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[ILLUSTRATION OMITTED]

Most middle school science teachers are familiar with the idea of reading and writing across the curriculum. We, as science teachers, understand that our students need time, practice, and lots of encouragement in order to learn how to read and write well. What we also need to remember, however, is that learning how to read and write in science is an important part of scientific literacy, and it can help students understand and retain key science content (NRC 1996; Saul 2004). In this article, we outline a technique that science teachers can use in middle school classrooms to help students learn to write, and write to learn, in science.

Why are reading and writing so important in science?

Science teachers need to help students learn how to read and write in science for a number of reasons:

* Students need to know how to learn about science on their own if we expect them to be lifelong learners. This requires students to be able to read, understand, and critique academic, nonfiction, and persuasive genres of writing.

* Reading and writing are important aspects of doing science. Scientists must be able to read and understand the writing of others, evaluate its worth, and share the results of their own research through writing.

* All students, regardless of their interest in a scientific career, need to be able to read and write about scientific issues so they can make educated decisions and participate in a democratic society.

* Students who are skilled at reading and writing in science are often able to learn the concepts, theories, models, and laws of science more deeply and retain more than students who are not (Shanahan 2004).

It is important to remember, however, that students will not learn how to read or write in science by reading novels or by writing short stories in language arts. Students need to be introduced to the various genres of science writing and how to combine words and symbols to create meaning in a manner that is consistent with the stylistic rules of science. They also need to practice this type of writing and receive good feedback about the quality of their writing so they have an opportunity to improve. It is therefore important for science teachers to engage students in real science writing as part of their science education. One effective way to do this is to give students opportunities to write refutational texts as part of their experiences in science.

Refutational texts

A refutational text introduces a common concept, idea, or theory; refutes it; offers an alternative concept, idea, or theory; and then attempts to show that this alternative way of thinking is more valid or acceptable. An example of a refutation can be seen in this excerpt below (the key sentence that identifies this passage as a refutational text is italicized).

Many people believe that a change in the Earth's distance from the Sun causes the seasons to change. However, this cannot be true, because the seasons are different in the Northern and Southern Hemispheres. The actual cause of the seasons is the way the Earth is tilted on its rotational axis. When the Earth's axis points toward the Sun, it is summer for that hemisphere. When the Earth's axis points away, it is winter for that hemisphere. This is because the hemisphere that points toward the Sun receives more direct sunlight and has longer days.

A refutational text, such as the example provided here, is one of three kinds of persuasive arguments that are often found in scientific writing (Hynd 2003). A one-sided persuasive argument only presents the concept, idea, or theory the author prefers a reader to adopt. Two-sided arguments can be nonrefutational or refutational. A twosided, nonrefutational argument presents both sides of an issue, but makes one side seem stronger by presenting more evidence, explaining it more logically, or in some other way making the argument more compelling without explicitly stating that the author prefers it. A refutational argument, in contrast, is more explicit than a nonrefutational argument about which is the preferred side.

Most textbooks and science trade books are written in an expository or narrative style and usually do not include persuasive arguments. When they do, they often use one-sided arguments rather than refutational, twosided arguments. Thus, students are likely to be unfamiliar with this type of writing and will need explicit instruction, a great deal of practice, and good feedback in order to learn how to write in this manner. Science teachers, however, can help students learn to write high-quality refutational texts (and to learn more content as part of the process) by using writing prompts coupled with analytical rubrics that provide students with feedback about their performance and teachers with insight about what students can and cannot do.

Writing prompts

A well-designed writing task in science essentially has three critical attributes:

* it provides an authentic purpose for writing;

* it motivates students to want to write; and

* it helps students plan and structure their writing (Turner and Broemmel 2006).

These three attributes, when made explicit to students, make the goal of a writing assignment understandable, the writing meaningful, and a high-quality product achievable. One way to ensure that a writing task has each of

these attributes is to use a structured writing prompt (Indrisano and Paratore 2005). A structured writing prompt begins with all the information a student will need in order to write (the topic, the audience, the purpose, the form of the text, and reminders). It then outlines the steps of the writing process (e.g., creating an outline, producing a rough draft, editing, and preparing a final draft) and provides space for the student to complete each step. An example of a structured writing prompt that encourages students to write a refutational text about the concept of condensation is provided in Figure 1. In this prompt, students are asked to produce a one-page essay (the form of the text) that refutes the claim that water from inside a container leaks through to the outside (the topic and the purpose of the text) for a group of people who believe that this claim is true (the audience of the text). The prompt also reminds the writer to state the misconception that they are trying to refute, to use evidence to support their claim, and to organize their writing in an appropriate manner. These reminders are designed to focus the writer's attention on important components of a quality refutational text that novices often forget or do not provide enough attention to in their writing.

FIGURE 1 Refutational writing prompt

What causes water to appear on the outside of a container?

People tend to believe that water from the inside of a container seeps through to the outside after a period of time. Write a one- to two-page paper to refute the claim that water from the inside of a container leaks through to the outside to convince someone that this is a misconception.

As you write the paper, remember to do the following:

* State the misconception you are trying to refute

* Include evidence from a lab experiment, research that you have done, topics from the class discussions, and examples to convince your audience to abandon this misconception

* Organize your paper properly and include an introduction with a topic sentence, supporting paragraphs, and a conclusion

* Use vocabulary that we have learned

* Correct grammar, punctuation, and spelling errors before writing your final draft

You will have two class periods to complete this assignment. The first period will be dedicated to planning and creating a rough draft and the second period will be spent revising and creating a final draft of the paper. The paper will be due at the end of the class period on day 2. outline

Create an outline for your paper explaining the misconception, the evidence against it, and justification for the evidence. Use this to help you write your rough draft.

Rough draft

Write a rough draft of your refutational text. After you complete the draft, use a different color pen to correct your work. Be sure to look for spelling and grammatical errors. You may use a dictionary or a grammar book if you need.

Final draft

Write the final draft of your refutational text.

Teachers should keep four issues in mind when designing these types of writing prompts. First, students need to refute a common misconception related to a big idea in the curriculum. This will help students learn the content required by the district, state, or national science standards, and it will give them an authentic purpose for writing. It will also motivate students to want to write. Teachers can find lists of common misconceptions by entering a topic (e.g., condensation) and the terms "misconception" or "alternative conception" into an internet search engine. Teachers can also uncover any specific misconceptions held by their students by simply asking them to explain an everyday occurrence. They could also use students' science journals or bell-work questions as ways for students to explain these occurrences and then as a source for student misconceptions. Second, teachers need to be sure that the "reminders" included in the writing prompt will help students plan and structure their writing. These reminders should help focus students' attention on the goal of the writing assignment, the 6 + 1 traits of writing (Culham 2003), or specific writing requirements outlined in district or state language arts standards. Third, teachers need to be sure that students complete each step of the writing process (outline, rough draft, editing, and final draft). This will encourage students to keep their thoughts organized and to look over their work before they are ready to submit the final product. Finally, the writing prompt needs to be coupled with an analytic rubric that can be used to inform and improve student performance. This way, both the student and teacher know what is expected and what needs to be done to improve.

Analytical rubrics

Analytical rubrics are designed to provide information that can be used to determine students' current level of achievement, diagnose their strengths and weaknesses, and allow them to learn more about what they know or can do. Also, and perhaps most importantly, it shows what they need to do in order to improve (Hodson 1992). Analytical rubrics are matrices that identify what is expected of students by defining important criteria that will be used to assess quality and various performance levels. To increase the clarity of this type of rubric, each criterion is "subdivided into more concise statements and then followed by the related performance descriptions" (Luft 1997). An example of an analytical rubric that we developed to assess students' understanding and their ability to produce a quality refutational text is provided in Figure 2. In this example, the analytic rubric consists of four sections (outline, content, etc.) that are divided into one or more criteria (the misconception is identified, etc.), which are followed by descriptions that illustrate three distinct levels of performance.

The multilevel nature of an analytical rubric can help teachers uncover specific strengths and weaknesses. The rubric can also be used to help students understand the criteria to which they will be evaluated. Analytical rubrics, perhaps more importantly, can also provide detailed feedback to students about their performance. This kind of detailed information about what a student is doing right and wrong is a key component of an assessment that is educative in nature (Wiggins 1998). It also enables teachers to examine the strengths and weaknesses of their curriculum and methods of instruction. Middle school teachers can use all this information to help students enhance their understanding of the important concepts and what counts as quality when writing in science.

An example lesson

To illustrate how this writing prompt, coupled with the analytical rubric, can be integrated into a science lesson, consider the following example lesson. This lesson begins with the classroom teacher pouring ice water into a drinking glass. Students are then directed to watch the glass and record their observations. After several minutes, condensation begins to form on the outside of the glass. The teacher then encourages students to explain the origin of this water. The teacher writes each explanation (right or wrong) on the board and then leads the class in a discussion that focuses on ways to test the various explanations (such as using hot water instead of cold or water colored with food coloring inside the glass). These tests are then carried out by the teacher or by small groups of students and the results are used to weed out the inaccurate explanations until the class agrees on the scientific explanation (i.e., water vapor in the air turns back into a liquid when it touches the cold glass).

The next day, students are given the writing prompt (see Figure 1) and the analytical rubric (see Figure 2) and are told to use their knowledge and the data they gathered to refute the idea that the water leaks from the glass. Students then submit their texts to the teacher or to one or more of their peers for an initial evaluation. This process is guided by the analytical rubric, which, as noted earlier, outlines the criteria that are to be used to evaluate the quality of text and space to provide feedback to the student. It is important for the evaluators to not only provide information about how the text should be scored (by circling values for each criterion) but to also provide explicit narrative feedback to the student about what needs to be done in order improve the quality of the text. This feedback needs to focus on both the quality of the writing (section 1-3 in the example rubric) and the accuracy of the content (section 4 in the example rubric) so the student knows what needs to be revised (e.g., understanding of the content, the organization or conventions of the writing, or all three). The texts and the rubric are then returned to students with directions to use the feedback to improve their final product. Students then rewrite their texts as necessary and resubmit the assignment for a final grade. This type of review process provides students with educative feedback, encourages students to develop and use appropriate standards for what counts as quality, and helps students be more reflective as they work. This type of feedback also provides a mechanism that can help all students, especially special-needs and ESOL learners, improve their ability to write in science, and ensure that all students understand the content. If you have special-needs or ESOL students in your class, you could modify the time constraints to be longer so as to allow them more time on the assignment. Since the rubric in Figure 2 is divided into sections, it makes it easy for the teacher to see if it is the content knowledge (section 4) that students don't understand or if they are just having difficulty with the language or the writing of the assignment (sections 1, 2, and 3). This review process requires about five to ten minutes for an evaluator to complete.

