Teaching and Learning Science Through *Writing*

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How can teachers help students develop the skills to observe and think scientifically? Writing is one of the most powerful, effective skills a young science student can develop. Writing about science not only helps students organize their thoughts and questions; it allows them to take an active role in the learning process as well.[1] It penetrates the external shell of memorized facts and superficial understanding and helps young minds tap into the core of learning.

In this article we will discuss three of the most successful types of writing assignments: explaining scientific phenomena, learning logs, and scientific reports.

Explaining Scientific Phenomena

Asking students to assume the role of teacher by providing their own oral and written explanations for phenomena is another way to encourage active learning. We all remember our first year of teaching when we finally understood our content because we had to teach it. In doing so, we became active learners. As most of us have discovered, it is impossible to teach effectively while being a passive learner. The rule works in reverse as well. When students work in pairs, explain concepts to each other, and then put their explanations on paper, they learn actively. This strategy is an adaptation of ideas drawn from cooperative learning[2] and reciprocal teaching,[3] both of which have proved highly successful.

To encourage clear and complete explanations, ask students to write for someone who knows nothing about the content. When students write for you, their explanations lack precision and clarity because they know you already understand the content. Why should they write detailed explanations for a knowing audience? If the intended audience knows nothing, however,

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explanations must be more thorough and clear. Allow students to choose their own audience, such as a parent, a younger sibling, or a friend. You can also encourage a variety of roles and formats for writing exercises. Instead of always writing as themselves, students can take on other roles, such as a blood cell, a pollen grain, or an amino acid. You may also vary the writing format from an essay to a letter, editorial, diary, obituary, or memo.

Writing experts tell us that students need to choose their own topics for writing.[4] School writing should mirror the work of real writers, covering topics of personal value for real audiences. Yet, as science teachers, we want our students to write about important science content. Allowing students to choose their own roles, formats, and audiences when explaining a topic provides some freedom of choice even when the topic is constrained. Explanations become livelier and more fun to read. And students learn much more in the process.

Benefits of Writing in the Science Classroom

***Writing* incorporates previous knowledge.**
Integrating new information with background knowledge is fundamental to science learning, and writing can help with this process. Writing about a topic *before* reading the lesson summons prior knowledge, which is then easily incorporated with new information.

***Writing* helps students become metacognitive.**
Good readers monitor their comprehension. They know when they understand and what to do when they don't. Writing helps students gain this awareness, in part by providing a means of measuring their own knowledge. Students cannot write clearly about something if they do not understand it.

***Writing* encourages active involvement in learning.**
Effective learning is not something we can do for our students; it requires initiative. Too often students remain passive, like empty vessels waiting for teachers to fill them with knowledge. It is impossible to remain passive as a writer, however. When writing about observations or a reading assignment, students are drawn into the learning process as participants.

***Writing* builds organization skills.**
Writing helps students see clusters of information and hierarchies of ideas. As students build systems of organization, they make new information their own.

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Learning Logs

The learning log is a student's written journal of questions and thoughts about the material covered in class. Entries may be questions about vocabulary, difficult concepts, or lab results. It should be a somewhat informal, even messy, record of their thoughts. The important thing is that students commit these thoughts to writing, which encourages them to remember, puzzle through, and perhaps find the answers to their questions. If you keep a personal log (which we also recommend), share it with the class. This can add a real sense of relevance to the practice.

To get your students started with their log, try using a reading assignment as a springboard. For instance, when introducing a new chapter in the textbook, have your students examine the title, subheadings, and chapter questions before they read each section of the text. Have them brainstorm what they already know (or think they know) about the topic and jot it down in their log. After they've read the text, ask them to write a second log entry on what they learned. Many students will be surprised to see their misconceptions refuted in their own handwriting!

Take a look at the example shown below—the reading entries of one student, Misha, from a section on flower reproduction. Misha's teacher concluded the lesson by asking her students how using their log helped them learn. If students understand why writing is effective, they are more likely to embrace it as a learning strategy. By providing opportunities for writing and talking about why it works, you can often convince students to write on their own.

