

Doing  
Good Science  
in Middle School:  
A Practical Guide to  
Inquiry-Based Instruction

By Olaf Jorgenson,  
Jackie Cleveland,  
and Rick Vanosdall

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# Integration Is Key

## Science, Literacy, Math, and Technology

**H**ow do we integrate reading, writing, and math with science? Good science instruction is by nature cross-disciplinary, weaving literacy and numeracy with problem solving, discovery, and other higher-order thinking skills. The increasing fragmentation of academic subjects—such as the separation of science from math and literacy—plays a role in the disappointing performance of U.S. students in international achievement comparisons such as the Third International Mathematics and Science Study (TIMSS) (Schmidt, McKnight, and Raizen 1997).

In many ways, good science is at the crossroads of a curriculum. More than any other core academic subject, science routinely incorporates key goals in literacy and mathematical reasoning, in addition to the procedural approach and higher-order problem-solving skills that science cultivates.

### Science and Literacy

While science and math seem a natural fit, those unfamiliar with the nature of scientific investi-

gation and inquiry activities may not be aware of the close compatibility between science and literacy. In fact, science and literacy involve many reciprocal cognitive skills, as seen in Table 4.1.

Veteran science educators recognize the connections between science, reading, and writing. Not only are many conceptual skills transferable between literacy and science (e.g., predicting, identifying cause and effect, and using evidence); reading and writing are also integral to good science instruction through science notebooks, lab reports, research projects, group presentations, and other elements of instruction that reflect national and state standards for the language arts. Middle school science teachers can collaborate with their colleagues in other fields to identify reading, writing, speaking, and listening activities that can be conducted across the curriculum. As with classroom management expectations (see Chapter 5), our experience tells us that efforts to have an impact on student outcomes in middle school are most likely to succeed if they are implemented schoolwide. That is because middle school learn-

TABLE 4.1

## RECIPROCITY BETWEEN LITERACY AND SCIENCE SKILLS

LITERACY	SCIENCE
Note details.	Observe and retain small details.
Compare and contrast.	Make notes about the way a variety of substances react (e.g., to heat).
Predict.	Hypothesize about what will happen next.
Work with sequences of events	Work with processes of logic and analysis.
Distinguish fact from opinion.	Use evidence to support claims.
Link cause and effect.	Study what causes things to react in a particular way.
Link words with precise meanings.	Develop operational definitions of a concept through experiences.
Make inferences.	Infer based on observation and evidence.
Draw conclusions.	Conclude by combining data from various sources.

Source: M. P. Klentschy and E. Molina-De La Torre. 2004. Students' science notebooks and the inquiry process. In *Crossing borders in literacy and science instruction: Perspectives on theory and practice*, ed. E. W. Saul, p. 342. Wilmington, DE, and Washington, DC: International Reading Association and NSTA Press.

ers have a developmental need for structure and will respond best to instructional approaches that they encounter in a variety of classes.

In schools where achievement test data can be used to identify performance patterns in individual students—for example, test results indicating which mode of writing (research, narrative, expository, persuasive, or creative) is a student's weak area—science teachers can often be part of a team effort to improve student performance by adapting assignments accordingly. Further, schools that adopt a template used consistently by teachers in every subject to teach the writing process can reinforce key skills such as presenting main ideas, organization, voice, word choice, sentence fluency, syntax, writing conventions, and effective presentation.

“Research” is an objective listed in the national standards for language arts, math, and science (NCTE/IRA 1996; NCTM 2000; NRC 1996). Too often, though, middle school research projects become individual competitions between students (and parents) rather than opportunities for cooperative learning, research skill development, and meaningful interaction. In her acclaimed study of young writers and the writing process, *Living Between the Lines*, Calkins (1991) recommends using whole-class research topics to maximize cooperative learning opportunities. In the whole-class approach, students work in collaborative teams to research, record, and present components of a *single* topic or theme, rather than working on many independent projects covering individualized top-

ics. This approach is compatible with the social needs of the middle school learner (as discussed in Chapter 1) and enhances the teacher's efforts to develop middle school learning communities. Whole-class research also makes it easier for students to gather resources, something that is particularly useful in schools with limited media center collections. We recommend that research and writing projects in middle school science courses incorporate a writing process (i.e., prewriting, drafting, revising, editing, and publishing) and strategies that are consistent with the students' other subjects. Narrative and lab reports, research projects, essays, biographies, even creative writing assignments can be used to promote a school's literacy goals.

### Science Lab Notebooks

Whenever students are involved in inquiry-based science, whether in a laboratory setting or while conducting field research, they should have the opportunity (and be expected) to record data as they progress through the process. Teachers can help students to develop this essential habit by providing them with commercially prepared lab worksheets or simply giving them blank sheets of paper inserted in binders. We've found that middle-level students generate more original thoughts and observations when they start with a blank page than when they fill out a structured worksheet, although teachers will need to provide some degree of introductory preparation, especially for younger students, about what sorts of thoughts and observations are to be recorded on the blank pages.