Why is this important?

This writing process helps students make sense of their experiences by requiring them to explain a phenomenon and by refuting a common misconception in writing. This promotes understanding and retention of the content (writing to learn) and makes their thinking visible to the teacher. This process also gives them a meaningful opportunity to improve their ability to communicate through writing (learning to write). The writing prompt provides an authentic purpose for writing, motivates students, and helps them plan and structure their writing. The analytical rubric then provides students with the guidance and feedback that they need in order to improve their ability to write. As a result, this lesson provides a way to support efforts to promote writing across the curriculum (which is clearly needed) in a way that fosters student understanding of important content and writing in science.

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FIGURE 2 Example of a refutational-text grading rubric

Section 1: Outline

Criterion	3 points
Topics/Format	Most points are made in a clear outlined fashion. The outline is neat and orderly.

Total:--/3 points

Comments:

Section 2: Rough draft

Criterion	3 points
Editing	The draft is edited in a different color pen. All grammatical errors are highlighted and corrected. and a revision was disregarded.

Total:--/3 points

Comments:

Section 3: Final draft

Criterion	3 points
Organization/ Grammar	The paper is free of grammatical errors. The flow of the paper has a beginning, middle, and end.

Total:--/3 points

Comments:

Section 4: Content accuracy

Criterion	3 points
The misconception is identified	The writer identifies a misconception and explicitly states why it is inaccurate.
Reasons against the misconception	The writer provides several reasons why the misconception cannot be true. The reasons are explained clearly.
Evidence and reasoning in support of the scientific conception	The writer gives a clear and accurate explanation of the scientific conception. The writer illustrates why it is more useful than the misconception.

Total:--/9 points

Comments:

Final Total:--/18 points

Section 1: Outline

Criterion	2 points
Topics/Format	Some points are presented or the format of the outline is missing. Most of the outline is presented in an organized manner.

Total:--/3 points

Comments:

Section 2: Rough draft

Criterion	2 points
Editing	Some errors were missed or the draft is not edited in a different color.

Total:--/3 points

Comments:

Section 3: Final draft

Criterion	2 points
Organization/ Grammar	There are few grammatical errors. The paper is somewhat lacking in organization.

Total:--/3 points

Comments:

Section 4: Content accuracy

Criterion	2 points
The misconception is identified	The writer identifies the misconception, but fails to explain that the misconception is inaccurate.
Reasons against the misconception	The writer provides a few reasons that show why the misconception is inaccurate but leaves some reasons out. The explanations may be unclear.
Evidence and reasoning in support of the scientific conception	The writer gives a vague or somewhat inaccurate explanation of the scientific conception. There are some reasons provided to support the scientific conception.

Total:--/9 points

Comments:

Final Total:--/18 points

Section 1: Outline

Criterion	1 point
Topics/Format	Outline is incomplete and flawed. The outline is messy and disorganized.

Total:--/3 points

Comments:

Section 2: Rough draft

Criterion	1 point

Editing	Many errors were missed and the draft is not edited with a different color. Directions were not followed

Total:--/3 points

Comments:

Section 3: Final draft

Criterion	1 point
Organization/ Grammar	The draft is incomplete and sloppy. The draft is disorganized.

Total:--/3 points

Comments:

Section 4: Content accuracy

Criterion	1 point
The misconception is identified	The misconception is buried, confused, and/or unclear. The misconception is disregarded.
Reasons against the misconception	The writer does not acknowledge or discuss any reasons for why the misconception is inaccurate. The writer may also have incorrect explanations.
Evidence and reasoning in support of the scientific conception	The writer makes no mention of the scientific conception. The writer provides no evidence or reasoning.

Total:--/9 points

Comments:

Final Total:--/18 points

Gale Document Number:A190934861

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Full Text:

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Writing and science are inextricably linked. Communicating scientific results is a vital part of any scientific study (Carlson 2007), and the ability to convey thoughts, ideas, and findings through writing is imperative for students in developing science literacy (Metz 2006).

Science writing among high school students, however, can be problematic. Student lab reports frequently lack concluding statements (Rutherford 2007) and when conclusions are present, they are often missing evidence--in the form of data--to support their claims (Keys et al. 1999; Rutherford 2007; Sandoval and Millwood 2005). Even when students do provide data, many fail to explain how it supports their conclusions (Sandoval and Millwood 2005).

As science teachers at a suburban California high school, we were concerned about the lab report conclusions written by our upper-level chemistry, biology, and ecology students--which were consistently of poor quality. Their work lacked inferences derived from data and support for their concluding statements. Working as part of a collaborative project with the University of California at Davis, we formed a teacher research group to investigate this matter (see "About teacher research"). This article describes our group's efforts and its implications for the classroom.

Identifying the teacher research question

Initially, we assumed that the poorly written lab reports were a result of our students' compositional skills. Students were able to answer prompted questions about specific labs, but did not show the same level of understanding in their lab report conclusions; therefore, we thought that an intervention designed to improve their writing skills would be the most appropriate strategy. However, after further investigation, we learned that many students who struggled to write high-quality conclusions were performing well on writing assignments in other subjects, including English and social studies.

We reconsidered our initial assumption and determined that students' data-analysis skills might be the problem instead--perhaps they did not have solid ideas to articulate in their conclusions. We decided to develop and test the effect of different levels of instructional intervention on students' lab reports. As a result, we came up with the following question to guide our teacher research project: What influence does the degree of instructional support have on the quality of data analysis and writing in student lab report conclusions?

By asking this question, we hoped to find ways to improve student lab reports and the quality of their data analysis. Our long-term goal was for students to undertake similar analyses in subsequent lab experiences, which would improve the quality of their lab report conclusions.

Intervention strategies

Students in three general college preparatory chemistry classes participated in this study. We wanted to use data they would be familiar with, but had not seen previously. Since these classes had recently been introduced to acids and bases, students were given a common set of related data to review and were asked to report their conclusions. This data set included 28 different foods, their pH, and their taste (e.g., tart, sweet, or salty). We chose this data set because it required reorganizing before any trends were evident--for example, students had to group (or reorganize) foods by pH or taste to analyze the data. It also provided us with a means of standardizing our analysis across the participating classes.

In previous lab reports, students were asked to write conclusions based on their data. We anticipated that students would elect to write their conclusions on the food versus pH data using this same approach. In particular, we were looking for how students organized data and how they used it to draw their conclusions. We expected students would look for trends within the data and use this information to make inferences and summarize relationships between different foods and their pH values.

For our study, each participating class received a different level of instructional support associated with the data set. We designed three levels for the intervention groups:

* Intervention 1: No instructional support was provided.

* Intervention 2: Students were provided with a checklist of conclusion guidelines derived from Rutherford (2007) (Figure 1). No additional instructional support was provided.

* Intervention 3: Students were provided with the same checklist of conclusion guidelines used in Intervention 2, but also participated in an accompanying in-class discussion on how to use the guidelines. Students in this group also participated in a teacher-led discussion on data analysis and how data can be organized to reveal trends (Figure 2). This discussion incorporated student practice with a different data set--on cars--before students were assigned the food data set activity.

Figure 1

Checklist of conclusion guidelines (derived from Rutherford 2007).

[] Did you summarize and include data or results essential to your conclusions?

[] Did you clearly explain your conclusions using your data or results?

[] Are there any additional experiments that you would perform to explore unanswered questions?

[] Did you discuss any real-world applications related to this information?

[] Did you use complete sentences?

[] Did you check for spelling and punctuation errors?

[] Did you cite sources where necessary, and did you use the correct citation format?

[] Did you anticipate any questions the reader may have?

All participating classes were of mixed gender, grade levels (juniors and seniors), and abilities. Each class was randomly assigned one of the three interventions: Class A (n = 31) received Intervention 1; Class B (n = 30) received Intervention 2; and Class C (n = 24) received Intervention 3.

Using the food data set in Figure 3 (p. 46), students in all three classes were given the following writing prompt: Analyze the given data and report your conclusions. They were permitted to use their chemistry textbooks, the internet, and class notes. Graph paper, notebook paper, and writing utensils, including colored pencils and markers, were also made available to them. All interventions were scheduled during regular laboratory times, and students were given the entire class period to complete the task. At the end of the period, student work was collected along with the data set and conclusion guidelines, if provided. Written conclusions were scored as low-, medium-, or high-quality using a conclusion scoring rubric (Figure 4, p. 47).

Results of the interventions

Of the students in Class A--who received no instructional support--71% chose to graph the data provided. All of the individuals who graphed the data plotted the names of the foods against their pH, while 23% also graphed their tastes. Additionally, 94% of the students in Class A wrote conclusions (Figure 5, p. 47); however, only 16% of these were deemed high quality. An example of a low-quality conclusion from Class A is available online (see "On the web").

Similar to Class A, the majority (83%) of students in Class B--who received only the checklist--also produced graphs; however, their graphs were more likely to associate food pH with taste than the students' graphs from Class A (67% in Class B compared to 23% in Class A; see "On the web" for a link to student graph examples). Students in Class B also wrote the fewest conclusions (79%; Figure 5); however, analysis revealed that the percentage of high-quality conclusions written by students in Class B (34%) was greater than in Class A (16%).

Students in Class C--who received the checklist and the accompanying in-class discussion--produced no graphical representations of any kind; however, all students wrote conclusions (Figure 5). These conclusions received the highest scores of all three classes--38% were ranked as high quality and none were ranked as low quality. While examining the collected work, we noted that more students in Class C used the conclusion guidelines to assist them in their writing than students in Group B. An example of a high-quality conclusion from Class C is available online (see "On the web").

Evaluating the results

The results revealed that students who received instructional support improved their written lab conclusions. Of the three invention strategies tested, the most effective was providing the writing guidelines and conducting the teacher-guided discussion on data analysis (Intervention 3). In Class A, in which there was no instructional intervention, most students did not understand what was expected of them. One student was overheard saying, "I don't know what to do. [I guess I will] just graph something." This was, in fact, the most common way students in Class A approached the data.

While it may seem encouraging that students graphed their data, when reviewing the students' work, we recognized that most graphs produced by Class A were simply visual representations of the information provided (i.e., pH versus name of food) and showed no data analysis. Although graphing can be a useful technique for analyzing some scientific data, the data set used in this study required some reorganization before a graphical representation could be informative. Furthermore, while 94% of the students in Class A wrote conclusions, only 16% of those were high quality--indicating that most students who struggled with data analysis also struggled to write quality lab conclusions.

