The New Science Literacy

Using Language Skills to Help Students Learn Science

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Activities That Merge Language and Science

Science is not a list of facts and principles to learn by rote. It is a way of looking at the world and asking questions.

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The idea that teachers can actively use the skills of literacy and science to support, strengthen, and enhance each other immediately raises questions among teachers. One of the first is “What exactly would this look like in my classroom?”

The answer, of course, will be different in elementary classrooms than in those of upper grades. As part of their kit of professional tools, elementary teachers are skilled in combining various categories of content with literacy activities. As a result, elementary classrooms usually are rich in language—talking, questioning, storytelling, listening, writing, debating, and, of course, reading for a variety of purposes—as teachers use weather, insects, and other aspects of the physical world to introduce science to children through the lens of language.

But there also is a danger in those opportunities. Elementary teachers often have little background in science; many are uncomfortable teaching science or even intimidated by their limited knowledge of the subject. In those classrooms, science content can too easily be lost in an emphasis on language. “For the most part, the elementary school classroom is a humanities culture,” according to education professor Mae Carson Reinhardt (2000, 2). “It is a culture that science specialists sometimes find difficult to enter.”
“On the other hand,” she points out, if teachers can capitalize on their “strengths in language arts and find new ways to integrate science throughout the curriculum, there might be greater success in bringing more science to elementary school classrooms and in developing comfortable, competent teachers of science” (2). In other words, fusing language and science enables those teachers to broaden their use of effective teaching strategies from other content areas to their science teaching as well. The teachers can use elements with which they already are comfortable to gain the confidence to address a broader range of science content.

In middle and high school, where tradition and sharp organizational lines segregate disciplines, the problem typically is the opposite. Science teachers, particularly in high school, usually have a deeper knowledge of particular scientific disciplines than elementary teachers do. But they often are less aware of the natural relationship between science and language.

In addition, teachers in the upper grades usually assume that students, by the time they begin their middle school years, need no additional strengthening in the use of language and that students have acquired adequate literacy skills to communicate science ideas effectively. However, as many educators know from hard experience, too often that is not the case—but not necessarily for the reason that most teachers think.

When adolescents have difficulty reading in science or other subjects, teachers often assume that the struggling students are unable to decode the words on the page. That often can be true for disadvantaged students. But research shows that typically students “are far less likely to have problems with decoding than with comprehension. These students typically have not [done] much [science content] reading. . . . As a result, they have very little stamina or persistence” (Schoenbach et al. 1999). Students can read the words but cannot as easily extract and link their meanings.

For science teachers facing the problem, this research implies good news. It means that by infusing their science teaching with some readily available tools of literacy, science teachers in upper grades can help these students on the spot. These students need not be remanded to special education or remedial reading classes. (In fact, such dramatic action can be counterproductive, doing additional damage to students’ motivation.) Instead, with some easy-to-use literacy techniques, teachers can help these students use science to learn to employ language more effectively while using language to learn science better.

In that way, teachers at every grade level can use science to strengthen students’ mastery of language skills. At the same time, they can employ the techniques of literacy to strengthen students’ skills and abilities in science. To do so, teachers can use various literacy performance expectations (detailed
in Chapters 3 through 7) to help them assess students’ growth in the use of language to capture and master scientific concepts and skills. The expectations also enable students to understand what direction that growth should take and what is expected of them.

In this chapter, we will offer a few glimpses of how the two disciplines already are being blended in science lessons to improve students’ achievement in both areas.

Guided Inquiry in Science Education

The quest to link science and literacy always depends on the creativity and awareness of individual teachers. But teachers are supported in that quest by the approach to science teaching, now gaining a foothold in U.S. schools, known as “guided inquiry” (H. Thier and Daviss 2001). The skills of science and of literacy join naturally in science experiences for students that are structured using the principles of guided inquiry.

After explaining what guided inquiry is, we will explore four inquiry-based activities developed by the Science Education for Public Understanding Program, based at the Lawrence Hall of Science at the University of California at Berkeley. The examples, drawn from a range of grade levels, fuse the skills of science and of literacy in the service of each other.

