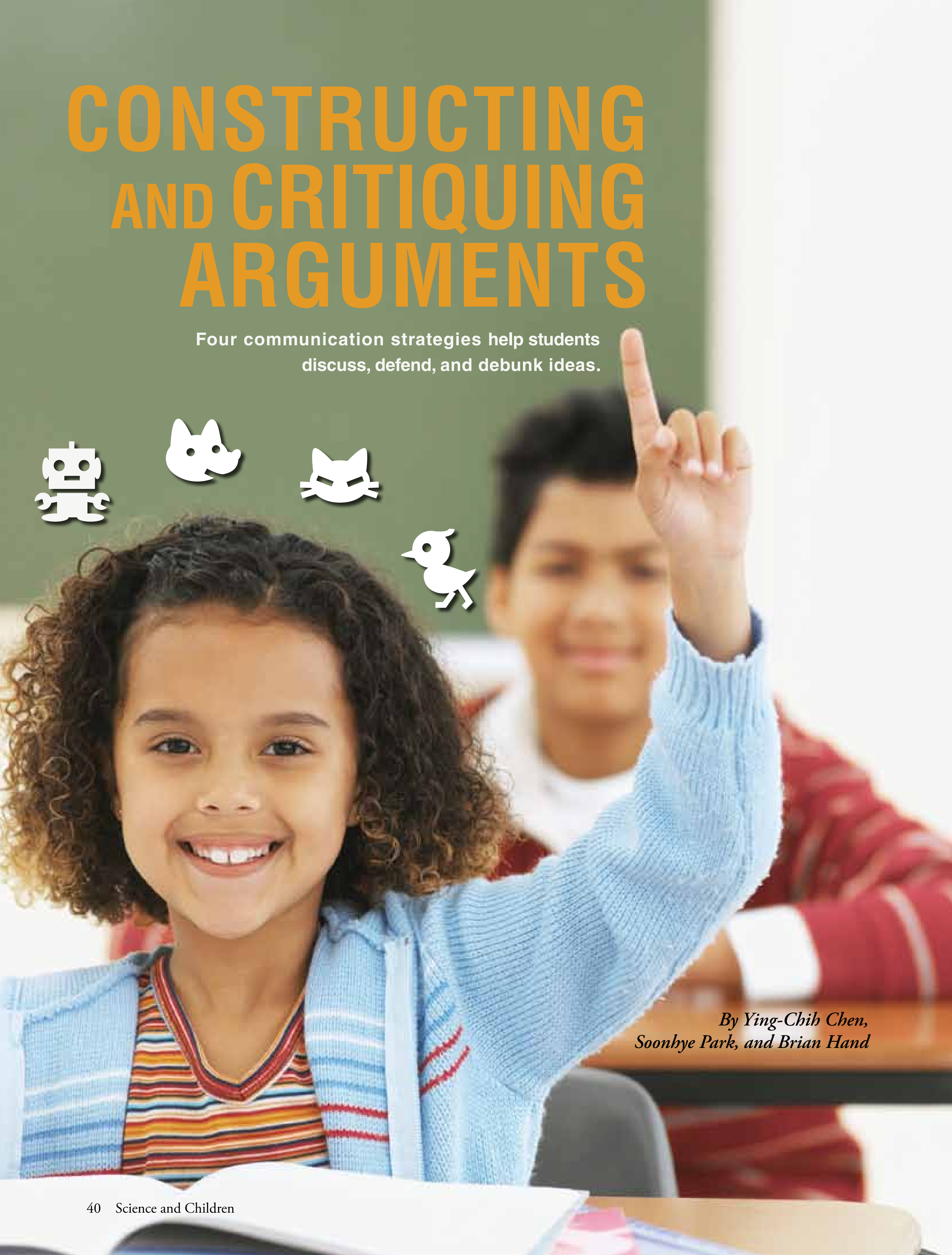
CONSTRUCTING AND CRITIQUING ARGUMENTS

Four communication strategies help students discuss, defend, and debunk ideas.