The students in Class B received indirect instructional assistance in the form of written conclusion guidelines. Similar to Class A, the majority of students in Class B generated graphs (83%). However, most of the graphs produced by students in this class showed data analysis, with 67% plotting pH against taste. Similarly, the number of high-quality written conclusions in Class B (34%) was greater than in Class A (16%) (Figure 5).

In class B, many students used the guidelines we provided as a tool when writing their conclusions. Because the quality of analysis and written conclusions increased from Class A to B, we believe that the conclusion guidelines helped students focus their efforts when analyzing data and showed them how to form a well-written conclusion. This thinking is consistent with Keys et al. (1999), who indicate that revealing specific characteristics of writing to students can help improve their writing. However, fewer students wrote conclusions in Class B than in the other classes, which may indicate that the written guidelines were not enough to scaffold some students' writing.

FIGURE 5
Percent of students writing conclusions.

Class C produced the most written conclusions of any of the classes. Of the written conclusions that were produced by students in Class A, only 16% were considered high quality. In Class B, 36% were high quality, and Class C had the most high-quality conclusions with 38%.

[GRAPHIC OMITTED]

Students who participated in a guided discussion on data-analysis strategies--Class C--produced written work that was different in both type and quality from the other two classes. The most striking differences in the resulting work were the lack of graphs (0%), and that all students wrote conclusions (Figure 5). When we associated these results with the increased quality of the conclusions, it indicated that students in Class C determined that graphing was not the best approach to explain the data, so they chose to describe and support their analysis through writing instead. These findings are supported by Hand, Hohenshell, and Prain (2004) who state that combining discussion with guidance in planning is important in promoting student learning through writing.

Conclusion

Our study suggests that the ability to reorganize data to identify trends and relationships may have a positive impact on conclusion writing. However, this skill is not intuitive to most students, and therefore instructional intervention is needed to show them how to organize data in meaningful ways and how to draw and support their conclusions. By challenging our original assumption--that low-quality lab conclusions were a result of poor writing ability--we have found that changes in the way we teach science can greatly improve the quality of student lab conclusion writing. Making sure students have well-organized and well-analyzed data may be the key to positive shifts in conclusion writing.

The results of this study illustrate key points for educators to consider in their classrooms:

* Challenge the assumption that students cannot write. Many students can write well, but may lack the skills necessary to analyze data effectively.

* Data analysis is not intuitive for many students. Students must be guided through meaningful data analysis and given specific examples to improve their lab report narratives.

* Small amounts of class time can have major impacts on students' understanding of data analysis.

Changes in curriculum and instruction that are driven by data are the core of teacher research (Tillotson 2000) and can help inform decisions with relevant classroom issues and best practices (Capobianco et al. 2004). Specific to the outcomes from this project, all of the participating teacher researchers have used their data to make changes in their practice. For example, in biology, the structure of written lab reports has changed to place a greater emphasis on conclusions, and the amount of discussion time devoted to data analysis after each lab has increased. In Advanced Placement chemistry and environmental science classes, the curricula have been modified to include specific class discussions on data analysis and lab report development.

Furthermore, the results from this project were extended to our school's science department and to teachers at other schools during an annual teacher research colloquium. To effect change and improve student learning more broadly, it is critical to share outcomes associated with new strategies for teaching and learning (Bernauer 2002). It is our hope that sharing the results from our teacher research project will have an impact on the teaching and learning of lab report writing in your classrooms!

About teacher research.

Teacher research is the intentional and systematic inquiry into classroom practice undertaken by teachers themselves (Cochran-Smith and Lytle 1993). It involves formulating a testable question, collecting and analyzing relevant data, and disseminating outcomes (Capobianco et al. 2004). Benefits of teacher research include improved practice and student learning and contributions to the literature (Abell 2007).

Strategies to improve student writing.

Examples of strategies to improve students' science writing can be found in the literature. For example, Gregson (2005) outlines an approach using teacher-modeled writing and introducing students to revision practices; Graham and Harris (1993) combine teacher modeling with timely feedback on written assignments; and Bereiter and Scardamalia (1987) and Keys et al. (1999) indicate that if teachers model writing and explain their thinking while writing, it can foster improvements in students' work. Additionally, Hohenshell and Hand (2006) discuss the need to develop strategies to support student writing in high school science, and state specifically that "guidance in planning during portions of the writing process combined with opportunities to discuss ideas" (p. 264) are important in enhancing students' performance.

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On the web

Example student graphs and sample student conclusions: www.nsta.org/highschool/connections.aspx

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FIGURE 2

Instructional guidelines for Intervention 3.

1. Have students examine this data set or one like it:

Car	Engine oil type	Tire type	Racer	Lap time
1	Sunoco	Pirelli	Racer X	1:03
2	Sunoco	Goodyear	Racer E Jr.	1:03
5	Torco	Dunlop	Racer X	1:08
6	Torco	Pirelli	Racer X	1:09
7	Torco	Dunlop	Ricky Bobby	:56
10	Torco	Dunlop	Racer E Jr.	:59
3	VP	Pirelli	Racer X	1:07
4	VP	Goodyear	Ricky Bobby	1:05
8	VP	Dunlop	Ricky Bobby	:58
9	VP	Pirelli	Ricky Bobby	:59

2. Have a discussion focusing on questions such as:
* What observations can you make by looking at the data?
* What would you need to do to write a good conclusion about this data?
* What are the elements of a good conclusion?

3. Introduce the conclusion guidelines in Figure 1.

* Discuss each guideline and why it is important. In particular, focus on the second item and how one can use evidence from the data to support assertions made in the conclusion. Help students see that it is the connection between the evidence and the claims that must be supported in a good conclusion.
* Demonstrate how reorganizing the data allows some trends to become more obvious. For example, the data could be reorganized by oil type so that a relationship between oil type and lap time can be explored.

4. Ask students to practice writing a conclusion using another data set (Figure 3, p. 46) and give them feedback.

Figure 3
Food data set.

Food	pH	Taste
Banana	4.7	sweet
Beets	6.0	sweet
Black olives	7.0	salty
Blueberries	3.3	sweet
Cantaloupe	7.1	sweet
Celery	5.7	salty
Chocolate cake (packaged)	8.0	sweet
Cow milk	6.5	mild sweet
Cranberry juice	2.4	tart
Egg whites	7.9	mild sweet
Egg yolk	6.1	mild salty
Frozen raspberries	3.2	sweet, tart
Golden Delicious apple	3.6	sweet
Grapes, seedless	2.8	sweet
Grenadine (cherry syrup)	2.3	sweet
Lemon	2.2	sour
Lobster, cooked	7.4	mild sweet
Mushrooms, white	6.7	mild sweet
Orange juice, California	3.3	sweet, tart
Peaches, frozen	3.2	sweet
Pickles	5.4	salty, tart
Pineapple, canned	4.1	sweet or tart
Strawberries	3.0	sweet, tart
Tofu	7.2	bland, milky
Tomatoes	4.3	sweet, tart, or salty
Tuna fish, canned	6.2	mild salty
Vinegar	2.4	tart

Figure 4
Conclusion scoring rubric.

Low-quality conclusion	* No inferences made or support for inferences based on data * No statement of data trend
Medium-quality conclusion	* Inferences made with little to no support based on data * Vague statement of data trend
High-quality conclusion	* Inferences made with clear support based on data * Detailed statement of data trend, possible mention of outlying data

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http://find.galegroup.com/gps/infomark.do?&contentSet=IAC-Documents&type=retrieve&tabID=T003&prodId=IPS&docId=A186141588&source=gale&userGroupName=wsalem&version=1.0

It may sound unorthodox, but as a middle school science teacher, Ive found that one of the best ways to engage students is through creative writing.

When students write research papers, their first instinct is often to collect as many facts as they can into a big pile and string them together into a report. If I am lucky, they will have avoided literally cutting and pasting, but really, how far away from copying is it to regurgitate whatever you have read, changing a few words here and there? What I really want is for students to make ideas their own. I want them to understand their subject as a result of their researchand be able to explain it in a way that makes it fresh.

My favorite tactic for this purpose is to ask them to do some original creative writing. One year, for example, I had them write science fiction stories describing travel to another planet in our solar system. I started with some modeling, reading passages from Arthur Clarkes classic story, aeA Fall of Moondust.g This story was written before the Apollo moon landings, and described a lunar surface very different from what we actually found there. But that was part of the fun. Students could see how Clarke had taken the limited knowledge we had of the moon and woven an adventure around those facts, filling in with imagination wherever the facts were lacking.

I allowed students to choose a planet they wanted to travel to and provided them each with a folder full of information about their planet. I had them do some basic research. What is the atmosphere? Does the planet have a solid surface? Does it have moons? What is the temperature? What resources might we find there? Then comes the challenge. They were asked to write a story describing a trip to this planet. The space travelers would need to be equipped to survive on the planet, and the story would need to include as many science details as possible.

My students had a lot of fun with this assignment. Some were more artistic, so I allowed them to create cartoon-style stories, illustrating the adventure, with dialogue written in bubbles over the characters heads. Others wrote elaborate soap operas, with characters living out the dramatic lives typical of a teenager. Planetary facts were not always foremost in their work, but the rubric gave them points for creatively incorporating as many facts as possible.

This strategy, of course, is easily adapted to math, social studies, and other content areas beyond English and language arts. Also, if youre looking for ways to integrate digital tools like blogs, wikis, podcasts, or photostory into your classsroom, this kind of imaginative writing activity can be easily adapted to those environments. Here are some other writing-project ideas in science:

A first-person diary describing a day in the life of your favorite animalwith information about habitat, predator-prey interactions, and survival strategies.

A first-person account of a major volcanic eruption, such as Mount St. Helens, including all relevant scientific details, the type of volcano, the nature of the eruption, the damage done, and so on.

A story describing the journey of a bite of food from the mouth on downward, with details showing all the steps along the way (this makes a great comic strip or first-person account).

A childrens book explaining acids and bases so that a 4th grader could understand, using examples of chemical reactions, and diagrams showing how the reactions occur.

With due credit to H.G. Wells, a story about a trip back in time to the Jurassic or any other era, describing the plants, animals, and topography of the time.

And with a nod to Jules Verne, a scientifically accurate journey to the center of the earth, describing the characteristics of each layer one would encounter.

