Science teachers understand the importance of arming students with reading strategies that will help them get more out of their science reading experiences. We also know that decades of research support inquiry and the learning cycle model of instruction as teaching methodologies that lead to increased student achievement and a greater understanding of the nature of science. We sometimes struggle with finding a way to bring together these two important methods of constructing knowledge.

Our difficulty comes, in part, from our belief that science is something you do, not something you read about. At the same time, we know that reading skills support the doing of science. How can we successfully integrate reading strategies into science instruction while honoring the investigative, hands-on nature of inquiry? In this article I hope to identify the types of reading that science students do in class on a regular basis, to describe inquiry and the learning cycle, and to offer some examples of how well-known reading strategies support inquiry.

Reading Science

Published science journals typically have at least one or more graphic displays and one mathematical expression per page of running text (Lemke, 2004). Considered as a whole, the text, graphical displays, and mathematical expressions present a complete picture of the topic being addressed. Remove any one of these elements, and the reader is left with an incomplete picture. Science textbooks and science articles in the popular media also rely upon multiple representations to accurately portray the topic being discussed.

It is difficult to represent scientific concepts with text alone. Consequently, the ability to read science materials requires skills that allow students to read procedural information; graphical displays including maps, charts, data tables, graphs, diagrams, and drawings; and mathematical expressions. Graphical displays may represent something as large as a galaxy or as small as a cellular component, they may be enhanced to show us what the naked eye cannot see, or they may be computer-simulated models. Reading science also requires understanding the shorthand the scientific community has developed to represent complex ideas, e.g., vectors, chemical equations.

It is not enough to be able to read in isolation each of these many ways that science is represented. Students must integrate these multiple representations in order to construct meaning (Lemke, 1998). One of the challenges science teachers face is determining how to foster these skills without sacrificing inquiry.

Inquiry

Inquiry is the method through which students investigate natural phenomena to build their understanding of science content and processes. Students involved in inquiry are:

- Making observations
- Asking scientifically oriented questions
- Collecting, representing, and interpreting data
- Drawing conclusions
- Communicating results

Participating in inquiry requires a set of process skills that can be separated into basic and integrated process skills (Padilla, 1990). The basic skills are:

- Observing
- Inferring
- Measuring
- Communicating
- Classifying
- Predicting
The integrated process skills are:

- Controlling variables
- Defining operationally
- Formulating hypotheses
- Interpreting data, experimenting
- Formulating models

Inquiry-based teaching occurs along a continuum. On one end of the continuum is teacher-guided inquiry. In teacher-guided inquiry, the teacher provides the question, the data, the evidence, and the procedure. The teacher tells the students how to analyze the data and how to use the evidence to formulate an explanation. On the other end of the continuum is learner self-directed inquiry. In learner self-directed inquiry, the learner asks the question, decides what evidence to collect, formulates an explanation after analyzing the evidence, and forms a reasonable and logical argument to communicate the explanations (Center for Science, Mathematics, and Engineering Education, 2000). Most classroom inquiry falls somewhere between these two extremes.

What Is the Role of Reading During Inquiry?

Throughout inquiry, students may need to read procedures, diagrams, data tables, safety information, mathematical expressions, and other written representations used in science such as chemical formulas, flowcharts, and schematics. It may not be immediately apparent how reading strategies can be used during these times when students are actively engaged in hands-on explorations. At these times, reading is typically short in duration and intermittent.

Learning Cycle

The learning cycle is a framework for doing inquiry. The learning cycle was developed in the late 1960s by Robert Karplus and others as they developed the Science Curriculum Improvement Study materials (Fuller, 2002). Since that time, it has undergone many revisions. These revisions have resulted in several versions of "E" learning cycle models, with the number of "E" phases ranging from four to seven. Regardless of the version used, the learning cycle instructional model supports inquiry. For this discussion we will use a widely accepted model built around the following phases: engage, explore, explain, and expand, with assess integrated into each of the E phases. Here is a description of each phase.

**Engage:** Instruction is planned to help students mentally focus. Engagement practices capture students’ attention, stimulate thinking, and help students access prior knowledge.

**Explore:** Instruction is planned to get students actively involved with science content and skill by doing substantive intellectual work. Exploration practices give students time to think, plan, investigate, observe, and organize collected information.