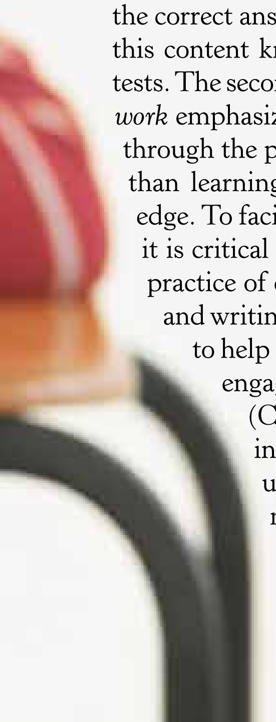
By Ying-Chih Chen, Soonhye Park, and Brian Hand

As the need for students to be able to construct and critique scientific argumentation is emphasized in *A Framework for K–12 Science Education* (NRC 2012), have you wondered how to support students in this process? Scientific argumentation is defined as the interplay between construction and critique involving both individual cognitive activities and a negotiated social act through talk and writing within a specific community (Cavagnetto 2010; Ford 2012). *A Framework for K–12 Science Education* (NRC 2012) identifies three dimensions for K–12 science and engineering classrooms: scientific and engineering practices, crosscutting concepts, and disciplinary core ideas. At the center of the first dimension is the idea that "critique is an essential element both for building new knowledge in general and for the learning of science in particular" (NRC 2012, p. 44).

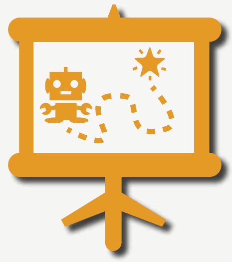
How can we as teachers engage students in written and oral scientific argumentation? In this article, we introduce four powerful strategies for teaching the practice of scientific argumentation: (1) Visualize ideas using a concept map; (2) Whole-class engagement in a negotiation circle; (3) Time to pause and reflect; and (4) Writing a letter to a younger audience. These four strategies emphasize speaking and writing to facilitate students' engagement in argumentation. These strategies can be used with grades 1 to 6 based on the activity.

The Science Classroom: A New View

Critique plays a significant role in shifting the construction of scientific knowledge from an individual, private level to a public level. However, students are rarely provided the opportunities and time needed to critique and construct ideas about scientific phenomena based on evidence (Krajcik and Merritt 2012). Instead, they are often given the final scientific content that scientists have developed over time. As a result, students focus on reciting the correct answers of scientific content and reproducing this content knowledge by rote in their homework and tests. The second and third dimensions of the new *Framework* emphasize learning a limited number of core ideas through the practice of construction and critique rather than learning disconnected and dense factual knowledge. To facilitate student understanding of core ideas, it is critical to embed language-based activities in the practice of construction and critique. Thus, speaking and writing become absolutely crucial language tools to help students as well as scientists and engineers engage in critiquing knowledge construction (Chen, Park, and Hand 2012). The following four strategies encourage students to use oral and written communication to promote knowledge construction and critique through scientific argumentation.