For each of these projects, I would scaffold the research by providing students with reference materials, books, and articles I have already printed out from the Internet. This gives them the basic information they need and cuts down on Web-surfing time. Allowing them to choose from several options increases their enthusiasm and sense of ownership. Their challenge is to make the facts come alive, through their own imaginations.

The results are a wide variety of projects, reflecting the diverse interests and talents of the students.

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Full Text:

[ILLUSTRATION OMITTED]

"I'm not an English teacher, so I can't use writing assignments in my class."

"I can't take time--that could be used for 'real' science activities--to set up, assign, and grade written products."

These are two of the thoughts that ran through my mind when my graduate studies advisor suggested I try "writing-to-learn" activities in my classes. Like many high school science teachers, I often thought that devoting class time to writing would take away from valuable time that could be spent doing "science learning" activities. I also felt that my training as a science teacher had not fully prepared me to instruct about or evaluate these kinds of assignments in the classroom.

However, as I encountered the growing body of research on writing-to-learn activities and their potential benefits (Prain 2006; Wallace, Hand, and Prain 2004), I gradually began to change my mind. Writing-to-learn activities are designed to use writing as a process in which students generate and clarify understanding of scientific concepts for themselves, rather than simply communicating with a teacher for evaluation. Instead of having students parrot science facts back to the instructor, writing-to-learn activities focus on the production of nontraditional writing assignments--such as poems, brochures, or letters--to develop student understanding (Yore and Treagust 2006).

In addition, I found that recent definitions of science literacy emphasize the literacy component (Yore, Bisanz, and Hand 2003; Norris and Phillips 2003), so I began to search for classroom activities that would improve students' reading and writing skills. This search led to my use of one particular kind of writing-to-learn activity called a multimodal writing task. Through these tasks, students combine different modes of representing information--such as graphs, diagrams, charts, mathematical equations, or pictures--with text to create a more complete description of the science concepts being studied. This article highlights my experience using multimodal writing tasks and their impact on student learning in my high school biology and chemistry classrooms.

Writing-to-learn in science classes

Using writing in science classrooms is not a novel idea. High school science students often communicate their understanding of a particular concept in some kind of written form for evaluation. However, current research aimed at viewing writing as a process that can help students develop and generate knowledge is leading to more widespread use of writing-to-learn tasks (Galbraith and Torrance 1999).

The goal of these tasks is to have students learn science concepts by conveying their conceptual understanding--in their own words--to authentic audiences. Authentic audiences are composed of people outside of the classroom who read and evaluate the written product. In the past, I have used parents, peers outside of our class, or even an elementary school class whose teacher was willing to have the students volunteer as authentic audiences. In doing so, students translate the information they have encountered in class through discussion, lab activities, or research into everyday vocabulary that can be used to explain their understanding to someone who is unfamiliar with the concepts (Prain and Hand 1996). This often leads to a realization that the student's initial understanding was inadequate or lacking some detail, initiating a process in which he or she strives to improve understanding and then communicate this new understanding. Ideally, this cycle promotes learning, as opposed to students simply repeating vocabulary they hear but may not necessarily understand (Gunel, Hand, and McDermott 2009). Prain and Hand (1996) suggest that asking students to create nontraditional science writing products may initiate this cognitive process (Yore and Treagust 2006).

Figure 1
Strategies for embedding alternative
modes in text.

1. Place the mode near the text that deals with the related concept.

2. Refer to the mode in the text (e.g., "Please refer to Figure 1.").

3. Include a caption with the mode summarizing what it describes.

4. Create the mode yourself rather than using a mode someone else created.

Figure 2
Progression of the lesson.

1. The teacher presents a lesson highlighting embeddedness strategies.

2. Students create an embeddedness assessment checklist.

3. The multimodal writing activity is assigned.

4. The assignment is evaluated by an authentic audience and then returned with feedback.

5. Students use the embeddedness assessment rubric they created to self-assess their multimodal assignments.

A sample rubric is available (see "On the web").

6. The final product is turned in to the teacher.

7. Students take the end-of-unit assessment.

My initial attempts at using writing-to-learn tasks were based on a model suggested by Prain and Hand (1996), in which the teacher considers the topic, type, audience, means of text production, and curricular purpose for the writing in setting up the task. My students participated in activities such as writing letters about stoichiometry to seventh graders, creating storybooks about the circulatory system for third graders, and designing magazine articles about atomic structure for their peers. These tasks provided some benefit for my students, who improved their scores on end-of-unit evaluations. This is consistent with research reporting conceptual improvement, greater grasp of the nature of science, and improved metacognition (Gunel, Hand, and McDermott 2009).

However, as I used more of these writing-to-learn tasks, I realized that for some students, the creation of text-only writing was daunting, not because of the science issues involved, but because of their difficulties and discomfort with writing skills. I realized that I needed to create writing activities structured to give students alternatives for expressing their understanding. Discussing this issue with my colleagues led to the idea of creating multimodal writing activities, in which students can choose to include other methods of explaining science information, such as pictures, charts, graphs, diagrams, and mathematical expressions, in addition to text.

Exploring multimodal writing tasks

The multimodal writing tasks I set up were similar to the writing-to-learn tasks I had used previously, in which students created nontraditional products for authentic audiences. However, for these modified tasks, students were required to use at least one mode of representation other than text. Several factors indicated the potential benefits of these types of tasks:

1. Student achievement is not dependent on writing skill alone: Using different modes of representation provided students who were not strong writers, were lacking confidence in their writing skills, or were not motivated to produce written products with an alternative way to express their understanding.

2. Scientists use multiple modes of representing information: Scientists use many different modes when communicating their ideas in journal articles or the popular press. Therefore, multimodal tasks serve as authentic representations of science processes, including how scientists communicate (Gunel, Hand, and Gunduz 2006).

3. Students are familiar with multimodal environments: Everyday life is more multimodal than ever. Through the internet and other technology tools, students encounter, communicate with, and respond to multiple modes of representation on a daily basis. The

use of multimodal products may be more familiar to students and thus may be a motivating factor.

4. Consideration of relationships between modes increases understanding: It was my hope that asking students to present information in a variety of formats would encourage them to consider how different modes fit together to describe a related concept--and this would lead to a more developed understanding.

With these factors in mind, I designed my first multimodal task and presented it to my students. To my dismay, the products they created did not meet my expectations, nor did they lead to any noticeable benefits.

Improving the multimodal learning process

The most obvious problem with the products of this first assignment was that almost all of my students simply added an alternative mode at the end of their written text to fulfill the requirement. There was little or no consideration given to how the different modes could work together to communicate the overall idea, and therefore the activity offered little benefit beyond that of a writing-only task.

In my next attempt at a multimodal assignment, I included a lesson specifically designed to highlight strategies that authors commonly use to integrate different modes within a text. This characteristic was termed embeddedness. In general, embeddedness refers to the purposeful use of strategies to connect all of the different modes used in a written product. In the embeddedness-encouraging lesson, students were asked to first locate different modes in common science sources, such as textbooks, journal articles, or magazines. They then identified the strategies authors used to tie information from the text to information from an alternative mode of representation, and explained how this created a well-integrated product. Figure 1 (p. 33) lists several examples of embeddedness strategies.

After discussing these strategies, students created a checklist that could be used to evaluate a multimodal product and determine whether the alternative modes were effectively embedded in the text. They then created small-scale models of well-embedded multimodal products, such as posters, to evaluate and share with the class. Students also received feedback on early drafts from their authentic audience. Finally, students used the checklist to self-evaluate their drafts and assess their own level of integration. Figure 2 (p. 33) provides a progression of the lesson.

The results of this second experience were much more encouraging. Not only did students improve their integration of the different modes, but their performance on the end-of-unit assessment was strongly correlated with the degree of embeddedness. In fact, the correlation between the degree of embeddedness in student writing and overall scores on unit tests following the final multimodal writing task were all significant ($p < .05$). In general, students who successfully integrated their written text with alternative modes were also more successful on the end-of-unit assessment. Many students who had struggled with science concepts in the past or with previous text-only tasks showed improvement in both conceptual understanding and in performance on the multimodal task. In fact, correlations between degree of embeddedness and overall student performance were strongest with lower-achieving students--meaning that multimodal tasks may be more beneficial for helping lower-achieving students gain a better grasp of science concepts.

[FIGURE 3 OMITTED]

I recently compared student performance between classes that received the embeddedness-training lesson with classes that did not receive the lesson in classrooms taught by four different teachers. These teachers taught the embeddedness lesson to only half of their classes. In all cases, classes receiving the integration lesson had higher levels of embeddedness in their writing; in three of the four cases, classes receiving the lesson had significantly higher end-of-unit exam scores on at least one assessment measure. These relationships certainly do not guarantee that multimodal tasks cause greater student learning, but the consistently positive relationship between the level of embeddedness and student performance on end-of-unit assessments suggests these tasks are useful in the classroom. Figure 3 provides examples of different multimodal writing products.

Student feedback

More powerful evidence of the benefit that these kinds of tasks offer, however, has come from the students themselves. In general, student comments for this assignment indicated that while they found these tasks more challenging than other classroom activities, they felt that the activities allowed them to more fully understand the concepts. Many students noted the benefit of dealing with a concept in multiple ways and seeing how different modes can communicate the same "big idea." In addition, students enjoyed being able to display their scientific understanding in whatever way they felt most comfortable and confident. The process of selecting the mode of representation was helpful in clarifying their understanding. Many students also noted that these tasks did not allow them to "hide behind vocabulary terms" and that they really had to consider and develop their science understanding to accomplish the multimodal tasks assigned. Finally, while some students felt these types of "language arts" tasks had no place in science classrooms, the vast majority indicated that it was helpful, productive, effective, and even "normal" to use writing skills in a science classroom.

Reflection

My colleagues and I have now used a number of multimodal writing tasks in our classrooms. Figure 4 lists several examples that have been used or considered. From my experience, I have noticed a few key issues that impact student success. First, as discussed, the benefit of asking students to use multiple modes is dramatically improved when these modes are successfully integrated into the text--this integration improves when students experience the lesson on embeddedness strategies. Therefore, the structure of the prewriting, embeddedness-training session is critical.

Second, student involvement in all aspects of the process is not only beneficial, but can also serve as a motivating factor. Asking students to help identify effective embeddedness strategies, debate the appropriateness of particular modes for particular topics, and design the multimodal tasks and evaluations are all ways to get students involved in the process.

Finally, students seem to gain increased benefit from multiple experiences with these tasks. The first products students create may not immediately lead to improved conceptual understanding, but being patient and letting them continue to try may be the key to success. Explore the different ways you can set up these activities so you can discover the best way to use multimodal writing tasks in your classroom.

