups of students to evaluate competing ideas and weed out any claim that is inaccurate, does not fit with all the available data, or contains contradictions.

This stage of the model is challenging for students because they are rarely asked to make sense of a phenomenon based on raw data, so it is important for teachers to actively work to support their sense-making. In this stage, teachers should circulate from group to group to act as a resource person for the students, asking questions that urge them to think about what they are doing and why. To help students remember the goal of the activity, ask "What are you trying to figure out?"; to encourage them to think about whether or not the data are relevant, ask "Why is that information important?"; to help them remember to use rigorous criteria to evaluate the merits of a tentative idea, ask "Does that fit with all the data or what we know about a particular phenomenon?"

It is important to remember that at the beginning of the school year, students will struggle to develop arguments and will often rely on inappropriate criteria, such as plausibility (e.g., "That sounds good to me") or fit with personal experience (e.g., "But that is what I saw on TV once"), as they attempt to make sense of their data. However, with enough practice, *students will improve their skills.* This is an important principle underlying the ADI instructional model.

Stage 4: Argumentation Session

The fourth stage of ADI is the argumentation session. In this stage, each group is given an opportunity to share, evaluate, and revise their tentative arguments with the other groups (see Figure 6). This stage is included in the model for three reasons:

FIGURE 6

A student presents her group's argument to students from other groups during the argumentation session.

1. Scientific argumentation (i.e., arguing from evidence) is an important practice in science because critique and revision leads to better outcomes.
2. Research indicates that students learn more about the content and develop better critical-thinking skills when they are exposed to the alternative ideas, respond to the questions and challenges of other students, and evaluate the merits of competing ideas (Duschl et al. 2007; National Research Council 2012).
3. Students learn how to distinguish between ideas using rigorous scientific criteria and are able to develop scientific habits of mind (such as treating ideas with initial skepticism, insisting that the reasoning and assumptions be made explicit, and insisting that claims be supported by valid evidence) during the argumentation sessions.

This stage, as a result, provides the students with an opportunity to learn from and about scientific argumentation. It is important to note, however, that supporting and promoting productive interactions between students inside the classroom can be difficult because the practice of arguing from evidence is foreign to most students when they first begin participating in ADI. To aid these interactions, students are required to generate their arguments in a medium that can be seen by others. By looking at whiteboards, paper, or slides, students tend to focus their attention on evaluating evidence and the core ideas that were used to justify the evidence, rather than attacking the source of the ideas. As a result, this strategy often makes the discussion more productive and makes it easier for student to identify and weed out faulty ideas. It is also important for the students to view the argumentation session as an opportunity to learn. The teacher, therefore, should describe the argumentation session as an opportunity for students to collaborate with their peers and a chance to give each other feedback so that the quality of all the arguments can be

FIGURE 7

A modified gallery walk format is used during the argumentation session to allow multiple groups to share their arguments at the same time.

improved, rather than as an opportunity determine who is right or wrong.

To ensure that all students remain engaged during the argumentation session, we recommend that teachers use a modified "gallery walk" format, rather than a whole-class presentation format. In the modified gallery walk format, one or two members of the group stay at their workstation to share their groups' ideas, while the other group members go one at a time to different groups to listen to and critique the arguments developed by their classmates (see Figure 7). This type of format ensures that all ideas are heard and more students are actively involved in the process. We recommend that the students who are responsible for critiquing arguments visit at least three different groups during the argumentation session. We also recommend that the presenters keep a record of the critiques made by their classmates and any suggestions for improvement. The students who are responsible for critiquing the arguments should also be encouraged to keep a record of good ideas or potential ways to improve their own arguments as they travel from group to group.