**Explain:** Instruction provides for classroom debriefing, discussion, reading, and reflective writing to clarify and verify valid scientific understandings. Explanation practices offer students opportunities to analyze, interpret, and compare their explorations with other sources of content knowledge. Student reflection supports clarified and modified understandings.

**Expand:** Instruction promotes conceptual expansion through teacher questioning organized around appropriate benchmarks and grade-level indicators, guiding students to organize new understanding of concepts and skills and apply them to novel or real-world situations. Expansion practices give students opportunities to connect, apply, and evaluate applications of science and technology.

**Assess:** Instruction integrates best practices in assessment into all parts of a learning cycle. This helps focus assessment on science concepts, skills, and the range of cognitive demands from recalling valid science accurately to the application of science and the evaluation of technological solutions. Assessment practices provide students and teachers with information and feedback to improve student work, enhance learning, and modify teaching and learning activities to meet students’ learning needs. (Woodruff, 2008)

Various types of reading tasks are more or less appropriate at each phase of the learning cycle. Likewise, various reading strategies may be more or less appropriate at each phase of the learning cycle. Additionally, the learning cycle approach can be used for research-based inquiries. Table 1 shows various reading strategies (most suggested by Barton and Jordan, 2001) that could be used in each phase of the learning cycle.
What might a reading strategy in Table 1 look like? Here are two examples:

**Anticipation guides** are sets of questions designed to activate students’ prior knowledge, help students focus on their reading, and generate interest in the topic. Anticipation guides can be a series of true-false questions that students answer before and after reading (Fisher & Frey, 2008). Or they can be a series of questions in which students compare their opinions with those expressed in the reading selection (Barton & Jordan, 2001).

An anticipation guide could be used as part of a teacher-guided inquiry in which the teacher provides the laboratory procedure. After the lab has been introduced but before the students are given the procedure, ask them to complete a short anticipation guide. You could include questions that would activate prior knowledge by asking about data collection techniques, safety procedures, or previously learned content; questions that would focus attention on the aspects of the procedure you want students to pay particular attention to; and/or questions that would generate interest by asking students to anticipate outcomes.

### Sample Anticipation Guide for Yeast Respiration Lab

<table>
<thead>
<tr>
<th>Learning Cycle Phase</th>
<th>Reading Strategy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Explore</td>
<td>Anticipation guide, directed reading/thinking activity, pairs read, PLAN (predict, locate, add, note)</td>
</tr>
<tr>
<td>Explain</td>
<td>Directed reading/thinking activity, graphic organizer, group summarizing</td>
</tr>
<tr>
<td>Assess</td>
<td>Anticipation guide, directed reading/thinking activity, PLAN, problematic situation</td>
</tr>
</tbody>
</table>

### Table 1

A *K-W-H-L chart* is very similar to the K-W-L chart in which students list what they know and what they want to know prior to reading. After reading, students complete the final column, indicating what they have learned. The K-W-H-L chart includes a column for the student to list *how* they will find out what they want to know.

This strategy could be useful in student-directed inquiries. Students could complete a K-W-H-L chart after reading the scenario for the Separation Science Lab ([http://www.ohiorc.org/record/2609.aspx](http://www.ohiorc.org/record/2609.aspx)) to determine what they need to know prior to designing their experimental procedure. The scenario describes a train wreck that has resulted in a chemical spill. The students are told that the spill mixture consists of three substances that must be separated. The following example represents what students might produce after reading the scenario.

### K-W-H-L Chart

<table>
<thead>
<tr>
<th>K</th>
<th>What I Know</th>
<th>W</th>
<th>What I Want to know or solve</th>
<th>H</th>
<th>How I will discover what I want to know</th>
<th>L</th>
<th>What I Learned</th>
</tr>
</thead>
<tbody>
<tr>
<td>Naphthalene is used in the activity.</td>
<td>What is naphthalene?</td>
<td>MSDS (material safety data sheet)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Final Thoughts

Integrating reading strategies into science instruction while honoring the investigative, hands-on nature of inquiry is not an easy task. Generally speaking, science teachers do not have sufficient expertise in reading to confidently implement the reading strategies suggested by reading experts. Likewise, reading experts do not have sufficient expertise in science content and processes to provide the depth of guidance science teachers need. I suspect that in time these two bodies of knowledge will come together in a way that is immediately helpful to science teachers. In the interim, science teachers have the task of examining suggested reading strategies through the lens of inquiry to identify the ones that support inquiry and improve students’ ability to read science.

References


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