Figure 4
Sample multimodal tasks for students.

* Create a magazine article for a high school journalism class discussing the structure of the atom, the periodic table of the elements, and the relationship between the two.

* Write a letter to your parents describing a week in the life of a cellular organelle.

* Develop a travel brochure describing a famous volcano and how it works.

* Publish a newspaper article about how recycling works in your school and what happens to the recycled material.

* Make a cartoon for a third-grade class explaining how Newton's laws impact their everyday life.

On the web

Sample embeddedness assessment rubric: www.nsta.org/highschool/ connections.aspx

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http://find.galegroup.com/gps/infomark.do?&contentSet=IAC-Documents&type=retrieve&tabID=T002&prodId=IPS&docId=A179135657&source=gale&userGroupName=wsalem&version=1.0

As she circulates, Ms. Adams observes third graders working in three-person teams. Students dig, stir, talk, draw, and write while observing a mix of brine shrimp eggs and sweet pea seeds placed in salt water and in soil. The task during this second lesson of Investigating Life Cycles (BSCS 1999) is to gather evidence and determine which objects are eggs and which are seeds.

Although Ms. Adams observes Emil (all names are pseudonyms) engaged over several days with team members, it is not until she reads her students' notebooks that Emil's confusion surfaces. Emil is learning English, and Ms. Adams relies not only on observations of students and conversations with them during investigations but also upon her examination of written and sketched notebook entries. By integrating science, literacy, and art, Ms. Adams provides multiple ways for students to communicate understandings and collects rich, ongoing assessments.

We feature Ms. Adams's approach as one example of how teachers can use writing and drawing in science to meet the needs of students learning English and also guide her teaching. We conclude by noting some of the difficulties posed by integration and offer recommendations.

Why Writing and Drawing?

Experts such as Klentschy and Molina-De La Torre (2004) emphasize writing in science notebooks to promote scientific understanding. As they make entries in notebooks, students question, predict, plan, record, explain, and interpret. Teachers read students' entries to guide instruction and assess growth. Science writing is more than a record of procedures, data, and facts; it is a tool for developing and articulating thinking (Vygotsky 1978).

By overlapping literacy and science instruction, teachers and students build on existing knowledge and skills in both subjects (Armon and Morris 2006; Saul 2002). Precise word choice, for example, is essential in both writing and science reporting. Teachers demonstrate science writing while linking vocabulary to visuals such as photographs and concrete materials, particularly for students learning English (Krashen 2003). As students develop academic vocabularies in content areas, academic achievement improves (Marzano 2004) as does clarification of thinking (Marzano, Pickering, and Pollock 2001).

Since drawing requires careful observation of an object's or phenomenon's distinctive characteristics, students attend to details they might otherwise overlook.

Assessing and Responding

The goal of the investigation described in the introduction is for third graders to understand life cycles. Students discover that seeds or eggs are the beginnings of life cycles and that seeds and eggs are alive. Ms. Adams observes students during science investigations and examines their notebooks to assess their understanding and her teaching. Periodically she questions students, asking them to construct on-the-spot drawings to demonstrate understanding.

Emil's notebook entry at the beginning of the unit in March appears in Figure 1, page 50. Emil's writing, "the little seeds are haching," suggests a lack of understanding that seeds grow into plants. No drawing accompanies the text. Ms. Adams is uncertain whether Emil does not understand the science concepts that seeds grow into plants and that eggs grow into animals or if the English vocabulary is unfamiliar. This is Emil's first year in this country, so he missed the second-grade science unit featuring seeds growing into plants. The writing suggests Emil may not understand the concept that an egg and seed are alive or that they occur at the beginning of the life cycle. Ms. Adams wonders if Emil understands these concepts and related vocabulary in his native language (Romanian) but is unable to express understanding in English. Highlighting specific vocabulary connected to concrete examples would benefit Emil. However, in the crowded curriculum, Ms. Adams lacks time to grow plants with Emil to assess and build background knowledge. Instead, in a one-on-one conference, she reads From Seed to Plant (Gibbons 1991), explaining pictures and vocabulary (seed, grow, root, stem, leaves, plant) of a plant's life cycle. As she talks, she draws the cycle in sequenced boxes on the whiteboard, adds labels, and asks Emil to repeat key words after her.

Next, to stimulate talk among Emil and his peers about the plant life cycle, Ms. Adams rereads From Seed to Plant with Emil and his group. Then, at the whiteboard, Emil and his peers collaborate to draw and label a plant life cycle, pronouncing each term several times. The drawings remain on the board.

Then Ms. Adams reads Where Butterflies Grow (Ryder 1989), which presents text and images describing the change from a caterpillar to a butterfly. Afterward, the group returns to the whiteboard to add (under their plant life cycle sketches) labeled drawings of the butterfly life cycle (egg, caterpillar, cocoon, butterfly). Ms. Adams emphasizes the egg's development and then compares and contrasts the two life cycles by pointing to and naming drawings in both cycles, first at the board and then in the two books. She explains the seed growing into a plant and then explains the egg growing into a butterfly.

Ms. Adams assesses Emil's emerging understanding of key vocabulary by asking Emil to point to each stage of each cycle and state the correct term. Ms. Adams notes Emil's growth several days later when Emil completes this task on his own and uses terms correctly during group work.

In April, Emil demonstrates growth in recording observations. A drawing accompanies the writing (Figure 2), and more detail appears both in the drawing and the written vocabulary ("cocoon"). The drawing and the writing include "yellow spikes" on the cocoon, and the drawing includes labels ("jar," "cocoon," and "food"). To build on the strategy of questioning, which students use during reading and writing, Ms. Adams asks Emil to generate a science-focused question about his observations. Emil writes, "Why isn't he moving at all?" and offers an explanation: "I think he is turning into a cocun." The concrete experience of observing a living caterpillar has captured Emil's interest and stimulated more detailed observations, which are evident in this notebook entry. An understanding of the concept that "change occurs in a life cycle" also is evident in this notebook entry.

[FIGURE 1 OMITTED]

By May, Emil shows increasing understanding of the life cycle of a butterfly (Figure 3, p. 52). Three components of the cycle appear, the writing and drawing again include greater detail than in previous entries, and the vocabulary shows more sophistication than earlier entries (e.g., in addition to "caterpillars" and "cocoon" present in the April entry, Emil adds the terms "turned into," "butterfly," "drink," and "net").

Assessing understanding from this entry, Ms. Adams notes that Emil omits wording or drawing of the egg as the beginning of the life cycle. Experiencing all four stages in a life cycle investigation is essential. In this classroom investigation, actual butterfly eggs are not observed; the investigation begins with caterpillars shipped to the classroom. Although Emil and his peers constructed a simulated life cycle of the butterfly with paper objects representing each component in the cycle, she wonders if Emil may not understand that the simulated paper egg represents the live egg missing in the classroom cycle.

[FIGURE 2 OMITTED]

Again, Ms. Adams returns to the whiteboard with Emil to assess his thinking, asking him to draw and label the butterfly life cycle. Building on his previous whiteboard drawings, Emil draws the egg first, and Ms. Adams reinforces the concept of the egg at the beginning of a butterfly life cycle. To provide additional reinforcement, Ms. Adams pairs Emil with Lily, a peer in his group, to reread and talk about the life cycle books.

Strategies to Support Integration

Reinforcing understanding through trade books is just one of many instructional strategies teachers can use to support integration and respond to students' differing needs. Teachers can also:

Assess students' understanding before, during, and after investigations, such as using a KWL (what I Know, what I Want to know, what I Learned) chart, one-on-one conferencing, or rereading notebook entries, to continuously correct false information and clarify thinking. Ms. Adams and Emil, for example, held several one-on-one conferences.

Deepen students' understanding of science concepts through concrete experiences with authentic materials and complete processes. In the experiences discussed in this article, the students observe, talk, draw, and label the full life cycle of both a bean plant and a butterfly.

If possible, take related field trips to complement science explorations. For example, next year, Ms. Adams hopes to raise funds to take students to a local butterfly pavilion during the life-cycles unit.

Model the writing techniques that you want students to emulate. Project your own notebook entries on an overhead, read them aloud, and demonstrate writing strategies, such as replacing vague words with more precise ones. Identify any missing or confusing details and clarify them for the class. For example, in the butterfly unit, Ms. Adams writes, "My caterpillar is interesting." She asks the class if this entry creates an accurate picture of a caterpillar in their minds. When students respond that it does not, she erases "is interesting" and writes "has a yellow wormlike shape with fuzz on it." Students agree that these words help them visualize a caterpillar.

Model drawing techniques using line, shape, texture, and color. These techniques foster accurate drawings that reveal specific information valued in scientific drawings. Such drawings rely on close observation but can improve when students build on skills learned in art classes. Teachers who lack knowledge of drawing techniques could involve the school art teacher.

Facing Integration Challenges

Of course, incorporating writing and drawing effectively into your science lessons is not without its challenges. Below we point out some of the main obstacles and suggest some remedies for addressing them.

Time--Adding writing and drawing to science investigations requires more time. To maximize time, include science writing and drawing throughout the day, overlapping strategies used in science, literacy, and art, such as questioning, informational writing with drawings, or inferences based on evidence.

Vocabulary--Some students, particularly those learning English, may not be familiar enough with science, literacy, and art vocabularies to demonstrate understanding through writing and drawing. Supports such as word walls (index cards display words with icons, photos, or drawings) or labeled objects on a table support and cement significant vocabulary.

Balance--One of the integrated disciplines may not be addressed as fully as the others. To avoid potential imbalance, deliberately highlight each discipline with focused instruction on certain days within the integrated study.

Despite the challenges posed by increased time, specialized vocabularies, and balance, integrating writing and drawing with science investigations is beneficial for teachers and students. Students, particularly those learning English, gain multiple ways of acquiring and expressing knowledge in several disciplines, and, as a result, teachers obtain valuable, ongoing data to assess students' understanding and improve instruction.

[FIGURE 3 OMITTED]

Connecting to the Standards

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

Teaching Standards

Grades K-4

Standard B:

* Teachers of science guide and facilitate learning.

Standard C:

* Teachers of science engage in ongoing assessment of their teaching and of student learning.