In science education, guided inquiry can be defined as using a series of structured, sequenced scientific investigations that integrate appropriate processes and information (or of activities and rigorous academic content, to use education’s preferred terms), chosen through research, to fashion meaningful learning experiences for students. Those experiences are effective when they

- engage students at an emotional level by confronting them with issues or problems that have meaning in students’ own lives. Placing scientific ideas and processes in the context of actual issues—balancing the risks and benefits of genetically engineered food, for example—can suddenly give abstract concepts a personal meaning to students, a key element in helping them master knowledge;
- capitalize on students’ engagement to lead them to use the concepts, techniques, and information of science to reason their way through a scientific or technological issue and to make an informed personal decision about the issue that is justified by the data or evidence; and
- help students master increasingly sophisticated scientific principles, concepts, methods, and information in ways that will enable them to retain that content beyond a final test.

A feature that distinguishes guided inquiry from conventional hands-on science learning is that, after students complete an assigned activity, they are
encouraged to design their own projects and investigations to continue exploring the topic. Through these self-chosen activities (guided and supervised by a teacher), students pursue their own questions about the subject. The additional work helps students link key ideas, rethink their own theories about the topic, and perhaps even satisfy their remaining curiosity about it.

The principles of guided inquiry are based on two ideas, proven by research.

First, students learn better when they experience something by doing it instead of reading about it in a textbook or hearing about it in a lecture. Students retain only 5 percent to 10 percent of what they read in textbooks but can recall as much as 80 percent of the details of something they have experienced (National Training Laboratories n.d.).

This principle expresses the essence of constructivism: When students work like scientists, they use language to organize, recognize, and internalize the concepts, principles, and information that they encounter through activities. Language becomes a scaffold on which students construct their understandings. By providing literacy opportunities for students in science, educators enrich the context for both subjects so students can more effectively expand their personal structures of science knowledge by improving their language skills.

Second, more than two decades of constructivist research show that mastery—the level of learning that our society and economy increasingly demand from each student—is best achieved through engagement (Thier and Daviss 2001). Studies have shown that true learning takes place only when students engage with information and processes deeply enough to weave that content into their personal views and understandings of how the world works (Harlen 2000).

Indeed, teaching and learning based on guided inquiry are squarely at the center of the National Science Education Standards, which call for:

**Less emphasis on:**
- knowing scientific facts and information
- studying subject matter disciplines for their own sake
- separating science knowledge and science processes

**More emphasis on:**
- understanding scientific concepts and developing abilities of inquiry
- learning subject matter disciplines in the context of inquiry; of technology and science; of personal and social perspectives; and of the history and nature of science
- integrating all aspects of science content
implementing inquiry as a set of processes implementing inquiry as instructional strategies, abilities, and ideas to be learned

(National Research Council 1996)

Clearly, the concept of guided inquiry gives equal weight to knowledge and skills, slighting neither science facts nor science processes. But it also emphasizes concepts more than rote formulas and emphasizes learning science in a personal and social context instead of as discrete sets of compartmentalized abstractions. To take students beyond the mathematical and formulaic aspects of science, teachers must rely on students’ language skills. By embedding an inquiry within both the context of students’ lives and strong science content, then sequencing investigations as part of a larger curricular design, educators can reach their curricular and instructional goals for science and for literacy at the same time.

Guided inquiry also provides teachers with an additional way to enlist literacy skills: the kind of embedded, authentic assessment becoming increasingly common in guided inquiry lends itself with relative ease to assessing language skills at the same time. Students read for basic and background information; they read and follow instructions on data sheets. They write reports and narrative procedures, make oral presentations, and engage in classroom discussions and debates. Each activity gives teachers ready opportunities to assess individual students’ strengths and weaknesses in the range of language skills against a set of specific performance expectations.

As our definition of guided inquiry implies, we do not suggest that the sole, or even main, reason to merge literacy and science is to enable students to do a better job of reading conventional textbooks. If teachers unite language and science skills in classroom activities, students will read textbooks more effectively, but that is not the goal. The goal of fusing literacy and science is to strengthen students’ abilities to combine science and literacy in processing evidence to reach, then express and communicate, personal knowledge, understanding, and decisions about the world around them. Fusing literacy with science through guided inquiry gives students the tools of language, and therefore of thought, to represent their understandings of the activity itself as well as the scientific concepts, information, and processes that they have learned through the activity. Articulating their experiences and conclusions clarifies their thinking. As Emmitt and Pollock put it, “Language is a pane of glass through which we can view our thinking” (1991).