Pre-reading Entry

In this chapter I am going to learn about flower reproduction. I know that flowers have male and female parts. I think that these parts are inside the flower. To see them you have to pull aside the petals. I think petals probably protect the reproductive parts, but I am not sure. I remember something about separate flowers for males and females, but I think many flowers have both parts on the same flower. I'm pretty sure you need to have at least two plants before they can reproduce.

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Post-reading Entry

I learned that stamens are the male parts of the flower. The stamen produces the pollen. The female part is the pistil. At the bottom of the pistil is the ovary. Plants have eggs just like humans. The eggs are kept in the ovary. I still am not sure how pollen gets to the female part. Do bees do all this work, or are there other ways to pollinate? I was right, sometimes male and female parts are on separate flowers. These are called incomplete flowers. Complete flowers have both male and female parts on the same flower. I also learned that with complete flowers just one plant can reproduce itself. So I was partially wrong thinking it always took two plants to reproduce.

Recording Observations

In addition to using learning logs for process discussions and as part of pre- and post-reading activities, students can also use them to record scientific observations. Observation is a cornerstone of science. Writing provides the feedback and direction students need to sharpen their observation skills. We want our students to find nuances in nature, to hypothesize and explain their observations. When students write about what they see, they are forced to organize their observations, often allowing them to see even more. Moreover, as students write their observations, they discover meaning in what they see.

See how Nina recorded her observations of a flower on the next page. Notice how easily Nina's observations led to questions. Her learning log set the stage for motivated learning. She wanted to know what her observations meant and then generated her own hypotheses, opening her mind to further exploration.

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Observation Entry

Right below the outside of the flower the stem thickens into a little case or holder for supporting the flower. It looks almost like a crown. From this crown-like form is a ring of petals. The petals are in two layers. The lower petals are greener and look more like the stem than the upper petals. I wonder what use all of these petals have? I know they might attract bees for pollination. It could be that their function is more for protection of the fragile internal parts of the flowers.

Next, I see a ring of tiny petal-like parts in the middle of the flower. There are four of these, and each tiny petal has two sharp spires on each side. I wonder if these are the stamen and pistils? They look very different from the surrounding petals—far more delicate.

Documenting Learning

While learning logs are very useful as observation tools, they can also be used in other ways. For example, after your students watch a film, complete an experiment, or listen to an oral presentation, allow some time for writing. Ask, "What struck you as important in this session? What do you want to remember?" You might want to participate in these assignments, writing in your log as your students write in theirs. Then you can read your entries aloud and invite students to do the same.

Logs provide opportunities to write informally and to explore content. The idea is to write without fear of teacher interrogation or a hemorrhaging red pen. The writer is always the primary audience. When students used logs in our classrooms, we never graded them, although we usually gave points for completion. We do recommend that you read the logs, because it will give you a better understanding of your students' knowledge. It can also provide important data about your presentation—their questions and confusions can guide your instructional planning.

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One colleague asks his students to leave space for him to write back. Student entries trigger his own ideas, and he can't resist responding. Sometimes his responses are questions, sometimes clarifying comments about their observations. More often he nudges with ideas for further exploration. This personal dialogue provides a strong feeling of individual attention for the student.

How do you nurture the development of students' learning logs? First, students must feel safe for their logs to be effective. Entries must be spared from red-pen intimidation and criticism. Second, students must write frequently. Set aside time in class for writing. Keep your own log and model your own writing after your students'. If students see that you take writing seriously, they will begin to believe in their own need to write. Third, write back to students in their logs. As you converse with students through writing, their responses will become more exploratory. Your encouraging comments make log writing feel safe.

Conclusion Entry

I felt more interested in reading about flowers because I thought about it before I read. I was surprised I knew as much about flowers before reading. Writing helped me realize what I already knew. It made me more curious about reading because I wanted to know if I was right. Knowing that I was going to have to write when I finished reading made me read more carefully. I got more out of my reading by writing. I wasn't very happy about doing it at first, but it helped.

