By now, nearly every science teacher in the United States has heard about the Next Generation Science Standards (NGSS) and the drive to practice scientific argumentation in their classrooms as they guide students to become scientifically literate citizens. In addition, argumentation is also included in the Common Core State Standards for reading and writing in science. Getting up to speed with the instructional tools advocated by these national documents is becoming a priority for many middle level science teachers.

But before we get into enhancing your toolkit with activities that teach argumentation, first ask yourself, “Besides the emphasis from the national standards, why would I want to have my students engage in scientific argumentation?” The answer may lie within a simple quiz. Read the seven statements below and place a check next to each statement that reflects a skill you believe your students should possess.

1. Formulate claims based on evidence
2. Construct a logical and coherent argument
3. Voice their privately held conceptions (and misconceptions)
4. Have evidence-based discussions
5. Debrief and reflect on another’s point of view
6. Analyze and understand arguments made in the media about science-related topics
7. Display proficient speaking and listening skills

Now add up the check marks. If you marked three or more, you probably have a sincere interest in having students engage in the practice of argumentation. This Toolkit column provides sample activities so you can construct lessons based on your prior understanding of argumentation and your students’ prior experiences in proposing, critiquing, refining, justifying, and defending their positions about a specific topic in science.

Given that, each reader will interpret and use the sample activities in different ways. For some teachers, the sample activities may become part of the 5E learning cycle within the stages of Engagement, Exploration, or Elaboration. For those familiar with the three dimensions or strands of the NGSS (Practices, Cross-cutting Concepts, and Core Ideas), the activities may serve to reinforce the Nature of Science statements from Appendix H in the NGSS document such as:

- Science knowledge is based upon logical and conceptual connections between evidence and explanations;
- Science explanations are subject to revision and improvement in light of new evidence; and
- Science findings are frequently revised or reinterpreted based on new evidence.

How you use these sample activities and others like them will certainly depend on which direction and level of integration you choose. Hopefully, all readers will see how easy it is to plan argument-based science lessons that reinforce the three strands of the NGSS.

According to the National Research Council, “the
study of science and engineering should produce a sense of the process of argument necessary for advancing and defending a new idea or an explanation of a phenomenon and the norms for conducting such arguments. In that spirit, students should argue for the explanations they construct, defend their interpretations of the associated data, and advocate for the designs they propose” (NRC 2012, p. 73). Although most of us would agree with the statement, fostering scientific argumentation is challenging because many students struggle with the task of proposing, supporting, refining, justifying, and defending a position. Therefore, teachers cannot expect such reasoning skills to develop without a strategic structure. Students need to be taught the skill of argumentation by scaffolding concrete experiences that provide evidence-based discussions and explanations (Llewellyn 2014). This article is the first of two Teacher’s Toolkit articles that will provide four levels of methods for teachers to build an understanding of argumentation for middle level students. The four levels include:

1. Making an inference from observations
2. Agreeing or disagreeing with a statement
3. Testing another person’s claim
4. Making your own claim from evidence

Because students are good at conventional arguing, but not good at framing a scientific argument, each level will highlight a graduating stage that scaffolds sensible, student-friendly steps toward using argument as specified in the national standards, understanding the nature of scientific investigations, developing science-reasoning skills, and better appreciating the work of practicing scientists and engineers. Note, however, that the activities suggested in this column are summaries and not intended to represent full-fledged and detailed “how-to” lessons. How teachers use or adopt the suggestions becomes very individual depending on the content of the lesson and students’ learning needs and capabilities. This first toolkit article introduces levels one and two.

**Level 1: Making an inference from observations**

At level 1, students are introduced to the notion of evidence and claims by first understanding the connection between observations and inferences. In the examples below, the inference is similar to a claim—a logical interpretation or conclusion based on prior knowledge, observational and reliable evidence, and reasoning. Just as student inferences are based on observations, claims are based on supporting evidence.

In activity 1 of level 1, students are presented with a “mystery box” or “black box” (Llewellyn 2014). To construct a mystery box, glue two wooden blocks (about 2.5 cm [1 in.] cubes) to the bottom of a cardboard shoe box. Next, place a small marble inside the box (Figure 1). Seal the box with duct or packing tape so the top lid is taped to the lower part of the shoe box and the box cannot be intentionally opened. Start the activity by telling a student that the box contains two blocks glued somewhere to the bottom of the box and a marble that can roll inside the box. Using the senses of hearing and touch, have the student pick up the mystery box, shake it, and roll the marble inside the box to determine the location of the two wooden blocks. Then have the student draw an illustrated model that shows the location of the blocks inside the shoe box. Finally, using the evidence collected through their senses, the student will explain the model and justify the location of the blocks to other students in the class (either in small groups or in front of the whole class) based on the sounds the marble makes when knocking against the blocks.