Visualize Ideas Using a Concept Map

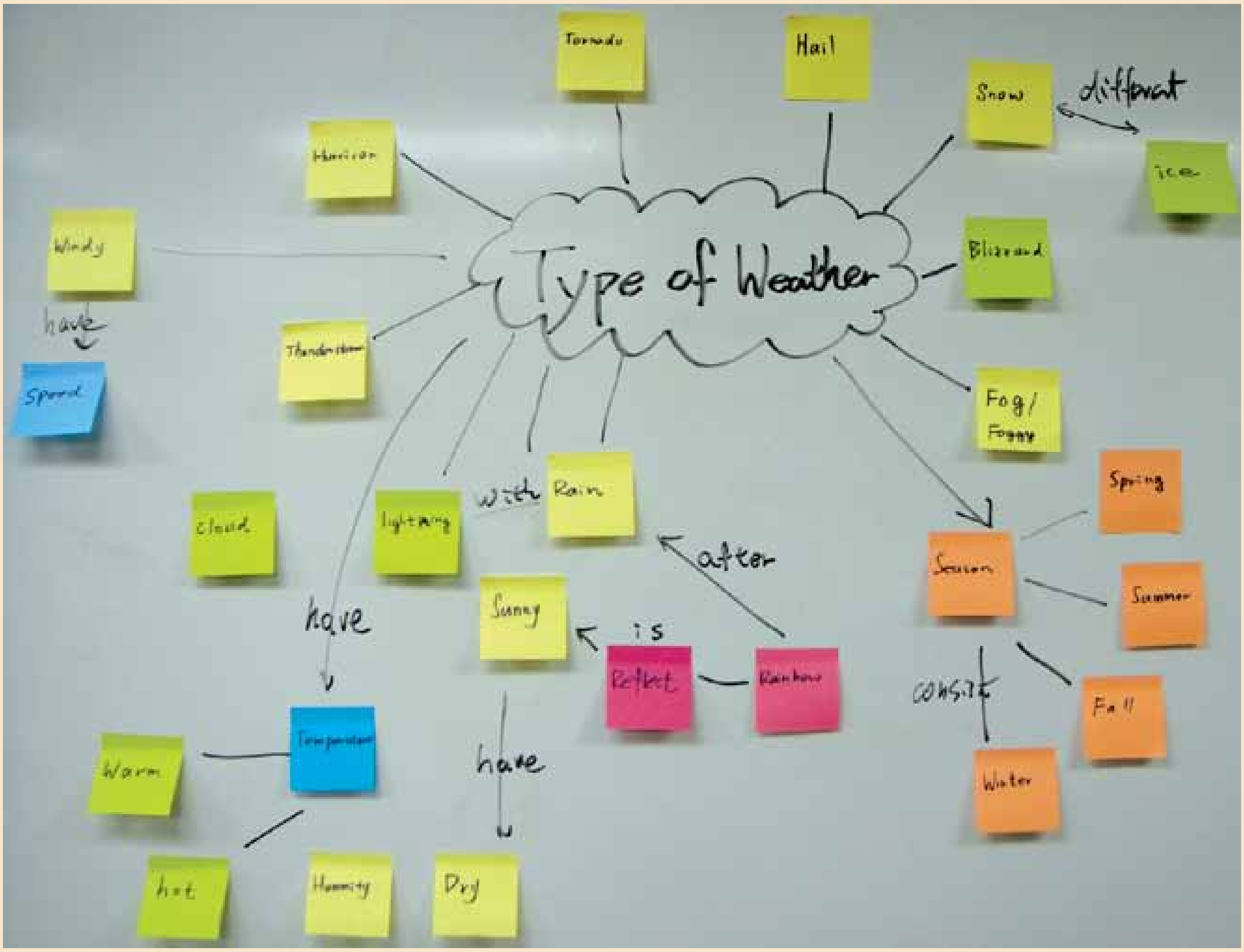


A concept map is a negotiation tool for both construction and critique. A classroom concept map can be used at the beginning of a unit to see what students already know. The teacher asks students to write down everything they know on sticky notes (one concept per sticky note) in relation to the core idea and use arrows and linking verbs to connect all the sticky notes. The arrows usually consist of a verb or a preposition, such as *contains*, *includes*, *can be*, *lives in*, *occurs in*, *have*, *like*, *which has*, *are*, *from*, *produces*, *causes*, and so on. Here is an example of observations from Mr. Smith's third-grade science classroom. In a class discussion within a unit on weather, students were working on a concept map with the core concept of "types of weather." A student suggested rainbow as a type of weather, several hands were raised up, and negotiation began as to where rainbow should be located on the concept map. One student claimed, "A rainbow is a reflection of the Sun. Put it with sunny." Mr. Smith made a note about the word "reflection" for himself so he could revisit this scientific term another time when appropriate. Another student claimed that rainbow must go with rain because it comes after it rains. A third student asked, "Aren't rainbow Sun and rain mixed together?" Mr. Smith asked challenge questions to students: "How are Sun and rain the same?" "Where do we see a rainbow?" Mr. Smith then guided the class to come up with questions that they would like to investigate based on the concept map. For example, students came up with the questions: *How does weather change from day to day and from season to season? What causes different kinds of weather? How does a rainbow form?* As a result of concept mapping, the classroom's concepts naturally evolved into a list of scientifically oriented questions about weather. Figure 1 (p. 42) features an example of using a concept map in the unit of weather.

To enable students to see that the development of a concept map is a constantly changing dynamic process, Mr. Smith can use sticky notes as the means to record the subconcepts and factual knowledge elements. This would allow students to move these around easily, remove them if they need to as their ideas emerge and grow, or use different-color notes to show their ideas building across time. Mr. Smith's role is to continually negotiate with students about what is being added and where new ideas are being placed on the map. This is not a situation of the teacher telling the students what to put on the map but a place where they can continually challenge the students about their ideas.

Figure 1.

A concept map used in the weather unit.