Just as is the case in earlier stages of ADI, it is important for the classroom teacher to be involved in (without leading) the discussions during the argumentation session. Once again, the teacher should move from group to group to keep students on task and model good scientific argumentation. The teacher can ask the presenter(s) questions such as "How did you analyze the available data?" or "Were there any data that did not fit with your claim?" to encourage students to use empirical criteria to evaluate the quality of the arguments. The teacher can also ask the presenter(s) to explain how the claim they are presenting fits with the theories, laws, or models of science or why the evidence they used is important. In addition, the teacher can also ask the students who are listening to the presentation questions such as "Do you think their analysis is accurate?" or "Do you think their interpretation is sound?" or even "Do you think their claim fits with what we know about X?" These questions can serve to remind students to use empirical and theoretical criteria to evaluate an argument during the discussions. Overall, it is the goal of the teacher at this stage of the lesson to encourage students to think about how they know what they know and why some claims are more valid or acceptable in science. This stage of the model, however, is not the time to tell the students that they are right or wrong.

At the end of the argumentation session, it is important to give the students time to meet with their original group so they can discuss what they learned by interacting with individuals from the other groups and revise their tentative arguments. This process can begin with the presenter(s) sharing the critiques and the suggestions for improvement that they heard during the argumentation session. The students who visited the other groups during the argumentation can then share their ideas for making the arguments better, based on what they observed and discussed at other stations. Students often realize at this point in the process that the way they collected or analyzed data during stage 2 was flawed in some way. The teacher should therefore encourage students to collect new data or reanalyze the data they collected as needed. At the end of this stage, each group should have a final argument that is much better than their initial one.

Stage 5: Explicit and Reflective Discussion

The teacher should lead a whole-class explicit and reflective discussion during stage 5 of ADI. The intent of this discussion is to give students an opportunity to think about and share what they know and how they know it. This stage enables the classroom teacher to ensure that all students understand the core ideas at the heart of the investigation and to help students think about ways to improve their participation in scientific practices such as planning and carrying out investigations, analyzing and interpreting data, and arguing from evidence. At this point in the instructional model, the teacher should also discuss one or two relevant crosscutting concepts and one or two aspects of the nature of science or scientific inquiry.

It is important to stress that an explicit and reflective discussion is not a lecture; it is an opportunity for students to think about important ideas and practices and to share what they have learned or do not understand through teacher-to-student and student-to-student talk. The more students talk during this stage of the model, the more meaningful the experience will be for them.

Teachers should begin the explicit and reflective discussion by asking students to explain what they know about the core idea at the heart of the lab (the core idea can be found in the "Introduction" section of the Lab Handout). The teacher can then encourage the students to think about how this core idea helped them explain the phenomenon under investigation and how they can use this idea to provide a justification of the evidence in their arguments. The teacher can also encourage the students to explain what they learned about the phenomenon under investigation. The teacher should not tell the students what results they should have obtained or what information should be included in each argument. Instead, the teachers should focus on ensuring that everyone in the class understands the content by providing a context for students to share their ideas and explain their thinking. Remember, this stage of ADI is a *discussion,* not a lecture.

Students do not learn how to participate in the practices of planning and carrying investigations, analyzing and interpreting data, and arguing from evidence by following directions that are given to them on a handout or by answering analysis questions. This is one reason that cookbook laboratory activities do little to help students learn how to participate in scientific practices. In ADI, students are expected to design their own investigations, decide how to analyze and interpret data, and support their claims with evidence. It is important to keep in mind that these practices are complex and students cannot be expected to master them without giving students opportunities to try, fail, and then learn from their mistakes.

To encourage students to learn from their mistakes, students must have an opportunity to reflect on what went well and what went wrong during their investigation. Therefore, as part of the explicit and reflective discussion, the teacher should encourage the students to reflect how they designed their investigation, analyzed and interpreted data, and argued from evidence and what they could do to improve in the future. To accomplish this task, we recommend asking students the following questions:

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

Two additional questions are asked in the design challenge labs: “Did you meet the goal of the design challenge?” and “Did you ensure that your solution is consistent with the design parameters?” The teacher can use the students’ responses to all of these questions to highlight what does and does not count as quality or rigor in science and to offer advice about ways to improve. This feedback during the explicit and reflective discussion helps students gradually improve their abilities to participate in the practices of designing and carrying out investigations, analyzing and interpreting data, and arguing from evidence.