Scientific Reports

We want our students to think like scientists, to be able to define and analyze problems and formulate conclusions. Having students conduct and write about experiments is an effective way to learn and practice these skills. When students write scientific reports they must organize their thoughts and consider how the various parts of an experiment work together. Writing helps them synthesize their ideas.

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We begin to teach the scientific method by having the class solve simple problems together, following written laboratory guidelines. Responses to the guidelines become part of the laboratory report.

Start with what your class already knows about a topic. Have them generate one or two questions to investigate. Students will recall knowledge related to the topic and write hypotheses as explanations. Then ask students to brainstorm ways to test the hypotheses, develop an experiment, and list procedures. Once they complete the experiment and record the results, have them answer their original questions. Did their results answer the questions? If not, ask them to come up with alternate ways to examine the issues. Finally, have the students draft a laboratory report from their notes. Stress that these need to be written without clutter, so that another scientist could replicate their results without confusion.

A colleague of ours has her classes do several reports in groups until they feel comfortable enough with the process to write their own. She then distributes copies of the final reports to the class for evaluation. From this evaluation the class develops a checklist of guidelines for writing and grading subsequent reports. This process of development is perhaps even more beneficial than the final product because it gives students ownership of their evaluation instrument. After writing reports in a laboratory group and evaluating the reports as a class, most students are ready to begin writing on their own. Before turning in their reports, students read each other's drafts in reaction groups. One student reads his or her work to the other two students, who listen and provide initial reactions based on the checklist. The students then revise their drafts and hand them in. You may find it helpful to take on the role of a student and demonstrate the reaction group process for the class. We also recommend that you develop reaction group rules to ensure that these sessions are productive.

In assigning scientific reports, remember that the goal is to teach scientific process as well as writing skills. If the reports are unclear, the students probably haven't thought through the procedure. If a student cannot write a logical hypothesis and then support it or refute it, he has missed the main point of the experiment. Clear writing is a sign that you and your students are working together successfully.

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Laboratory Report Guidelines

1. **Purpose.** Why are you doing this lab?
2. **Problem.** What problem are you investigating?
3. **Hypothesis.** What do you think the outcome of this lab will be? Think about what you already know about the topic, and make an educated guess about the outcome.
4. **Materials.** What do you need to do this lab?
5. **Procedure.** How will you do this lab?
6. **Data or Results.** Draw, record, and chart all detailed observations.
7. **Analysis or Conclusion.** Reread your problem statement. Did your results resolve the problem? Explain why, using data from the experiment. If the results did not resolve the problem, explain why.
8. **Class Conclusion.** Final conclusion after class discussion. Modify your earlier conclusion if necessary.

Laboratory Report Checklist

1. **Purpose**
   - ✓ Have I explained why I am doing this experiment?
   - ✓ Did I conclude this section with a hypothesis?
2. **Materials and Procedure**
   - ✓ Did I explain the materials and procedure?
   - ✓ Did I explain the steps used to test my hypothesis?
3. **Results**
   - ✓ Did I present the data from the experiment?
   - ✓ Are the differences among variables clearly presented?
4. **Conclusions**
   - ✓ Are my conclusions directly based on the data?
   - ✓ Did I refer to the hypothesis?
   - ✓ If the data did not support my hypothesis, did I provide some reasons for the discrepancy?

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Conclusions

There was a time when many science teachers thought writing had no place in their classrooms. We had enough trouble just covering the content. We certainly did not welcome the extra duty of teaching writing.

Our science classrooms are far richer now. Learning logs have added vitality to learning. Writing has also empowered students to grasp the complexities of the scientific method. Their thinking travels from the problem to the conclusion and, as they write, they internalize scientific patterns of thought. Finally, we can be sure our students understand concepts when they can teach them to their peers.

As we examine our growth as teachers, we see that our knowledge is similar to the bud of a flower. At the beginning of our teaching careers we are still emerging. Fortunately, we have our classrooms where we can watch our students read, write, talk, and experiment. By continuing to take our nutrients from them, we will surely grow and develop into magnificent flowers.