Whole-Class Discussion by a Negotiation Circle

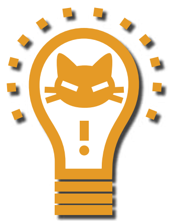
This strategy can be used when students are not familiar with how to negotiate their ideas with other students and is especially useful for students who have been exposed mainly to lecture-based learning environments. Students often initially hesitate to talk out their ideas and share conflicting opinions. A teacher can ask students to sit in a large circle and use a volleyball to determine the speaker. A student who takes the volleyball must talk out his or her ideas. The students toss the volleyball back and forth among themselves. The teacher informs the students of the following rules:

- If a student is holding the ball, he or she should share his or her ideas. The teacher will write down the ideas and then the student will pass the volleyball to another classmate.
- If someone disagrees with another classmate's ideas, he or she can nicely say his or her thoughts and provide evidence as support.
- Students can use their journals to help support or critique others' claims and note questions they want to ask.

If discussion does not have the desired depth and continuity, the teacher can take the ball and provide appropriate facilitation. After that, another round of discussion can proceed by students throwing a ball. "The ball is speaker" rule can be also loosened as time goes on to promote a more natural student-to-student dialogue. When students become familiar with negotiation, their debate can become very hot. For example, Noah in Mr. Jones's fifth-grade science classroom shared his claim "an object with less mass goes farther than an object with more mass." Initially, most students nodded in agreement, but as they discussed the claim, different ideas and challenges were made. Kate asked, "Which one could you throw farther, a balloon filled with air or a balloon filled with water?" Noah answered "A water balloon." Then, Mary raised a question, "But you said lighter objects should go farther with the same force, so shouldn't the air balloon go farther?" At that point, Mr. Jones jumped in and guided the discussion by asking probing questions such as "What is the relationship between force and weight?" and "Do we need to consider other variables?" During the discussion, Mr. Jones encouraged students to use various representations including drawings, tables, and diagrams to support their ideas.

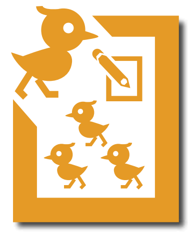
This example demonstrates how the ownership of learning can shift from teacher to students. Mr. Jones could have simply introduced the core concept of how force affects mass ($F=ma$) to students through readings or PowerPoint slides. However, by engaging students in the process of knowledge construction and critique, he enabled the students to develop responsibility for their own learning and build meaningful understanding. The negotiation circle can be used for all elementary grade levels K–6 to promote students' oral argumentation.

Pause and Reflect



This is a writing strategy that can be used during a whole classroom discussion for all elementary grade levels. Classroom debates are sometimes dominated by talkative students so that only a few students are involved in the discussion. This strategy, "pause and reflect," is a useful tool to use to enable all students to contribute to the class discussion. This strategy is to pause students' verbal argument during a classroom discussion or debate and give them time for reflection by writing their ideas in their science journals. This is a great opportunity for individual students to express their own voices. Teachers could use this strategy when discussion does not go well, saying, for example, "Our conversation doesn't seem to be moving forward. I want you to write your ideas on the question, 'From what do you think humans get their energy? Why do you think so?' Write down your ideas and find evidence to support it. We'll talk about it tomorrow." Teachers can also use this strategy when debates become too hot. By being engaged in writing, students can reflect on others' ideas as well as their own. Writing then becomes a tool for communicating and negotiating their ideas. The following day, students' discussion will be more focused with more elaborated explanations and justifications related to their ideas. Figure 2 is a template to help students' writing about what they think in relation to other students' ideas.

Writing a Letter to a Younger Audience



This writing activity can be used in the end of a unit to help students reflect on and explain what they learned over the unit to a younger audience. This activity is appropriate for grades 4–6. It is important to note that changing the audience changes the way students write their explanation (Gunel, Hand, and McDermott 2009). For example, they should use simpler vocabulary to explain difficult scientific concepts, include detailed explanations about the big idea and claims, and reorganize the concept in an easy way for their younger audience. Teachers can share the following guidelines with students:

- Support claims with evidence from experience or class investigations. Be sure to include a thorough explanation in evidence-based scientific writing.
- Use different ways to show evidence: diagrams, charts, tables, and so on.
- Be sure to use appropriate language that is understandable for the recipient of the letter.

Figure 2.

Reflection template for comparing claims and evidence.