Next, the teacher should discuss one or two crosscutting concepts, using what the students did during the investigation to illustrate how these concepts can be used to explain natural phenomena. For example, a teacher might decide to talk about the relationship between structure and function or the importance of tracking the flow of energy or matter in a system. The teacher needs to highlight these ideas in an explicit manner and encourage students to reflect on them in a wide range of contexts before students will begin use them as a way to understand the world around them. Without this type of sustained focus, students will not learn the value of these crosscutting concepts as way to explain natural phenomena. They also need to discuss these important ideas over and over again before they will begin to use them in future investigations.

The teacher should end this stage of the ADI instructional model with an explicit discussion of one or two aspects of the nature and practices of science, building on the students' own investigations to illustrate these important concepts (NGSS Lead States 2013). Examples of what a teacher might include are

- the diversity of methods that scientists can use to collect data,
- what does and does not count as an experiment in science,
- how scientists must be open to changing their minds in the face of empirical evidence, and
- the role that creativity and imagination play during an investigation.

Teachers might compare and contrast observations and inferences, data and evidence, qualitative data and quantitative data, or theories and laws. This stage provides a golden opportunity for explicit instruction about the nature of scientific knowledge and how this knowledge develops over time, in a context that is meaningful to students. Current research suggests that students only develop an appropriate understanding of the nature and practices of science when teachers discuss these concepts in an *explicit* fashion (Abd-El-Khalick and Lederman 2000; Lederman and Lederman 2004; Schwartz, Lederman, and Crawford 2004).

Stage 6: Writing the Investigation Report

Stage 6 is included in the ADI model because writing is an important part of doing science. Scientists must be able to read and understand the writing of others, as well as evaluate its worth. They also must be able to share the results of their own research through writing. In addition, writing helps students learn how to articulate their thinking in a clear and concise manner, encourages metacognition, and improves student understanding of the content (Wallace, Hand, and Prain 2004). Finally, and perhaps most important, writing makes each students' thinking visible to the teacher (which facilitates assessment) and enables the teacher to provide students with the educative feedback they need to improve.

In stage 6, each student is required to write an individual investigation report using his or her group's argument. The report should be centered on three fundamental questions:

- What question were you trying to answer and why?
- What did you do to answer your question and why?
- What is your argument?

Teachers should encourage students to use tables or graphs to help organize their evidence and require them to reference this information in the body of the report. Stage 6 is important because it allows them to learn how to construct an explanation, argue from evidence, and communicate information. It also enables students to master the disciplinary-based writing skills outlined in the *Common Core State Standards* in English Language Arts (*CCSS ELA;* National Governors Association Center for Best Practices and

Council of Chief State School Officers 2010). The report can be written during class or can be assigned as homework.

The format of the report is designed to emphasize the persuasive nature of science writing and to help students learn how to communicate in multiple modes (words, figures, tables, and equations). The three-question format is well aligned with the components of a traditional laboratory report (i.e., introduction, procedure, results and discussion) but allows students to see the important role argument plays in science. We strongly recommend that teachers *limit the length of the investigation report* to two double-spaced pages or one single-spaced page. This limitation encourages students to write in a clear and concise manner, because there is little room for extraneous information. This limitation is less intimidating than a more lengthy report requirement, and it lessens the work required in the subsequent stages.

Stage 7: Double-Blind Group Peer Review

During stage 7, each student is required to submit to the teacher two to three typed copies of their investigation report. Students do not place their names on the report; instead they use an identification number to maintain anonymity—to ensure that reviews are based on the ideas presented and not the person presenting the ideas.

We recommend that students be placed into groups of three (these groups can be different from the groups that students worked in during stages 1–4). Each group then is given a set of reports (i.e., the two or three report copies submitted by a single student) and a peer-review guide (see Appendix 4, p. 419). They are then asked to review the set of reports as a team, using the peer-review guide (see Figure 8). The peer-review guide contains specific criteria that are to be used by the group as they cooperatively evaluate the quality of each section of an investigation report, as well as the mechanics of the writing. There is also space for the reviewers to provide the author with feedback about how to improve the report. Once a group finishes reviewing a report, they are given another set to review. Each group is responsible for reviewing three different sets of reports during this stage.