It is important to remember that guided inquiry has a place in literacy skills as well. For example, when helping students learn to help themselves, teachers often find it useful to teach students to ask explicit questions about
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a work before they read it. From the title, what would you expect the work to be about? Why does the author make this particular statement or claim? What will happen next? As students become aware of their own expectations and responses to a work, they can use their ongoing questions and answers to focus their reading and make it meaningful to them. Huber and Walker (1996) found this technique distinctly effective in helping students increase their comprehension.

**Guided Inquiry, Literacy, and Special-Needs Students**

Children are born with a drive to make sense of the world. As Wells puts it, they are “active seekers of meaning. . . . It does not take young children long to learn that language is the medium that human beings use to construct and reconstruct meaning” (1986). But he also points out that “the emphasis has been on language learning but not learning through language. However, in practice, the two are, to a very considerable degree, co-extensive. . . . Just as children learn the language system through experience [and by] using it as a resource, so in increasing their control of the resources of language they also increase their understanding of the experience” (Wells and Nicholls 1985).

Much of a child’s early learning occurs through linguistic interactions with parents and others. Students with special needs or from deprived backgrounds often have not had those necessary experiences. For those students, experiences in school can capitalize on the child's curiosity to expand the child's universe. One of the most effective ways to do that is through the exploratory talk that accompanies collaborative activities in guided inquiry. In that way, children figure out for themselves how language conveys meaning and how to use language to construct their personal understandings of the world. The responsibility of the teacher is to be a facilitator of language: the teacher arranges and maintains optimum conditions within which students enhance their language skills. Inquiry-based science provides an environment for learning both science and language.

As Harlen puts it, “The ideas that we form from direct experience have to be communicated and this involves trying to find words that convey our meaning to others. In this process, our own ideas often have to be reformulated in ways that are influenced by the meaning that others give to words. . . . an important element of learning is ‘negotiated meaning’” (2000). Through guided inquiry’s vehicle of exploratory speech, students exercise their innate drive to create and negotiate meaning. For students who have had little opportunity to do so, the process can be transforming.

That aspect of guided inquiry in science provides two additional benefits to students who face special challenges in learning, such as students with
learning disabilities or minority students from inner-city areas, who often have difficulty using language to find meaning in abstract ideas. First, guided inquiry can make science content relevant to these students’ own lives and, therefore, accessible to them. Second, it shows these students that language empowers them to find and unlock the meanings within ideas for themselves. In sharing knowledge (a key element in guided inquiry), a student must develop and articulate ideas and understandings more fully in order to express them, an important step in enhancing students’ higher-order thinking skills.

The National Science Education Standards prescribes “the inclusion of all students in challenging science learning opportunities” and the “inclusion of those who traditionally have not received encouragement and opportunity to pursue science . . . students of color, students with disabilities, [and] students with limited English proficiency. . . . But all should have opportunities in the form of multiple experiences over several years” to master the principles and processes of science (National Research Council 1996).

The approaches that form the basis of guided inquiry are ideally suited to help all students achieve that goal.

**Elementary Examples: Mirrors, My Sweet Tooth, and the Mystery Spill**

As noted, elementary teachers tend more easily to integrate language learning with other subject areas. Because one teacher teaches all subjects, the teacher can use considerable imagination and discretion in using one subject area to highlight another.

In one simple instance, teacher David Keystone tells of his approach to using mirrors as the basis for melding science and literacy activities (Scott 1992). First, he asked children to talk about, then list, different things that can be done with mirrors. By writing and then comparing and contrasting lists, students grasp that language is the framework within which thoughts and knowledge are structured so that they can be retained and also communicated to others.

Then each child was given a pair of mirrors and some free time to experiment with them to discover their various uses. As they described their discoveries to classmates, the students gained practice in using language as the vehicle by which ideas are shared. Each student also kept a daily diary to answer a series of questions such as “What did I do?” and “What did I learn?” Keeping the diaries helped students understand that language can be the repository of facts, observations, ideas, and reflections—that language is the chief vehicle through which they express the scientific content they are learning. Expressing an idea through language helped the students give the idea a distinct identity
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and “shape,” enabling them to integrate it into their personal understandings of the world.

Throughout the activity, the students listed questions that occurred to them: “How do you make a rainbow with a mirror?” and “Why are things backwards in mirrors?” Keystone asked his students to group their questions and reflections under three headings: “what I want to know or do,” “how I will find out,” and “what I will need.” The lists strengthened students’ sense that language can be used to differentiate between what they know and what they want to know and also to plan and predict.