Science lab notebooks are becoming prevalent in middle school science across the country. Students use them to record lab observations, describe findings, list questions or problems, practice journaling skills, and engage

in critical reflection. Teachers may incorporate prompts into the lab activity that bring students back to the journals to think, write, and reflect. Notebooks also give the teacher a means of ongoing formative assessment to the extent that instruction is adjusted according to the needs and deficiencies identified in the notebooks.

Science lab notebooks are different from the personal journals frequently used in language arts classes, in part because they are more structured. A typical lab book activity begins with a question to investigate. Students then add a prediction of outcome, observations made, procedures used, and a conclusion. (See Appendix B, "Sample Lab Report Form.") Like journals, though, lab notebook entries often involve reflection, and in the case of inquiry, we know that observations and investigations lead to more questions. Teachers encourage students to cultivate skepticism and critical analysis in their lab notebooks based on students' experiences with hands-on activities. That is why it's important for teachers to provide time for students to write in their lab notebooks after completing investigations. Well-organized writing takes time... like good science!

We've found that teachers shouldn't assume that students automatically understand the purpose of lab notebooks or what's expected when writing in the notebooks. Students need to know how to use the notebooks and why scientists use them, including the value they hold for scientists whose work can lead to important discoveries, closely guarded secret findings, and sometimes patented solutions to problems. Students will develop ever-stronger notebooking skills through practice, especially if the teacher regularly views the notebooks, makes comments, and assigns a formal grade for completion and accuracy. (If teachers choose to formally evaluate notebooks, students should not have to guess at what it takes

to get a good grade. We recommend that initially the notebooking process should be modeled and monitored for students so the expectations are clear. A checklist for evaluating the notebooks is found in Figure 4.1.)

Lab notebooks are your portal to your budding scientists, and can indicate how much of your instruction and influence is getting through.

Another asset of lab notebooks is that they can be infinitely manipulated to involve varied writing proficiencies and to meet specific na-

tional and state literacy standards. In their roles as tools for inquiry and for literacy integration, science lab notebooks have been successful vehicles for improving student writing (Klentschy and Molina-De La Torre 2004).

### Personalizing Literacy in Science

There are numerous ways teachers can make “scientific” writing more stimulating and creative for students. For example, when address-

**FIGURE 4.1**

#### SCIENCE LAB NOTEBOOK CHECKLIST

The following checklist can be used to assess how well a student is keeping records during science activities. You may consider giving students a copy of the checklist to enable them to monitor themselves through the process.

##### GENERAL INFORMATION

- Question being investigated is stated.
- All entries are dated.
- Writing conventions (e.g., punctuation, capitalization) are correct.
- Presentation is clear.

##### OBSERVATIONS

- Description is very detailed.
- Description is complete.

##### ILLUSTRATIONS

- Drawings are accurate.
- Drawings are labeled.
- Drawings are in color.

##### PROCEDURE

- List materials used.
- Sequence steps followed.

##### COMMUNICATION OF DATA

- Graphic/table is complete.
- Graphic/table is labeled.
- Graphic/table is mathematically correct.
- Written portions are clear and complete.

##### ANALYSIS AND CONCLUSION

- Analysis is clear and logical.
- Explanation is complete.
- New questions or investigations are proposed.

##### LINE OF LEARNING

- New learning is shared.
- New curiosities are shared.

ing ecologically sound ways to improve the environment, you might ask students to

- write a paper convincing a neighborhood curmudgeon to recycle,
- write a letter to a legislator urging support of a clean air (or water) bill,
- outline a plan for cleaning up a neighborhood vacant lot or park,
- create a recycling jingle for radio to raise the level of listeners' concern, or
- create a 30-second "drought awareness" spot for television.

And this is just the beginning. Rick Wormeli (2001), a leading expert on teaching in the middle grades, notes that "science has many natural uses for writing, from lab reports to poetry. The blend of personal discovery and science that we might see in *National Geographic* or *Discover* magazines is achievable in our middle school classrooms" (p. 132). Wormeli recommends the following writing activities as appropriate and exciting options for students in middle school science courses:

- *Write the life story of a scientist.*
- *Make a schedule.*
- *Make up a tongue twister.*
- *Write instructions (procedures).*
- *Write a consumer's guide.*
- *Write an origins myth.*
- *Create a calendar in which the picture for each month shows a particular aspect of a scientific topic.*
- *Write a science fiction story.*
- *Examine a common scientific misconception, how it is perpetuated, and what can be done to correct it.*
- *Explain why another student obtained certain lab results.*
- *Create a board game focusing on the basic steps of a science cycle or principle.*

- *Research and write a report about a scientific discovery that changed the world.* (p. 132)

## Reading and Science

In addition to the many writing opportunities that inquiry-based science instruction makes possible, it also helps students to develop reading comprehension skills. Teachers can use the following questions from Thier and Daviss (2002) to help students learn to reflect on science writings and develop their reading and research strategies:

### *Reading Comprehension Prompts for Students*

- *Predicting:*  
*With a title like this, what is this reading probably about?*  
*What will happen next? (Turn to your partner and tell what might happen.)*
- *Reflective questioning before reading:*  
*Why am I reading this?*  
*Why does the author think I should read this?*  
*What do I expect to learn from reading this?*  
*How does this relate to my life?*  
*What do I already know about this topic?*
- *Reflective questioning after reading:*  
*What do I still not understand?*  
*What do I still want to know?*  
*What questions do I still have about this topic?*
- *Paraphrasing or retelling:*  
*What was the reading about?*  
*Can I explain to my partner or group, in my own words, the meaning of what I just read?*
- *Summarizing:*  
*Can I identify all the key concepts from the reading and write a summary using these concepts?* (pp. 42–43)

Good science instruction also incorporates speaking and listening activities through presentations, projects, discussions, and reports,

which are other areas of skill development called for in state and national language arts standards.

A number of documented and forthcoming studies support the role of science as an effective content vehicle combined with instruction in discrete reading skills. In particular, science has been used successfully to reach limited English proficient and disadvantaged readers and significantly improve student achievement on standardized tests (Klentschy and Molina-De La Torre 2004). Cole (1995) recommends several strategies shown to encourage active reading skills, such as reading aloud (teachers to students, student to students) and “meaning-driven” reading—that is, reading rooted in investigations and problem solving. These strategies, of course, are compatible with inquiry-based science instruction.

## Science IS Mathematics

Like writing and reading, math is an essential part of good science instruction. While the two disciplines are widely perceived as inseparable, however, too many middle grades science teachers miss the opportunity to reinforce mathematical concepts, skills, or modeling in a way that will enhance student proficiency and achievement. Math concepts are present in scientific operations such as graphing, predicting, measuring, weighing, and collecting and analyzing data, but teachers must help students see the connections between the mathematical processes that are embedded in science activities and the mathematical principles students are learning in their math classes.

Regarding grades 5–8, the NSES call for “mathematics that students should use and understand” (NRC 1996, p. 219)—that is, math is or should be a natural extension of middle grades science content and inquiry teaching benchmarks.

Specifically, middle school students should do math in science activities that challenge them to

- *Represent situations verbally, numerically, graphically, geometrically, and symbolically*
- *Use estimations*
- *Identify and use functional relationships*
- *Develop and use tables, graphs, and rules to describe situations*
- *Use statistical methods to describe, analyze, evaluate, and make decisions*
- *Use geometry in solving problems*
- *Create experimental and theoretical models of situations involving probabilities.* (NRC 1996, p. 219)

Beyond basic computation, well-planned inquiry science activities typically call for students to engage in estimation, proportionality, and even basic algebraic and geometric concepts—topics identified as weaknesses in U.S. students’ science performance on the TIMSS international comparison (Schmidt, McKnight, and Raizen 1997). Middle school science teachers should focus on developing activities that explicitly engage students in these mathematical operations, especially algebra and geometry operations. Please refer to the 10 activities in Chapter 6 to see how mathematical processes may be incorporated in good science activities.

Math and science are sometimes lumped together as “aptitudes” that some students have, and others don’t. In math as well as science, the middle grades are where students begin to develop an identity as a learner—successful or unsuccessful—in these subjects. As in science, many of our colleagues involved in math coordination and training believe that mechanical, teacher-centered methods are one reason middle schoolers perceive themselves as “bad at math.” We believe that the integration of math into good science instruction must adhere to the



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same inquiry-based instructional principles that we discuss throughout this book.

## Good Science Can Be Low Tech

Looking at the NSES, it is important to distinguish between the common use of the term *technology* and its meaning as it relates to doing good science. The NSES stress that technology should be used to meet a need or solve a problem, but this doesn't mean you need computers and expensive electronic probeware to conduct inquiry activities. Technology can simply be the means to a solution and can involve little more complexity than challenging students to design and build shockproof containers used in an egg drop or to recombine everyday materials to invent a better mousetrap—without a mousetrap. According to the NSES, the use of technology “should be readily accomplished by the students and should not involve lengthy learning of new physical skills or time-consuming preparation and assembly operations” (NRC 1996, pp. 161, 165). In light of this statement, we can conclude that the NSES discount the need perceived by some teachers and schools to purchase complex computer programs or specialized hardware for science instruction. Good science is *not* dependent on hardware and software. Good science can be low tech.

That's not to say that we're opposed to using scientific technology, if a school or district can afford it. Indeed, we've worked with fifth graders in scaled-down electronic flight simulators to learn the physics of flight and with eighth graders using night-vision goggle technology to study rock formations under desert starlight. We encourage teachers to pursue technology resources and training to use technology, as many investigations can be enhanced by technology. We also appreciate the advantages

of using prepackaged science kits, particularly when they are part of a systemic plan for inquiry science and accompanied by training from the kit vendor or through the Association of Science Materials Centers (ASMC). However, the absence of science kits or computer networks does not prohibit teachers from implementing inquiry methods or from providing students with exciting learning opportunities.

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