When students are grouped together in threes, they only need to review three sets of reports in a period. Be sure to give students only 15 minutes to review each set of reports (we recommend setting a timer to help manage time). When students are grouped into three and given 15 minutes to complete each review, the entire peer-review process can be completed in one 50-minute class period (3 sets of reports × 15 minutes = 45 minutes).

Reviewing each report as a group is an important component of the peer-review process because it provides students with a forum to discuss what counts as high quality or acceptable and, in so doing, forces them to reach a consensus during the process. This method also helps prevent students from checking off "good" for each criterion on the peer-review guide without thorough consideration of the merits of the paper. It is also important for students to provide constructive and specific feedback to the author when areas of the paper are found to not meet the standards established by the peer-review guide. The peer-review process provides students with an opportunity to read good and bad examples of the reports. This helps the students learn new ways to organize and present information, which in turn will help them write better on subsequent reports.

FIGURE 8

A group of students reviewing a report written by a classmate, using the peer-review guide

This stage of the model also gives students more opportunities to develop reading skills that are needed to be successful in science. Students must be able to determine the central ideas or conclusions of a text and determine the meaning of symbols, key terms, and other domain-specific words. In addition, students must be able to assess the reasoning and evidence that an author includes in a text to support his or her claim and, when they read a scientific text, compare or contrast findings presented in a text with those from other sources. Students can develop all these skills, as well as the other discipline-based reading standards found in the *CCSS ELA*, when they are required to read and critically review reports written by their classmates.

Stage 8: Revision and Submission of the Investigation Report

The final stage in the ADI instructional model is to revise the report based on the suggestions given during the peer review. If the report met all the criteria, the student may simply submit the paper to the teacher with the original peer-reviewed "rough draft" and peer-review sheet attached, ensuring that his or her name replaces the identification number. Students whose reports are found by the peer-review group to be acceptable can maintain the option to revise it if they so desire after reviewing the work of other students.

If the report was found unacceptable by the group during peer review, the author is required to rewrite his or her report using the reviewers' comments and suggestions as a guideline. Once the report is revised, it is turned in to the teacher for evaluation with the original rough draft and the peer-review sheet attached. The author is required to explain what he or she did to improve each section of the report in response to the reviewers' suggestions (or explain why he or she decided to ignore the reviewers' suggestions) in the author response section of the peer-review sheet. The teacher can then provide a score on the peer-review sheet "Instructor Score" column and use these ratings to assign an overall grade.

This approach provides students with a chance to improve their writing mechanics and develop their reasoning and understanding of the content. This process also offers students the added benefit of reducing academic pressure by providing support in obtaining the highest possible grade for their final product.

The Role of the Teacher During Argument-Driven Inquiry

If the ADI instructional model is to be successful and student learning is to be optimized, the role of the teacher during a lab activity designed using this model must be different than the teacher's role during a more traditional lab. The teacher *must* act as a resource for the students, rather than as a director, as students work through each stage of the activity; the teacher must encourage students to think about *what they are doing* and *why they made that decision* throughout the process. This encouragement should take the form of probing questions that teachers ask as they walk around the classroom, such as "Why do you want to set up your equipment that way?" or "What type of data will you need to collect to be able to answer that question?"

Teachers must restrain from telling or showing students how to "properly" conduct the investigation. However, teachers must emphasize the need to maintain high standards for a scientific investigation by requiring students to use rigorous standards for what counts as a good method or a strong argument in the context of science.

Finally, and perhaps most important for the success of an ADI activity, teachers must be willing to let students try and fail, and then help them learn from their mistakes. Teachers should not try to make the lab investigations included in this book "student-proof" by providing additional directions to ensure that students do everything right the first time. We have found that students often learn more from an ADI lab activity when they design a flawed method to collect data during stage 2 or analyze their results in an inappropriate manner during stage 3, because their classmates quickly point out these mistakes during the argumentation session (stage 4), and it leads to more teachable moments.