Resources

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Baker, William P., Renee Barstack, Diane Clark, Elizabeth Hull, Ben Goodman, Judy Kook, Kaatje Kraft, Pushpa Ramakrishna, Elisabeth Roberts, Jerome Shaw, David Weaver, and Michael Lang. "Writing-to-learn in the inquiry-science classroom: effective strategies from middle school science and writing teachers. " The Clearing House. 81.3 (Jan-Feb 2008): 105(4). General OneFile. Gale. West Salem High School. 17 June 2010 http://find.galegroup.com/gps/infomark.do?&contentSet=IAC-Documents&type=retrieve&tabID=T002&prodId=IPS&docId=A175445621&source=gale&userGroupName=wsalem&version=1.0

Abstract: Student writing skills are an important concern for every teacher. This is especially true when using inquiry-based approaches in the science classroom. Writing promotes critical-thinking skills and construction of vital scientific concepts and challenges ingrained misconceptions. Yet, many teachers encounter practical problems when incorporating writing into science-inquiry activities. In this article, the authors asked middle school science and writing teachers to generate a list of common barriers to implementing writing-to-learn strategies in science-inquiry lessons and suggest methods by which these difficulties might be overcome. The resulting suggestions should help teachers deal with the inevitable problems that arise when incorporating writing-to-learn in their classrooms.

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Writing skills are an important concern for every teacher. Research and experience, however, indicate that this is especially true when using inquiry-based science activities (Keys 1999; Lawson 1995; Ryan and Walking-Woman 2000). Researchers have demonstrated that writing not only allows students to reflect on existing knowledge and experiences, but it also enables them to actively construct new understandings (Anders and Guzzetti 1996; Yore, Hand, and Prain 1999). Writing thereby promotes metacognition and conceptual understanding (Wallace, Hand, and Prain 2004). Ryan and Walking-Woman state, "Exploratory writing, written field observations, close description, and written discussion, among other activities, are essential components of scientific inquiry" (1). Not surprisingly, many teachers have enthusiastically embraced writing-to-learn strategies in their science classrooms (Keys et al. 1999; Klein 1999). The goal is to help students develop skills that enable them to think critically, construct vital scientific concepts, and challenge their ingrained misconceptions.

Yet, we found that many teachers encounter practical problems when incorporating writing into their science-inquiry activities. Therefore, in this article, we briefly describe how we identified some of these problems and suggest solutions. We argue that instead of viewing writing as "one more thing" added to science, writing should be understood as an integral part of doing science. We provide teachers with a list of potential barriers and solutions so that they may avoid common problems altogether or reduce their severity. In our view, it is vital that teachers work to effectively implement writing-to-learn strategies in the context of inquiry-based science activities.

Identifying Concerns

During a recent semester, we asked middle school science and writing teachers to generate a list of common classroom problems they experienced while implementing writing-to-learn strategies in science-inquiry lessons. We then ranked the problems by their severity (that is, not a problem, slight problem, moderate problem, or serious problem). We initially grouped responses based on common elements. We then narrowed these initial groupings into categories reflecting similar concerns and gave the categories a descriptive, summary title. We then asked the teachers to consider each in turn and suggest methods by which the difficulties might be overcome.

Solving the Problems

When first introduced to writing-to-learn strategies, virtually every experienced teacher agrees with the emphasis on creative and critical thinking. Nevertheless, when confronted with the task of incorporating such activities into science-inquiry teaching, many ask, "Will I be able to do it with my students?" The answer is an emphatic yes. None of the difficulties we identified is sufficient to prevent a teacher from using this effective tool.

However, to successfully infuse writing into the science-inquiry classroom, specific learning strategies and practical solutions for problems encountered are needed. The following sections outline key writing-to-learn strategies and offer classroom-specific teaching tips for middle school teachers to handle common barriers.

Scheduling and Time Constraints (Serious to Moderate Problem)

Many teachers were concerned about having enough planning time for the management of both students and course work. Workloads for teachers are already high. Scheduling writing-to-learn activities in science necessitates coordination of two subject areas. Some teachers claimed this involved too much time and energy. This was particularly true for teachers who relied on text-based programs and commercially prepared materials for which daily planning is relatively easy. This objection is valid. Yet, teachers must keep in mind that just as with other teaching styles, although initial preparation is time-consuming, their time commitments decrease significantly each year once they have developed lessons.

In many cases, teachers were able to overcome scheduling and time constraints by asking for opportunities to plan that were directly related to writing instruction. They stressed organization and flexibility, and frequently renegotiated and adjusted scheduled activities. Middle school teachers we questioned also said planning must take into consideration school-wide interruptions such as holidays and test days. In their experience, no more time is required for writing-to-learn strategies than for traditional activities. Writing that is authentic and embedded into inquiry activities actually requires less time to teach because students soon become motivated and involved in the process (Lawson 1995). Writing becomes an integral part of the science and not simply an additional task to perform.

Regardless of school or grade level, teachers agreed that students need multiple opportunities to write in the same genre. For example, students should use reflective journal entries, short essay reports, written observations, and cooperative writing at several stages in the inquiry process. At the middle school level, teachers should repeat similar instructional activities over the course of a semester or school year. In this way, students have multiple opportunities to practice and hone particular writing skills, and educators have the opportunity to model the use of writing in scientific investigation.

Teacher and Student Attitudes about Writing (Moderate to Slight Problem)

Why are middle school teachers hesitant to add writing-to-learn activities to their inquiry-science teaching? Many of the middle school science and writing teachers consulted felt they need a stronger "buy in." When teachers understand and accept a method, they actively include it in their classroom repertoire (Turnbull 2002). Our experience indicates the same is true for writing in the science-inquiry classroom. We found that teachers must feel comfortable with both the inquiry science and basic writing-to-learn strategies. Granted, leaving the comfort zone of traditional, expository, or text-based teaching takes some courage. Yet, the modest personal risk can be viewed as less than that of the risk to society if schools fail to provide students with effective writing and problem-solving skills.

To this end, teachers must become familiar with lessons ahead of time and modify activities to meet both science content and writing objectives. An excellent strategy is for writing and science teachers to develop projects together. Our science teachers recommended teaching science activities to cooperating language arts teachers prior to working with students to obtain feedback on writing ideas. They also suggested developing a repository of exemplary inquiry lessons that may serve as models for developing new activities. These might be centered on thematic units or tailored to the resources of a particular school.

An often-heard student objection is "Why are we writing in science? This isn't writing class." Usually, this concern is encountered not because the writing tasks are difficult, but because students have not been given adequate instruction in writing content and forms. As Hand, Wallace, and Yang (2004) noted, laboratory activities and reports are traditionally prescriptive in nature and mainly an exercise in memorization. In our view, encouraging students' problem solving and creative thinking is far better than testing their ability to memorize. Effective critical-thinking and writing skills can be developed and are transferable to other content areas; however, rote recall of specific facts has limited value (for a review, see Lawson 1985). By consistently infusing writing into the science-inquiry classroom, teachers have the opportunity to model the use of writing as the norm in science.

Evaluation and Feedback (Serious Problem)

The middle school teachers identified evaluation and feedback as serious concerns. As Akerson and Young (2005) noted, "Learning to write well is a long process that comes through teacher modeling, instruction, practice, and feedback." Direct instruction in writing skills is not sufficient. In the words of Wallace, Hand, and Prain (2004), "The data indicates [sic] that students are unfamiliar with and need enculturation into scientific report genres." We define scientific genres as scientific forms of expression. We suggest that teachers model the use of appropriate genres so that students understand how the final product should be written (for examples, see Miller 1997). Then, provide them with a heuristic, such as the science writing heuristic (Hand, Wallace, and Yang 2004), to guide their writing and problem-solving activities. Wallace (2004) provides many good suggestions. Research has demonstrated significant gains in student achievement using these activities in an inquiry-learning environment (Rudd et al. 2001).

Regular feedback and encouragement with ample opportunities for revision are also essential (Jones 1991). Teachers use written reviews, peer-response sessions, individual face-to-face conferences, and large-group discussions of sample student papers. Based on our current understandings of writing-to-learn science, students who receive meaningful feedback regarding revisions and their rationale gain a better understanding of the writing process and the nature of science (Jones). This process also develops metacognitive awareness that stimulates science content learning (Wallace, Hand, and Prain 2004).

Ideally, evaluation of inquiry activities should emphasize both content and process skills (Lawson 1995). For example, while the class is engaged in an activity, many teachers observed each student's performance. They used portfolio research notebooks to collect products of individual-student and group work, such as lab worksheets, drawings, journals of observations, self-evaluations, and answers to assigned questions. Many of the teachers with whom we spoke had students journal about their learning, write analytical or reflective essays, or use e-mail discussion boards for conversations about experiments. Such activities encourage students to reflect on their developing knowledge and demonstrate scientific-thinking skills in assessable ways (Akerson and Young 2005).

Implications for Teaching Practice

As Keys (1994) noted, "The task of creating a written product can be a powerful tool for developing science understandings because it requires the writer to retrieve, synthesize and organize information." Yet, as we mentioned earlier, we found that many teachers encounter practical problems when incorporating writing into their science-inquiry activities. Clearly, a great deal must be kept in mind when implementing writing-to-learn strategies in the context of inquiry-based science activities. Developing the needed teaching skills takes considerable practice and commitment. However, once those skills have been acquired, the inquiry classroom becomes an exciting and rewarding place. The middle school teachers' suggestions featured here are intended to help teachers new to inquiry deal with the inevitable problems that arise when implementing writing-to-learn in their classrooms. We encourage you to give these suggestions a try. The potential benefits to your students are great.

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Byline: Sandra K. Abell

"My fourth graders write all the time in science. They record Purpose, Equipment, Procedures, and Results in their science notebooks for every activity. But lately they seem to resist writing. I'm thinking of dropping the writing-it just takes too much time. After all, they just need to learn science in science class."

Why use writing in science?

Many teachers use writing in science as a recording tool (science notebooks) or to find out what students have learned (constructed response tests). Yet writing experts Judith Langer and Arthur Applebee (1987) tell us that writing to evaluate knowledge and skills is only one of several purposes for writing. According to their framework, writing in science classrooms can also: 1) draw on prior knowledge to prepare for new activities, 2) foster new learning, 3) consolidate and review ideas, and 4) reformulate and extend knowledge.

Can writing help students understand science better?

One of the most important reasons for using writing in science is to foster conceptual understanding. Mason and Boscolo (2000) studied Italian fourth-grade student writing in science. Students who engaged in writing to reflect, reason, and compare understood photosynthesis better than students who did not write to learn. Fellows (1994) found that urban middle school students who had more opportunities for writing explanations produced better logical arguments and changed their concepts about matter and molecules. Other studies have shown that students who write to explain their ideas learn science better than students who write only to record or summarize (Hand, Prain, and Yore 2001).