Teachers can enhance these natural connections between science and literacy in elementary classrooms by applying the principles of guided inquiry. One such activity is My Sweet Tooth (SEPUP 1997), which helps students gather evidence and make decisions about the taste, nutritional value, and health implications of sugar and its substitutes.

Students begin the activity by brainstorming ideas about sweeteners in their diets. They might note that sugar is a source of energy and it makes sour foods taste better. One student might say, “Sugar makes you fat and gives you cavities, so our family uses artificial sweeteners”; another might respond, “Yuck! That stuff’s made out of chemicals.” The conversation helps students begin to define the properties of, and differences among, sweeteners.

Next, the activity leads students through three stages. In each, students use language in slightly different forms to gather information, evaluate it, and make evidence-based decisions. In the first stage, students note physical details; in the second, they record personal impressions; in the third, they read to fill gaps in their knowledge.

Working in small groups, students look closely at small samples of sugar and two artificial sweeteners. Students note the details of the materials’ physical appearance, first by looking at them unaided and then by looking at the sweeteners through magnifiers. In discussions with their group members, students compare and contrast the magnified and unmagnified appearances of the various substances. Then the students make solutions of each of the three sweeteners, taste each one, and discuss and record their personal preferences along with the reasons behind their choices. (Note: Students with PKU, a genetic condition that makes them sensitive to aspartame, should not taste substances containing this artificial sweetener. Check with the school nurse to see if any students in your classroom suffer from PKU and also caution the class accordingly. In science, students usually are cautioned not to taste anything. In this or any other activity, students are allowed to taste only when instructed by the teacher.) The teacher asks students to choose which sweetener they would use at home and to explain to each other their reasons. The discussions help students use spoken language to explore and organize their knowledge and
thoughts about sweeteners and to articulate them based on different kinds of evidence. Just as important, they use language to identify information they *do not* have but would need in order to make a better-informed choice.

At this point—when students are motivated to find out more—the teacher asks whether the students would like additional information before finalizing their decisions and, if so, what kinds of information they would like. Students are likely to know which sweetener tastes best to them, but perhaps the discussion has raised concerns, for example, “I like this one best, but is it good for me?” The teacher then distributes a page of background information about different sweeteners for students to read, asks them if their choices have changed, and then offers to help students conduct additional library or Internet research on sweeteners. Working through each stage, students come to learn that decisions can change as the evidence captured in language grows and changes.

To extend the activity’s use of language, students can present their choices to classmates and explain their decisions. The presentations often initiate a discussion of the benefits and drawbacks of different kinds of sweeteners and why different people prefer different ones.

Throughout the activity, students are using many of the reciprocal processes that literacy and science share. Looking at the sweeteners, they *note physical details* and then *compare and contrast* the substances’ appearances. They gain experience in understanding language operationally—experiencing a concept before learning its abstract name and definition, thereby being able to viscerally associate a term with a concrete meaning. They *infer*, from scientific studies using animals, how artificial sweeteners might affect humans. They *draw evidence-based conclusions* about which sweeteners they personally would or would not use. Through their observations and discussions, they use language to sort through evidence and to *distinguish facts from opinion*. As they read, write, discuss and debate, listen critically to other students, and work through a rudimentary scientific investigation, they also begin to understand that evidence can be a powerful factor in understanding the world.

*My Sweet Tooth* links science and language through the discussions as well as through students’ answers to questions on the data sheets as they use evidence gained from reading and observation to explain and justify their decisions.

In addition, the activity’s links between science and language can be broadened and strengthened through additional, student-designed investigations. For example, students could conduct a classroom-wide taste test between a regular cola and its low-calorie alternative, then graph the number of students who preferred the taste of each (or found no difference between them). Students also could write reports about the origins, benefits and
drawbacks, and health implications of corn syrup, honey, cane sugar, and other sweeteners.

My Sweet Tooth also provides an effective way to sharpen students’ response to media. The class can collect advertisements touting products that are “sugar-free,” contain “no calories,” or are made with “all-natural sugar.” Students can dissect and compare the products’ advertising strategies and even can write their own jingles or raps selling their preferred sweeteners.