Because the teacher's role in an ADI lab is different from what typically happens in laboratories, we've provided a chart describing teacher behaviors that are consistent and inconsistent with each stage of the instructional model (see Table 2). This table is organized by stage, because what the students and the teacher need to accomplish during each stage is different. It might be helpful to keep this table handy as a guide when you are first attempting to implement the lab activities found in the book.

TABLE 2

Teacher behaviors during the stages of the ADI instructional model

Stage	What the teacher does that is …	
	Consistent with ADI model	**Inconsistent with ADI model**
1: Identification of the task and the guiding question; "tool talk"	• Sparks students' curiosity • "Creates a need" for students to design and carry out an investigation • Organizes students into collaborative groups • Supplies students with the materials they will need • Holds a "tool talk" to show students how to use equipment or to illustrate proper technique • Reviews relevant safety precautions and protocols • Provides students with hints	• Provides students with possible answers to the research question • Tells students that there is one correct answer • Provides a list of vocabulary terms or explicitly describes the content addressed in the lab
2: Designing a method and collecting data	• Encourages students to ask questions as they design their investigations • Asks groups questions about their method (e.g., "Why did you do it this way?") and the type of data they expect from that design • Reminds students of the importance of specificity when completing their investigation proposals	• Gives students a procedure to follow • Does not question students about the method they design or the type of data they expect to collect • Approves vague or incomplete investigation proposals
3: Data analysis and development of a tentative argument	• Reminds students of the research question and what counts as appropriate evidence in science • Requires students to generate an argument that provides and supports a claim with genuine evidence • Asks students what opposing ideas or rebuttals they might anticipate • Provides related theories and reference materials as tools	• Requires only one student to be prepared to discuss the argument • Moves to groups to check on progress without asking students questions about why they are doing what they are doing • Does not interact with students (uses the time to catch up on other responsibilities) • Tells students the right answer
4: Argumentation session	• Reminds students of appropriate behaviors in the learning community • Encourages students to ask questions of peers • Keeps the discussion focused on the elements of the argument • Encourages students to use appropriate criteria for determining what does and does not count	• Allows students to negatively respond to others • Asks questions about students' claims before other students can ask • Allows students to discuss ideas that are not supported by evidence • Allows students to use inappropriate criteria for determining what does and does not count
5: Explicit and reflective discussion	• Encourages students to discuss what they learned about the content and how they know what they know • Encourages students to discuss what they learned about the nature of science • Encourages students to think of ways to be more productive next time	• Provides a lecture on the content • Skips over the discussion about the nature of science and the nature of scientific inquiry to save time • Tells students "what they should have learned" or "this is what you all should have figured out"

Table 2 *(continued)*

Stage	What the teacher does that is …	
	Consistent with ADI model	**Inconsistent with ADI model**
6: Writing the investigation report	• Reminds students about the audience, topic, and purpose of the report • Provides the peer-review guide in advance • Provides an example of a good report and an example of a bad report	• Has students write only a portion of the report • Moves on to the next activity/topic without providing feedback
7: Double-blind peer group review	• Reminds students of appropriate behaviors for the review process • Ensures that all groups are giving a quality and fair peer review to the best of their ability • Encourages students to remember that while grammar and punctuation are important, the main goal is an acceptable scientific claim with supporting evidence and justification • Holds the reviewers accountable	• Allows students to make critical comments about the author (e.g., "This person is stupid") rather than their work (e.g., "This claim needs to be supported by evidence") • Allows students to just check off "Yes" on each item without providing a critical evaluation of the report
8: Revision and submission of the investigation report	• Requires students to edit their reports based on the reviewers' comments • Requires students to respond to the reviewers' ratings and comments • Has students complete the checkout questions after they have turned in their report	• Allow students to turn in a report without a completed peer-review guide • Allow students to turn in a report without revising it first

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