What supports do students need for science writing?

Many students find it easier to express their ideas through talking than writing. In a study by Warwick, Linfield, and Stephenson (1999), 11-year-olds were able to express clear understanding of fair testing and other experimental design ideas in interview settings, but those ideas were less apparent in students' written work. However, teachers can help all students become better writers and better science learners by teaching them how to write scientifically. Warwick, Stephenson, and Webster (2003) found that the writing of fourth-grade students in England reflected high levels of understanding of ideas like variables and fair testing after teachers provided a writing frame with prompts such as: "We are trying to find out...We made the test fair by...." (p. 176). Working with second-grade students in Wales, Patterson (2001) found that when teachers provided explicit instruction in writing, students were able to express greater scientific understanding. For example, when teachers showed students how to use connectives (words like for, to, when, because) in their science writing, students moved from descriptions like "It has dots" to explanations like "It has got dots for bugs to eat" (p. 9). Thus, teaching writing techniques led students to express more thorough understanding.

How can teachers provide feedback on student science writing?

Owens (2001) found that elementary teachers are often frustrated about how to respond to science writing-Do we respond to the ideas or the writing? If students use the right words, does that mean they understand? How will my comments affect student learning?

How teachers respond to student writing will depend on the purpose of the writing. If writing is aimed at building science understanding, then teacher responses need to push for clarity in explanation and point out discrepancies in thinking. Teachers should not accept the right word as a substitute for conceptual understanding. For example, a student who writes, "Things float because of their density" might understand, or may just be making "noises that sound scientific" (Osborne and Freyberg 1985) without understanding that an object's mass and volume are both important considerations in sinking and floating. Teacher responses to science writing will help students become better writers and thinkers (Spandel and Stiggins 1990). In the density example, responses such as "What do you mean by density? Can you give an example? What about things that sink?" will help students move beyond vocabulary to conceptual understanding.

Should all students be expected to write in science?

All students can be involved in writing in science. For kindergarteners, science writing might include pictures and invented spelling. Even in second grade, students can improve their science thinking and writing when teachers provide writing supports such as concepts maps (Patterson 2001). But what about English language learners (ELLs) who struggle to communicate verbally, let alone in writing? Amaral, Garrison, and Klentschy (2002) conducted a longitudinal study of elementary science learning in a California district with 54% ELLs. The district instigated "kit- and inquiry-based science instruction that included the use of science notebooks" (p. 213) in grades K-6. According to research results, the longer ELLs participated in the program, the greater their science and writing achievement. By grade 6, ELL students who had been in the program for four years outperformed their English-proficient peers on a test of writing proficiency. The results of this study send a strong message that teachers should expect and support all students to succeed in science and writing.

What can teachers do to help students write to learn science?

Instead of merely writing about science, students need to engage in writing to learn science (Owens 2001). Writing to learn helps students build their knowledge through conjecture, explanation, comparison, and reformulation. Teachers can do the following to help students learn science better through writing:

Ask students to write in science every day;

Expect all students to be successful writers in science;

Provide writing tasks that go beyond recording and summarizing;

Include writing prompts that help students structure their writing; and

Respond to writing with direct feedback about the science ideas.

In these ways, writing and thinking become essential components of the elementary science classroom.

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http://find.galegroup.com/gps/infomark.do?&contentSet=IAC-Documents&type=retrieve&tabID=T002&prodId=IPS&docId=A139757252&source=gale&userGroupName=wsalem&version=1.0

Byline: Bill Robertson

Question:

What writing represents what scientists actually do?

Answer:

Often the writing that students in elementary school do in connection with science is their final report of a science fair project. They diligently file a report in the form of the scientific method-introduction, hypothesis, materials, procedure, results, and conclusion. This form of science writing persists through college courses in science, and it isn't unusual for someone majoring in a science discipline to have lab reports as his or her main writing product in science. Of course, one must do a paper or two based on researching and understanding a particular topic in science, but that's usually the extent of writing that ventures beyond reporting labs.

This situation brings up a couple of questions. The first is whether or not a report based on the scientific method accurately represents what scientists do. The second is what kind of writing scientists engage in that goes beyond the reporting of conclusions. I'll try to address those questions in this column. And no, I won't be providing a list of ideas for science fair projects! I know that's a major concern, but it's a topic for another column. For now, just tell 'em to do a baking soda and vinegar volcano (joking!).

First Do, then Write

Does the reporting of science using the scientific method really represent how scientists do science? The short answer is no. Scientists seldom follow the scientific method, even though the reporting of experiments in scientific journals more-or-less follows that template. The question that follows is, "Okay, smart guy, what procedure do scientists follow?" To understand that process, it might help to consider what most kids do when they get a new video game. Do they read the instructions? Nah. They familiarize themselves with the controls and just start playing. They mess around with the game for a while and see what happens. Only then do they go back to the instructions to learn a few things. The instructions make a whole lot more sense once you are somewhat familiar with the game.

Scientists do something similar to what kids do when first playing a video game. They "mess around" a bit with the subject matter. Of course, messing around in science isn't exactly the same as messing around with a video game. Messing around in science means you become familiar with the research already done in your area, and it means trying out a few experiments (or thoughts in the case of theoretical science) just to see what happens. You might even try to reproduce what others have done to hone your skills. The main point is that, until you become familiar with what you're studying, you can't begin to formulate a hypothesis. Formulating a hypothesis is a first step in the scientific method, but it is not the first step in doing science.

Just a quick note about how scientists proceed from the point of formulating a hypothesis. A scientist might start with a particular question to investigate and soon realize that the original question was the wrong one or that the original question has led to a more intriguing question. A scientist who is truly interested in his or her field of study soon has more questions than he or she can answer in a lifetime. This is one of the reasons that scientists take on research assistants to help accomplish goals. Another reason is that graduate assistants are a cheap source of labor!

"Talking" Results

It would be pretty boring if all of science writing involved nothing more than people publishing the results of their experiments. Thankfully for us, that's not all they do. The "scientific community" wouldn't put up with that, anyway. When you make a claim of an experimental result or alteration of a scientific theory, you can expect that others in your discipline will scrutinize your work, looking for errors in procedure or errors in the logic that led you to your particular conclusions. Most science journals publish not just original research but also responses from other scientists to that research. A back-and-forth conversation regarding relevant issues is not uncommon.

A good example of this was the "discovery" of cold fusion a number of years ago. The original research publication on cold fusion sparked a whole bunch of articles in which scientists mostly refuted the original results. Without this written criticism, we would not now know that cold fusion was an unfulfilled dream.

Some of the more interesting historical science artifacts are letters written back and forth between prominent scientists who disagreed on various theories, from the theories of electricity and magnetism to the theories of quantum mechanics. With increased publication in national journals, the mobility of scientists, and the presence of the internet, such personal written correspondence between scientists is not as common as it was 100 years ago, but such correspondence still established the need to be able to communicate one's ideas and be able to criticize others' work in a coherent way.

Communicating Concepts

One of the most important uses of writing in science is to communicate the concepts of a discipline to both future scientists and laypeople. Textbooks are one obvious means of doing this, but we should also include synopses of major science ideas intended for the general public as well as magazine and newspaper articles that convey general ideas and recent discoveries.

Although some people who might not be active in research specialize in translating scientific concepts for laypeople, practicing scientists also contribute in this area. Stephen Hawking's books provide an insight into how his mind works; and James Watson's The Double Helix is a great book that not only explains his and Francis Crick's investigations into DNA, but gives a glimpse into the excitement of scientific discovery.

Science Writing for Students

Okay, so what does any of this suggest with respect to students writing while doing science? One obvious place to introduce science writing is in the presentation of science fair projects. Instead of having the classmates ask a few questions of the presenter, have them choose one project and write a formal critique of the procedure, results, and conclusion. Where was the procedure particularly good or particularly flawed? Does the conclusion follow logically from the results? You can use this process to teach students how to be critical while not biting the head off the experimenter!

In the realm of reporting science to the public, you could have students compose a column for the school newspaper or bulletin that briefly explains what your class has been doing in science and what conclusions you've reached. You could circulate this column in your class for review and comment prior to submitting it to the school.

Lastly, there's the old standby of having the kids do a report on some scientific subject. While it's perfectly okay to have the students report on the adaptations of the red fox or the rings of Saturn, keep in mind that these kinds of reports are not typical of what practicing scientists do. It might be worthwhile to spice up their science writing with some of the other alternatives suggested in this column. Now, here's how to create the perfect vinegar and baking soda volcano ...

Resource

Watson, J. 2001. The double helix: A personal account of the structure of DNA. New York: Touchstone.

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Byline: Thomas Turner and Amy Broemmel

In 1905, a young scientist named Albert Einstein published a three-page paper presenting his theory of relativity. That brief paper was a major step in revolutionizing how physicists throughout the world thought, and it would change the way that the world in general thought about science (Penrose 2005). That a relatively small piece of writing could be so important certainly illustrates the significance of writing to science. Good scientists record what they do-their results, procedures and operations, observations, and hypotheses, as well as their problems and questions.

Scientists need to develop their writing skills for a number of reasons:

Writing down their ideas and describing what they do and find gives scientists and those that read and depend on their work a more accurate record from which to attempt to replicate results.

Written accounts of what scientists observe, which are recorded at the time of their observations, help scientists remember more accurately and completely.

Written summaries of scientific work allow scientists to synthesize bodies of work and look at them holistically so that they or other scientists can extend and develop ideas further.

Written notes about their work allow scientists to reflect on and mentally process what they have observed.

Written presentations of their work allow scientists to share and publicize their findings, get credit for their work, and, as a result, claim the benefits of their successes.

Written descriptions of planned work enable scientists to obtain funding to continue their often-expensive work.

Written summaries of their ideas allow scientists to share the importance of their work with nonscientists.

Why we need to teach writing in science classes

Any science teacher who wants his or her students to be engaged in real science is going to engage them in real science writing. Students do not intuitively know how to do such writing, nor is instruction in scientific writing necessarily or even likely going to occur in other school subjects. This writing instruction can serve two purposes. It can increase science understanding and engage students in activities that are useful in the assessment process in science itself. Montgomery (2005, p. 28) points out that student writing provides the teacher with "a tangible demonstration of learning and gives students the opportunity to connect their personal experiences to the content." Montgomery goes on to say that well-crafted, thoughtfully planned writing assignments require the student to do a "deep analysis of subject material."

Well-designed science writing assignments essentially have three critical attributes:

They provide authentic purposes for writing.