Another guided inquiry for elementary students is called The Mystery Spill (SEPUP 1997). It deepens and extends the connection between classroom science experiences and social issues. The investigation introduces fifth and sixth graders to aspects of chemistry through a very real safety issue: the transport of hazardous wastes. The activity incorporates elements of a mystery, a game, and social action, all built on the twin cornerstones of science and literacy.

Before class begins or while students are out of the room, the teacher dumps some baking soda on a table or on the classroom floor. (To add a suggestion of realism, the teacher might overturn a toy truck beside the spilled material.) When students enter, the teacher announces that there has been a chemical spill in the classroom and that the students must determine what the spilled substance is and whether it is dangerous. The teacher discusses the meaning of the word *simulation* with students and explains that the material spilled here is not dangerous and that in a real emergency, anyone approaching a potentially hazardous material would wear safety goggles, gloves, and other protective gear. (Even so, beware of making the simulation too realistic. One teacher we know surrounded her spill in the school science lab with yellow “caution” tape. A colleague passing by in the hall saw the tape and the spill and notified the school office that there had been a chemical spill. The principal announced the spill over the school’s public address system and told everyone to stay far away from the science lab.)

The students then discuss various ways to determine how the mystery substance might be tested. Does it burn? How does it react to water? They use language skills to *compare and contrast* different approaches, to *make inferences*, and to *predict* how different substances will react under different circumstances.

Each work group of four students is then given a small amount of six different substances that simulate hazardous materials. The first is labeled “corrosive,” the second “flammable,” the third “irritant,” the fourth “oxidizer,” the fifth “poison,” and the sixth “radioactive.” (In reality, the substances are citric acid, flour, detergent, baking soda, table salt, and sugar, respectively.) The students first *note the details* of each material’s physical appearance and record their observations in a data table. Next, they test each material with
moistened pH paper and note the color of the paper after the reaction. Finally, they add twenty drops of vinegar to each substance and observe the details of the reactions. The students describe all results in their data tables.

The teacher explains that the mystery substance is among one of the six kinds of materials the students have tested and that the students must now determine which category it belongs to. Each work group tests a small amount of the spilled powder with pH paper and then with vinegar. They compare and contrast the results with those listed in their data tables for the previous six materials tested, then make inferences and draw conclusions about the mystery spill’s identity. The activity not only helps students understand that language is the repository of information but also shows them the importance of sequencing events within a process. Understanding the correct sequence of events is a necessary step in gathering information required to move from observation to inference and then to an ability to draw conclusions.

Another aspect of the activity can help students link words with precise meanings. The teacher hangs a poster showing the colors and wording of eight diamond-shaped placards. Each placard represented shows the word for the kind of material inside—“radioactive” or “infectious substance,” for example—and the distinctive logo that represents that category of hazard. The poster launches a discussion of the practical meaning of scientific terms such as flammable and oxidizer.

The teacher then distributes worksheets divided into eight squares, with each square containing the design of a placard warning of a specific hazard. The students color the designs and cut them out. On the same sheet there are eight additional squares that the students cut out. Each square contains the definition of a term listed on the placards. The students then play a matching game, linking the definition printed on a square with the appropriate colored square representing the hazardous material.

The Mystery Spill activity can lead students to create their own investigations that also join the skills of science and literacy while helping students understand the meaning of the activity in their own lives. For example, perhaps trucks with diamond-shaped placards pass the school. Students might decide that there are just too many trucks carrying hazardous materials past the school. Some students might think that the trucks should be banned from traveling through town. Other students may have parents who work at a factory that uses those hazardous materials and fear that their mothers or fathers will lose their jobs if such a ban is implemented. The resulting debate could lead to additional research: What is the likelihood that there will be a spill? How many people would be affected? What could the damage be?

The students then can use language skills to present the scientific evidence they have collected to support their opinions. Some might write letters to the
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editor of the local paper presenting evidence to predict the odds of an eventual spill; others may write newspaper editorials comparing and contrasting the odds of a spill with the possible economic consequences for the town of banning the trucks. They might arrange a mock debate before a “city council” of their peers or parents and undertake a science project to design spill-proof containers for hazardous materials.

Throughout the activity, students constantly employ the processes of literacy to sharpen and illuminate their understanding of scientific facts, concepts, and processes. At the same time, they use their newly gained scientific knowledge to shape their use of language in articulating evidence-based choices and decisions and making their cases to others.

When students can relate activities to issues in their own lives and communities, they develop a visceral understanding of the interdependent roles of science and language in developing and using evidence to reach decisions about societal issues.