You can prepare different mystery boxes with varying block locations to demonstrate the integration of the crosscutting concept that models can be used to represent systems and their interaction, as well as an introduction to the performance expectation that students will develop and use a model to describe the
Activity 2, “Inference Tube,” may mystify students. The Inference Tube is made using a 50 to 56 cm (20 to 22 in.) cardboard cylinder (the kind found with holiday wrapping paper), two 76 cm (30 in.) lengths of thin rope, and a small rubber ring that will fit inside the tube. You can buy a puppy chew toy from a pet store for $1 that works well. PVC piping can also be used in constructing a more durable tube. Place a hole at the top and bottom of both ends of the tube. Now, using the 76 cm (30-in.) length of thin rope, feed the rope through the top hole at one end and then through a rubber ring, and then through the bottom hole of the tube. Repeat the procedure for the other end, being sure the second rope also goes through the rubber ring. Tie a knot at both ends of the two ropes so the rope does not slide out the holes (Figure 3).

Next, have someone hold up the tube with their hands over the ends so others can’t see what’s inside the tube. The teacher then pulls one end of the rope gently while the class watches what happens to the other end. Next, pull the rope of the opposite side of the tube and again have the class observe what happens to the end of the rope. Do this several times, alternately pulling different ends. From these observations, direct students to draw an illustration or model (inference/claim) that shows what’s going on inside the tube. Have students share their models and provide the observations or evidence to support their model.

Activity 3, “Track Stories” (NRC 1998), is one you may already be familiar with. In this activity, students...
are presented with three frames of animal tracks (see Resources). In this activity, students make inferences from observations and state a concluding story based on their observations and inferences. Start by showing the frames, one at a time, so students can make observations and draw inferences about the tracks. Take about three to five minutes at each frame. At this point, it is important to emphasize the difference between observations and inferences and insist that an observation (evidence) precedes a stated inference (claim). After discussing all three frames, several students can tell (1) a story about how the tracks were made, (2) what animals made them, and (3) how the animals may have interacted. However, a thoughtful student may contend that the tracks were made at different times and there was no animal interaction. This activity also shows how students can form diverse "stories" (claims) based on observing the same set of prints (evidence). Track Stories is an excellent way to demonstrate the integration of NGSS practice 4 (analyze and interpret data to provide evidence for phenomena) and as an introduction to using observations and inferences to understand the stories from fossils.

After a summarizing discussion, the level 1 activities will lead students to transferring their knowledge about observations and inferences to understanding the connection between evidence and claims, making them ready for level 2 (agreeing or disagreeing with a statement).

Level 2: Agreeing or disagreeing with a statement

At level 2, students respond to a given statement provided by the teacher and give a rationale and evidence for either agreeing or disagreeing with the statement.

Activity 1 of level 2 is called "4 Corners." After the teacher reads a controversial statement in science, students will go to one of four corners in the classroom based on whether they strongly agree, agree, disagree, or strongly disagree with the statement. In their subgroups, students propose reasons for their stance, discuss their reasons within the small group, and then report on their stance to the whole class. Examples of statements may include:

- All magnets are made of iron.
- Solar power is better than fossil fuels.
- Light is a particle vs. light as a wave.
- The giraffe got its long neck from stretching to reach leaves on tall trees.
- The table you are working on is mostly empty space.
- A meteorite hitting the Earth caused the extinction of dinosaurs.
- Global warming is caused solely by human pollution.
- Hydrofracking should be banned.

For this activity, subgroups may need additional time to research the topic either online or in the school library to prepare a persuasive response. In addition, for some classes the teacher may provide verbal prompts (or starter sentences) for students to use in framing their arguments. Prompts include:

- "The statement claims that ______. I agree with the statement because _____" 
- "The statement contends that ______; however, I disagree with the statement because _____"
- "On one hand I agree with the statement about ______, because _____; on the other hand, I disagree with it because ______."

Activity 2 for level 2 is called "Settle an Argument." In this activity, the class is given a case study about a dispute two individuals are having over a science concept. The students' task is to design an investigation to prove which individual is correct. The first example, "The Density of Wood," demonstrates the integration of NGSS practice 7 ("compare and critique two arguments on the same topic and analyze whether they emphasize similar or different evidence or interpretations of the facts" and "construct, use, and/or present an oral and written argument supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem"), crosscutting concept 3 (Scale, Proportion, and Quantity) and serves an introduction to a unit on density or disciplinary core idea PS1.A: Structure and Properties on Matter (each pure substance has characteristic physical and chemical properties that can be used to identify it).