Question: Where does our energy come from?	
My claim is (A statement that relates to the question that you believe to be true): Our energy comes from food.	**Other students' claim is** Our energy comes from the Sun
My evidence is (I believe because): I think that because the Sun does not give directly to us. It gives it to the food we eat which has energy inside it. We do need sunlight to live but that does not necessarily mean that it gives us energy.	**Their evidence is** If you took the Sun out of the process, plants would then die. Take plants out of the pictures then cows, horses, pigs, and just all animals would die because no plants to eat and then we would die because no animals to eat.
Do I want to change my claim? (Yes or No) Yes	
The reason I (don't) want to change my claim: Our energy comes from the Sun, but not directly. I think what we're both saying is that it has to go through a process to get to the food and to get to our bodies. We do not directly get energy from the Sun, but we need it. I think we indirectly get energy from the Sun. It is a process.	

Figure 3 is a student work written by Neil, a sixth grader in Mrs. Johnson's class, who explained the concepts of air resistance to a fourth grader by using examples of a parachute, a leaf, and a quarter. Neil used simple vocabularies and multimodel representation to describe a relatively difficult concept to a younger audience. However, teachers should carefully select the science concepts about which students will write letters to younger students because some difficult scientific concepts might not be appropriate for younger audiences given their level of cognitive development and progress through the science curriculum.

We can also use students' letters for the purpose of summative assessment and as an opportunity to provide students feedback at the end of a unit. A scoring rubric for student writing is provided in Figure 4. This rubric includes five components that are critical for crafting high-quality writing. Using the rubric guides students toward understanding what a good claim and good evidence consist of, and how to make a good connection between a claim and evidence by using multimodel representations and audience-appropriate language. Teachers can tailor the rubric as needed to fit a specific unit or a situation.

Conclusion

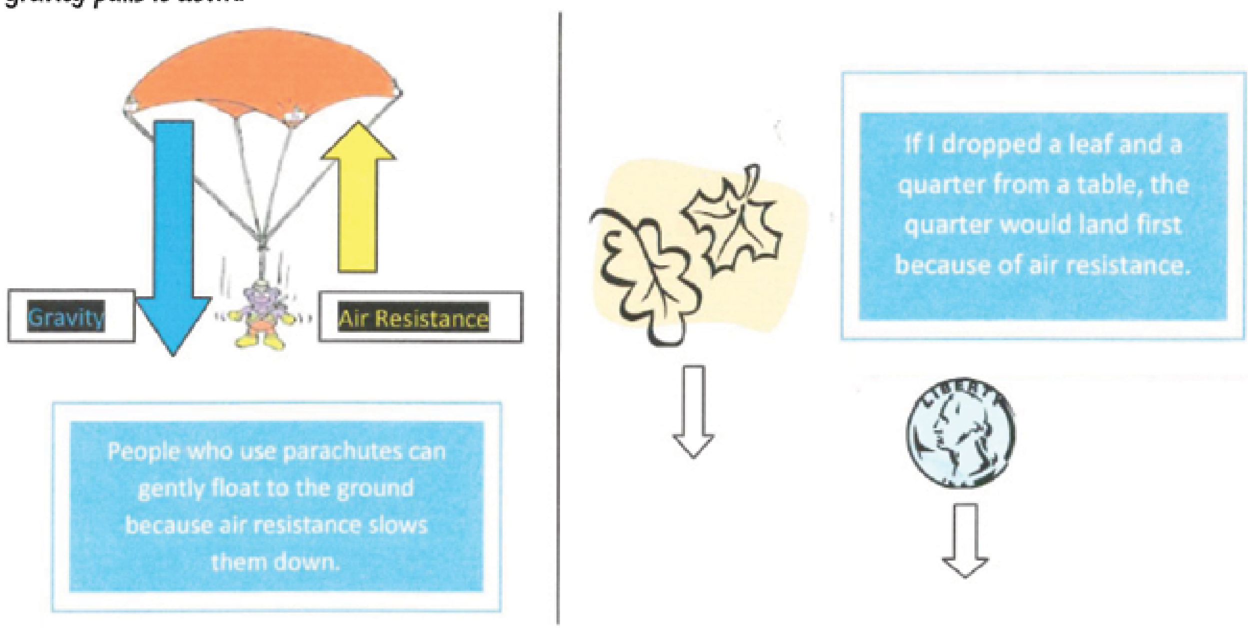
A Framework for K–12 Science Education emphasizes that "constructing and critiquing arguments are both a core process of science" (NRC 2012, p. 73). "Communicating in written or spoken form is…[a] fundamental practice of science" (p. 74) and can be used to help students become successful critics for knowledge construction. Rather than viewing the use of talk and writing just as representational tools, we provide four strategies to use spoken and written communication as learning tools for critiquing and constructing knowledge. We hope these strategies serve as practical tools for teachers when incorporating the *Framework's* (and forthcoming Next Generation Science Standards') emphasis on speech and writing into their lessons. ■

Figure 3.