A Middle School Example: The Fruitvale Story

This investigation (SEPUP 2002) is centered around a practical problem that puts the student in the central role of investigator and decision maker. Students are asked to imagine that they are college students coming home to the town of Fruitvale for summer vacation. While there, they become embroiled in a local investigation of polluted water. (We now describe the activity in the second person, both for simplicity’s sake and so that readers may more easily put themselves in the student’s place.)

When you arrive home, hot and thirsty from the long bus ride, you go to the kitchen sink for a drink of cold water. Your mother tells you not to drink the water—that, for the last few months, water in the creek behind the house has had a funny smell. The family members now only drink bottled water because they fear that their well might be contaminated.

You begin to investigate. Your family and the one next door are the only families in the area still drawing water from their own wells; everyone else uses city water. The neighbors still drink from their own well, but they mention that their dog has been sick and wonder if he might have drunk bad water from the creek. You also learn that water wells drilled beneath a new housing development nearby, next to a farm, have been found to be contaminated with pesticide.

You begin to keep a journal. In it, you record the facts you find, your questions and conjectures, and your conclusions, inferences, and predictions about the meaning of the evidence you compile. You also make a map of the area to place important sites in relation to one another. You note additional
The pieces of evidence you must gather to determine the source of the water’s funny smell. You write down a sequenced series of steps you could take to collect that evidence. You conclude which three sites around Fruitvale are the most likely sources of the pollution and explain in your journal the reasons and evidence that led you to predict those sources.

Next, you talk with workers at the city water department. You learn that the pesticide has been found at five times its maximum safe level in one well on the housing development. The pesticide manufacturer, whose factory is also adjacent to the farm, originally had thought that the chemical would safely decompose in every kind of soil. That was not the case and the compound was banned in the United States eight years ago. City officials fear that old residues of the pesticide may be leaching into Fruitvale’s main water wells.

The city has enough money in the budget to drill twelve test wells to map the spread of the pesticide beneath Fruitvale’s soil. Impressed with your methodical investigation, the city water department manager asks you to help select the combination of test sites that will yield the most accurate and complete information.

Now students go to work in the classroom. In the first activity, students examine the concepts of porosity and permeability to understand the properties of an aquifer and an aquitard.

The teacher asks students to predict how long water will take to move through various earth materials, such as soil, clay, sand, and gravel. Students are asked to rank the materials according to the speed with which the students think water will pass through them. After students record their predictions, the teacher pours 30 to 35 ml of water through each material in turn. Students record the amount of water poured in, measure the time the water takes to move through each material and drain into a container underneath, and also measure the quantities of water that exit the material. (The teacher points out that the results from one material may lead students to alter their predictions for others.) Students record the results in their journals.

The activity engages students directly in scientific processes: it asks students to begin with a hypothesis, take quantitative measurements, tabulate data, and compare the results with their predictions, just as conventional science experiments do. The activity also enlists the reciprocal skills of science and literacy as they note details (the exact amount of time water takes to move through a material), compare and contrast the transmission times of the various materials, and use evidence to separate fact from opinion about how long the water will take to move—and, of course, to write these details clearly and concisely in their journals.

As the inquiry unfolds, the journal becomes a crucial tool in linking literacy and science. It serves as a record not only of the evidence they gather,
but also of their questions and speculations about what the evidence means and how individual facts relate to one another. The journal enables a student to erect a personal scaffold of language on which to assemble data, observations, and other evidence. It also provides a repository for speculations, reflections, and questions awaiting additional data for answers. The journal becomes a reflective space in which students use language to knit together their scientific data and evidence, their ideas, and their inferences and conclusions. It is in their journals where students are constantly asking themselves, “What new insights do I have that I didn’t have before? What do these new insights mean for Fruitvale’s water quality? What don’t I know and how will I find out?”

A journal becomes both a tool for, and a record of, each student’s personal growth in scientific understanding and skill. Therefore, it also can serve as an assessment tool. By comparing a student’s writing in a journal against a list of performance expectations for journal writing, the teacher can gauge the student’s growth in science and in written language. To keep students focused as they write, teachers can give them the same list of performance expectations, which students often paste inside the front covers of their journals for reference. (The next five chapters provide teachers with detailed literacy performance expectations that they can use in science activities to help students improve language skills over time. The chapters also show how these expectations can be applied as assessment tools if teachers choose to do so.)