Mike and Melinda are having a dispute. Mike has a block of balsa wood from his model airplane supplies and has calculated its density at 160 kilo-
grams/cubic meter (10 pounds/cubic foot). Mike contends that if he cuts the block of wood in half, the density of the half block will be half of the full size block. Melinda, on the other hand, contends that regardless of the size of the block of wood, the density remains the same. Design an investigation to resolve who is correct, Mike or Melinda. Plan your investigation by writing out the steps of the procedure you will follow and design a data table to organize your results. Use the data you collect to make a claim as to which one is correct. Provide evidence to support your decision. Summarize your investigation with an explanation comparing the density of the half block to the full-size block of wood. Using the Question-Claim-Evidence-Explanation (QCEE) sheet for notes (Figure 4), make a three-to-five minute oral presentation to defend your findings. Include in your presentation (1) the question investigated, (2) the claim made based on the findings, (3) the evidence to support the claim, and (4) a summarizing explanation.

The second example, “Seed Germination”, shows the integration of NGSS practice 7 (“compare and critique two arguments on the same topic and analyze whether they emphasize similar or different evidence or interpretations of the facts” and “construct, use, and/or present an oral and written argument supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem”), crosscutting concept 6 (Structure and Function), as well as an introduction to a unit on the life cycle of a plant or disciplinary core idea LS2.A (organisms, and populations of organisms, are dependent on their environmental interactions both with other living things and with non-living factors).

Gina and George are having a dispute. Gina has a bag of bean seeds and contends that in order for the beans to germinate, the seeds need light. George, on the other hand, contends that the seeds do not need light to germinate. Design an investigation to resolve who is correct, Gina or George. Plan your investigation by writing out the steps of the procedure you will follow and design a data table to organize your results. Use the data you collect to make a claim as to which student is correct. Provide evidence to support your decision. Summarize your investigation with an explanation comparing the germination of a bean seed with and without light.

As with the first example, students will make a three-to-five minute oral presentation to defend their findings, including (1) the question investigated, (2) the claim made based on the findings, (3) the evidence to support the claim, and (4) a summarizing explanation. The presentation for both examples can be assessed using the QCEE rubric (Figure 5).

As a closure to these activities, return to the list of skills and attributes you checked in the beginning of the article and reflect on how each activity leads to having students experience increased ease in citing evidence and claims as part of a scientific argument. Your next step is to design similar level 1 and 2 activities that correlate with the content that is being studied—knowing full well that such activities are better presented in conjunction with a unit of study than as isolated, stand-alone events. With continued opportunities throughout the school year to engage with argument-based activities, students will
<table>
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<tr>
<th>Score</th>
<th>Question</th>
<th>Claim</th>
<th>Evidence</th>
<th>Explanation</th>
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<tbody>
<tr>
<td>3</td>
<td>The student states an investigable question that is clear and focused. The question invites a statement to be tested and leads the student to one or more possible solutions.</td>
<td>Based on the data collected, the student draws a clear and detailed conclusion to the inquiry. The claim is a statement derived from an analysis of the data and includes patterns and relationships among the variables of the investigation.</td>
<td>The evidence is derived from data that either support or refute the claim. The evidence is empirically-based information, free from opinion or personal interpretation.</td>
<td>The explanation is clear and concise. It shows cause and effect and links the supportive evidence directly to the claim. The explanation also connects the student's prior knowledge with the new knowledge gained from the investigation.</td>
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<tr>
<td>2</td>
<td>The student states a question that is somewhat clear but needs to be revised before guiding the investigation and leading the student to a possible solution.</td>
<td>Based on the data collected, the student draws a reasonable conclusion to the inquiry. The claim is a statement derived from an analysis of the data but does not include patterns or relationships among the variables of the investigation.</td>
<td>The evidence is derived from data that either support or refute the claim. The evidence is somewhat empirically based but includes evidence that is circumstantial in nature.</td>
<td>The explanation is clear and generally to the point. It links the evidence to the claim. The explanation relates the student's prior knowledge with the new knowledge gained from the investigation.</td>
</tr>
<tr>
<td>1</td>
<td>The student states a question that does not lead to an inquiry investigation. The question is unclear and unfocused. The student cannot completely identify the purpose or direction of the question.</td>
<td>Because the data collected are questionable, the student does not draw a conclusion to the inquiry, draws an inaccurate claim, or fails to state a claim. The claim is not derived from an analysis of the data and does not include patterns or relationships among the variables of the investigation.</td>
<td>The evidence is loosely derived from data and does not either support or refute the claim. The evidence is unclear, opinion-based, or circumstantial in nature.</td>
<td>The explanation is unclear and rambling. It does not link the evidence to the claim. The explanation does not connect the student's prior knowledge to the knowledge gained from the investigation.</td>
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surely develop the kinds of attributes and proficiencies that model argument-based practices from the NGSS.

In the next issue, level 3, “Testing another person’s claim” and level 4, “Making a claim from evidence collected during an inquiry-based investigation,” will be presented to enrich your instructional toolkit.

References

Resources

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