A sixth grader's writing sample.

Dear 4th Grader,

Have you ever wondered why snowflakes fall so slowly to the ground and why rain falls so fast? It's because of air resistance. Air resistance is when air causes an object to fall slowly to the ground by pushing it up while gravity pulls it down.



If you look above at the diagram of the parachute, the blue arrow is gravity. It is longer than the yellow arrow because when a person uses a parachute, they float down. The yellow arrow is air resistance and it is smaller than gravity because when a person uses a parachute, they float gently instead of crashing straight down. So, the blue arrow is longer because it has a stronger force on the person. If you look above at the picture of a falling leaf and a falling quarter, you can see that the quarter is falling faster. The four main details that control air resistance are size, shape, speed, and density. Density is basically the thickness of an object. Since the quarter is smaller than the leaf, it has a different shape, and is thicker; it will have less air resistance. When an object has less air resistance, it will fall faster.

Figure 4.
Scoring rubric for a letter to a younger audience.

Component	Score		
	1	2	3
Accuracy of claim	Makes a scientifically incorrect claim	Makes a scientifically correct claim and partially catches the essence of the investigation	Makes an scientifically correct claim and completely catches the essence of the investigation
Sufficiency of evidence	Provides one piece of evidence	Provides two pieces of evidence	Provides more than two pieces of evidence and makes a rebuttal
Quality of evidence	Makes an inappropriate and inadequate explanation or reports data as evidence	Makes an appropriate and adequate explanation partially based on interpretation of investigation data	Makes an appropriate and adequate explanation completely based on interpretation of investigation data
The relationship between claim and evidence	Makes a weak connection between claim and evidence	Makes a strong connection between claim and evidence	Makes a strong and sophisticated connection between claim and evidence
Multimodel representation	Only uses one mode (text) to explain the concept(s) in writing	Uses more than one mode (text) in explaining the concept(s) but does so separately from text	Uses more than one mode (text) in explaining the concept(s) and it is tied to the text
Audience language	Does not consider the audience's language	Although clearly aware of an audience, the writer only occasionally speaks directly to that audience	Language is appropriate, easy to understand, and meets the demands of the audience
Total Score			

Ying-Chih Chen (chen2719@umn.edu) *is a research associate at the University of Minnesota in Minneapolis, Minnesota. Soonhye Park* (soonhye-park@uiowa.edu) *is associate professor at the University of Iowa in* Iowa City, Iowa. *Brian Hand* (brian-hand@uiowa.edu) *is a professor at the University of Iowa.*

References
Cavagnetto, A.R. 2010. Argument to foster scientific literacy: A review of argument interventions in K–12 science contexts. *Review of Educational Research* 80 (3): 336–371.

Chen, Y.-C., S. Park, and B. Hand. 2012. Unpacking the use of talk and writing in argument-based inquiry: Instruction and cognition. In *The future of learning: Proceedings of the 10th international conference of the learning sciences (ICLS 2012) – Volume 1, Full Papers*, eds. J. van Aalst, K. Thompson, M.J. Jacobson and P. Reimann, pp. 159–166. Sydney, Australia: ISLS.

Ford, M.J. 2012. A Dialogic account of sense-making in scientific argumentation and reasoning. *Cognition and Instruction* 30 (3): 207–245.

Gunel, M., B. Hand, and M.A. McDermott. 2009. Writing for different audiences: Effects on high-school students' conceptual understanding of biology. *Learning and Instruction* 19 (4): 354–367.

Connecting to the Standards
This article relates to the following National Science Education Standards (NRC 1996):

Teaching Standards
Standard A:
- Teachers of science plan an inquiry-based science program for their students.

Standard B:
- Teachers of science guide and facilitate learning.

Standard C:
- Teachers of science engage in ongoing assessment of their teaching and of student learning.

National Research Council (NRC). 1996. *National science education standards*. Washington, DC: National Academies Press.

Krajcik, J., and J. Merritt. 2012. Engaging students in scientific practices: What does constructing and revising models look like in the science classroom? *Science and Children* 49 (7): 10–13.

National Research Council (NRC). 2012. *A framework for K–12 science education: Practices, crosscutting concepts, and core ideas*. Washington, DC: National Academies Press.