Next, to understand the degree of risk lurking in Fruitvale’s tainted water, students need to grasp the concepts of “parts per million” and “parts per billion.” Working in groups, students use cups and eyedroppers to create progressively weaker solutions of colored water. Students must carefully observe and record the presence, absence, and strength of color in each cup. As they do, they develop skills in observing and collecting quantitative data. They then use language to interpret their observations and to explore, clarify, and express their thinking about the presence of the pollutant in the solution. As they record their data in their journals, they note details, sequence events, and make inferences and draw conclusions about why groups’ results differ, leading to a discussion about human error, variability in the test samples, and so on.

As students use those skills of science, they also are strengthening the reciprocal skills of literacy as they use written language to note details, record the sequence of events, compare and contrast possible explanations and courses of action as they grapple to link cause and effect, and reflect on what they are learning. As students work in groups to gather and analyze data, plan, and interpret results, they also practice the same literacy skills verbally and aurally that their journals strengthen through writing.
After reading the details of the story, students are ready to test Fruitvale’s water. They are presented with a map of forty possible well sites around the town and are asked to use information from the story, and clues from previous activities recorded in their journals, to decide where to drill twelve test wells. In other words, they must use the scientific concepts and skills they have gained through the activities in conjunction with fundamental literacy skills: they must note details from the story, compare and contrast various drilling schemes, and make inferences and draw conclusions about which plan will yield the most useful information. Formulating a plan and describing it in detail in their journals also give students experience in weighing alternatives and making trade-offs, key skills in science and in making satisfying choices in one’s personal life.

Again working in groups of three or four, students then “test the wells”: they draw water from sample bottles that have been formulated with different concentrations of pH buffers, then add one or two drops of a universal indicator. Students assign each well a numerical rank of 0 through 5, depending on the parts per billion of pesticide each contains as judged by the color of each water sample after the reaction. After testing a group of three wells and tabulating the data in their journals, students review and perhaps revise their drilling plans, then test another three wells. As they review and revise, the students note details of their results and use them to compare and contrast possible alternatives, then to make predictions about which sites would be most informative to drill next.

When all test results are in, each group of students maps the area of Fruitvale that seems to have groundwater unsafe for humans to ingest (defined as test wells with a contamination of 1 or higher). The teacher asks students why the map needs to be as accurate as possible. The ensuing discussion about determining risk, plotting the movement of contaminants, and cleanup procedures emphasizes the importance of noting detail, comparing and contrasting well readings and alternative plans, making inferences, and ultimately drawing conclusions to arrive at a workable plan.

Next, the groups compare and contrast their maps and talk about the reasons for similarities and differences. They also weigh the value of the information that would be gained by drilling additional test wells against the expense and time it would take to gain the extra information. This step requires students to demonstrate an operational understanding of science vocabulary—first in their individual journals to sort out and order their own ideas, then in discussions to communicate, compare, and contrast their findings and opinions (another essential step in science).

This discussion leads to a final activity, one that knits together the skills and processes of science and literacy even more tightly. In a town meeting,
students take on roles representing Fruitvale’s residents, parents, public officials such as the mayor or the manager of the city water system, executives of the local chemical company, and pollution cleanup experts. The student-actors and audience use the evidence compiled in their journals and knowledge gained from the activities to debate the merits of various approaches to, and plans for, cleaning up the contamination.

In this culminating activity, students must marshal the facts and processes of science that they have learned in previous facets of the investigation, interrelate ideas, and integrate their ideas and information. At the same time, they also must rely on the skills of literacy to discuss together, and reach consensus about, what the science has told them. They must fuse their knowledge of scientific facts and processes with the skills of language to reason through evidence to make an informed decision—and to express their views, listen effectively, counter opposing arguments, and persuade others. They must note the details of the well tests and of what others say, distinguishing fact from opinion. They must sequence events to determine the source of the contamination and to link cause and effect, both in analyzing the test results and in making an effective argument. They must compare and contrast the positions taken by themselves and others to understand how they differ and how they complement one another. Finally, they must make inferences and draw conclusions in order to make predictions about the relative effectiveness of competing cleanup schemes.

An activity such as Fruitvalue draws together all aspects of literacy—reading, writing, listening, speaking, and analyzing media—in the service of good science. In addition, the activity helps students construct their own internal processes of collecting, ordering, and employing evidence to reach personal decisions.

As students work, teachers can monitor students’ growth in literacy by comparing their use of language against several sets of explicit performance expectations, then tracking their progress using running records (see Chapter 6) or rubrics.

For example, teachers can observe students in learning groups and in mock debates to gauge each student’s skills in group interaction, such as whether the student listens carefully or responds appropriately to questions. Teachers also can compare students’ drafts of narrative procedures against a list of performance expectations. Does the student use the right words to express intended meanings? Does the student sequence events accurately as well as clearly enough for others to follow? In writing a narrative procedure to enable another person to reproduce the investigation and result, the student learns the power of words (and precision in using them) to shape actions and determine their outcomes.
The skills and procedures students learn in the Fruitvale activity translate directly to environmental issues beyond the classroom, giving students ample opportunities to employ their new knowledge in their own lives and communities in order to develop an “enduring understanding” (Wiggins and McTighe 1998).

A High School Example: Using Evidence to Weigh Alternatives

Students are presented with a scenario: to stimulate business investment and promote its emerging market economy, the Chinese government is opening land controlled by the state to private development. Its latest offering is two hundred acres on the outskirts of Beijing (SEPUP 2000).

Students examine satellite photos of the region taken several years apart to learn the patterns and features of surrounding development. Then the students divide into eight interest groups, each promoting a distinctly different use for the land: a residential area, a car factory, a park and nature preserve, a nuclear power plant, farmland, a water reservoir, a wastewater treatment plant, and an amusement park. Each group must make as compelling a presentation as possible for its point of view before the Beijing land-use committee—including a plan to remediate any harmful environmental effects of the proposed use. The groups must gather and organize data, prepare to answer the committee’s probing questions, and be ready to rebut negative evidence and comments about their positions that competing groups put forward, all while remaining within the strict time limit that the committee has allowed for each presentation.

Each group must research and gather as much data and information as possible relevant to its position—the economic and environmental impacts of its proposal, the plan’s costs and returns, its benefits and drawbacks. (Usually, the research and presentation assignments are parceled out so that one student researches and prepares a single aspect of the group’s presentation.)

The activity calls on high school students to integrate their skills of scientific research and data organization with their skills in language, and to stretch both to new limits. To make their cases, the students must note the scientific details that favor or weaken their positions. They must use evidence to make inferences and draw conclusions about the advantages and disadvantages of their plan for the land. Those steps, in turn, require them to predict from evidence the positive and negative outcomes of the land use they urge, which means that they must link cause and effect and distinguish fact from opinion. Finally, they must compare and contrast the strong and weak points of their case with others so that they can argue more forcefully for their views.
In making their presentations, they must rely on the power of their language to present their evidence as strongly as they can. They must note the details of opposing arguments and compare and contrast those arguments, both with their own ideas and with the evidence that they have gathered. They must be ready to predict any negative consequences of opposing land uses that those groups try to conceal, linking cause and effect and distinguishing fact from opinion as they do so. (Part of that process involves linking words and meanings so students can internalize those meanings and make those words part of their repertoire—in this example, to make sure that opposing groups are not using deceptive language.) Throughout the presentations, the students will exercise their analytical skills, asking questions such as, “What is the source of this information?” and “What evidence is not being presented?” (Once developed, these skills can be applied just as effectively to television commercials, political ideologies, and other messages intended to persuade.)

Students can apply the skills and insights they have gained from the activity to conduct similar comparisons, debates, and investigations of their own designs about issues in their own communities.

Conclusion: Blending Language and Inquiry in Science Education

Inquiry-based activities that address issues personal to students are more than engrossing. Data shows that students who work through guided inquiries such as My Sweet Tooth, the Fruitvale activity, and the Beijing land-use debate understand science concepts at least as well as students who are taught through textbooks, lectures, and worksheets. Teachers who regularly use guided-inquiry science materials in their classrooms report that students understand science concepts more deeply and thoroughly than students who learn through more traditional methods.

But guided inquiry brings an additional advantage: it enlists language as a key element in the development of students’ scientific knowledge and skills, giving teachers a powerful additional resource to help more students achieve high standards. Guided inquiry recognizes that language and its skills are the lenses that focus students’ thinking, the catalysts that help students turn facts into knowledge that they can retain long past their school careers and apply in their own lives.
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