They motivate students to want to write and to "do" science.

They help students plan and structure both their writing and their science activities.

These attributes are inextricably and symbiotically related. They combine to make the writing assignment comprehensible, authentically important, and feasible. Matsumura and his colleagues (2002) found that the cognitive challenge of the writing assignment had a significant effect on the quality of students' final drafts. That is, when students felt that assignments were cognitively challenging and satisfying to complete, they worked more effectively in producing a finished writing product. Writing experiences should help students feel good about their own writing.

Writing in science should begin with clear, imaginative writing purposes and stimuli that are then scaffolded in such a way that students are able to find an organizational structure for their writing. Writing fluency is often enhanced and supported by experiences like brainstorming or free writing.

Writing assignments that work in science classes

Writing in The American Scientist, Gopen and Swan (1990) asserted that, "The fundamental purpose of scientific discourse is not the mere presentation of information and thought, but rather its actual communication" (p. 550). Of course, much of the public and many scientists would question this idea because they often think that scientific concepts, data, and analysis are extremely complex, difficult, and abstract. However, like Gopen and Swan, we would argue that what matters most in scientific writing is that a majority of the reading audience accurately perceives what the science writer has in mind, and that when science writing improves, it is a sign that the thinking is better. In the interest of promoting such thinking, we would like to offer 14 examples of different kinds of writing assignments that can provide legitimate, purposeful writing practice while promoting solid science learning and review.

1 Writing hypothetical letters-Often scientists share their observations and questions as well as their differences of opinion by letter or, in today's world, by blogs and e-mail messages. A very simple, yet effective example of a scientific exchange can be seen in the children's book, Dear Mr. Blueberry, by Simon James. In this book, James has created a story line through an exchange of letters between a little girl named Emily and her teacher, Mr. Blueberry. Read the book aloud and talk about how Emily seeks help, information, and even opinion, but is strongly true to her own observations. Students can work collaboratively to create their own hypothetical exchange of letters between themselves and a scientist or teacher. An important lesson of this poignantly sweet book is that a person should believe in the power of evidence even when it contradicts authority. A second lesson is that it is possible to do this without being disrespectful to authority. In adapting the activity for class, students, in their letters, can share observations about some theme or topic. If possible, the return letters by the authorities or scientists can come from older children or parents with science backgrounds. This could also be accomplished electronically in collaboration with university students studying to be science teachers.

2 Process steps analysis-After observing and/or taking part in a demonstration of a scientific process, the class could discuss what they saw. After talking the observations through, they can analyze and document the sequential steps that they would need to completely replicate the demonstration. In some cases, where it is safe and feasible, students might even have the opportunity to recreate the demonstration following their own steps.

3 Identifying critical attributes-Small groups of students are asked to look at something. This can be an object of any kind or even a plant or an animal. Each group has a different object. They are given the opportunity to make a thorough examination, and identify its critical attributes. Critical attributes are those observable qualities that make the object, plant, or animal unique, allowing it to be distinguished from all others. The groups can then compile a list of what they believe to be the critical attributes of what they have seen. The lists are shared with the whole class, and students attempt to match the correct item with the critical attribute list. If accurate matching is not possible, students are encouraged to revisit and revise their lists.

4 Collaborative writing of scientific stories-The teacher begins by reading (or having the students read) a science-related trade book. Fiction books, such as How Groundhog's Garden Grew (Cherry 2003), and nonfiction books, such as One Tiny Turtle (Davies 2001), can be used effectively for this activity. After students have become familiar with the story, the teacher needs to start a discussion focusing on the scientific content or process described in the book. Once the teacher is satisfied that students understand the science of the book, he or she has the class sit in a circle on the floor. Three clipboards with paper are given to students positioned at equal intervals around the circle. Each student holding a clipboard is asked to think about the science described in the book and then writes one sentence that describes the first event in the book. They then pass the clipboard to the right. Students are instructed that when they receive a clipboard, they need to read what has been written up to that point on the paper and then write an

additional sentence describing the next event in the scientific process described in the story. Each paper will, in the end, contain a complete retelling of the story in the sequence it occurred. (Three papers are used to provide a means of keeping students actively engaged and to document student understanding of various parts of the content/process.)

5 Chain of evidence-Because most students have watched many television shows dealing with forensic evidence in criminal investigations, those observation experiences can be used as the basis for writing activities. First, the teacher identifies a crime that the team will investigate. Appropriate possibilities could include robberies, kidnappings, acts of vandalism, or simple crimes that happen around the school every day. (Avoid scenarios involving violent or graphic crimes.) Begin with a brainstorming session. Have the class create a detailed summary of the chain of evidence leading to the arrest and trial of a suspect in their invented crime. Encourage them to use rich details with leading questions, such as: What kind of evidence are we going to look for? Where are we likely to find evidence? How do we distinguish evidence related to the crime from what we would normally expect within the crime scene? What are some different ways of reconstructing the crime based on the evidence? What possibilities does the evidence suggest?

As an alternative to providing students with only the hypothetical crime, the teacher could also provide a list of "suspects" with a brief introduction to each. Students might then choose a "guilty" suspect and create a well-reasoned written explanation of fictional clues and evidence that could lead to the suspect's arrest. Students then have to learn the difference between being reasonably sure that someone is guilty and having sufficient evidence to bring them to trial, and then having enough evidence to convict. Students can assume the roles of judge and jury in response to one another's assembly of evidence, ultimately deciding if the written chain of evidence is sufficient to lead to a trial and subsequent conviction.

6 Accident report-In this activity, a teacher creates an accident scene by either using photos or actually staging an accident. Examples of cases might include a lunchroom mishap such as spilled trays; a playground incident such as a fall from a piece of equipment, someone being hit by a ball, or a collision between two running students; or a classroom situation such as stacks of papers falling on the floor and getting mixed together. After examining the accident scene and gathering evidence, the accident scene investigators are asked to write reports based on their observations. In very small groups, students then read each other's reports, noting inconsistencies or missing details.

7 Label analysis-The teacher first organizes students into groups and then provides each group with an empty package or label for some product. The products can be foods, medicines, household cleansers, or anything else with a label that lists its ingredients. Each group then writes a description of what they know about the product based on the list of ingredients-in other words, what the contents list tells you, and what it doesn't tell you. For example, if something advertised as a juice product has little or no actual fruit

juice in it, what does that mean? What does the label tell you about nutrition? What are the risks and benefits of using the product?

8 Technical directions-The teacher begins by giving students toys or models that require some assembly. Students are then asked to take the role of the marketing staff at the product's manufacturing company. Students must first practice assembling the toy or model, carefully noting the quickest, most efficient steps for assembly. Then, they are responsible for writing the directions that will be included on the package. Finally, students attempt to assemble other groups' toys or models using the new directions.

9 Scientific directions-The teacher organizes the class into small groups and assigns each group a familiar location within a short distance from the school. Each group then discusses the best route to the assigned place and writes directions for getting there using landmarks based on scientific observations taken along the route. For example, the directions could include descriptions of plants, geological formations, or environmental cues. As a follow-up, have students see if they can navigate to a spot using others' directions.

10 Scientific reporting-After a discussion of the essentials of accurately reporting scientific observations, students are organized into groups. Each group is given a video recording of a scientific experiment and asked to create a detailed list of observations that someone could use to recreate the experiment. The group is allowed to view the video as many times as they like to ensure that their observation list is accurate and complete. (See Resources for recommended video collections.)

11 Proposal writing-The basic function of a proposal is to describe and pitch to others ideas for projects, papers, and research studies. Proposal writing is an essential activity for many scientists and the skills needed to write proposals should be developed as early as possible. Instead of simply assigning projects and research reports, teachers can provide general parameters for the intended assignment (e.g., research related to rock formation or a project depicting a food chain). Proposal writing activities can begin with a simple brainstorming for project ideas. The fundamental question is, What do we want to do? After generating a list of ideas, the teacher can then lead students through the process of selecting and refining a single idea from the list. The next step is to create a proposal outline. To help students with this the teacher may have a set of specifications or even provide a simple outline such as the following:

Title (a proposal...)

Abstract or summary

An introduction giving background and explaining the situation

A statement of the project problem to be solved

Some suggestion or suggestions about solutions to the problem

Some explanation of how you will solve the problem

An outline describing the proposed project outcome

Step-by-step description of your research methods

Conclusions

After the outline has been created, assign a different group to write a draft for each part. Finally, piece together the proposal, editing each part so that it is consistent with the rest. The combined class effort can then serve as a model for small groups or individual students to develop their own proposals.

12 Porquois story writing-Porquois stories are fictional explanations of natural phenomena. They are usually based upon definitive descriptions of the phenomena themselves. One example is "How the Elephant Got His Long Trunk." A series of logical plot actions are described, connecting the main characters in the story to the creation of the phenomena. Provide students with a list of natural phenomena and have them create their own porquois stories for one of these. Stress the importance of including scientific facts in explanations. Examples of appropriate subjects include why magnets attract, why we have tornadoes, why snakes shed their skin, why hens cackle and roosters crow, why owls hoot, how squirrels got their bushy tails, and why volcanoes erupt.

13 Preparing descriptive research through web quests. Web quests are designed to be structured inquiry activities in which information is drawn from the internet. Web quests focus the learners' time on using information rather than looking for it, and emphasize thinking at the levels of analysis, synthesis, and evaluation. Essentially, students are directed to a sequenced series of specific websites to solve a structured inquiry problem. A number of websites provide examples of WebQuests (see Resources). An example of a teacher created web quest might ask students to determine which simple machines would be most effective in performing a particular multistep task. The web quest would be designed to lead students to a series of websites that present verbal and/or pictorial information about simple machines. Students would use the information to develop a written solution to the problem. Teachers can also train students to develop their own web quests as an alternative means of demonstrating understanding of particular scientific content and/or processes.

14 News clip observations-The teacher shows short news film clips without sound. These clips may show natural disasters, the effects of weather, destruction brought about by human effort, or other science-related concepts. Students then write descriptions of the event based on their observations. After students have completed their descriptions, replay the film clip with sound and ask students to compare the accompanying news commentary to what they wrote.

Final note

A science class is not complete unless it helps students learn to think like scientists, and writing is an essential part of such thinking. The 14 writing experiences described here for integrating meaningful, interesting writing into science are not intended to be followed to the letter. Rather, they are all adaptable ideas. Neither are they intended to replace traditional science instruction. However, if we want our students to think like scientists, then it is only logical that we should ask them to observe, document, and write like scientists, as well. We believe that these and other thoughtfully structured writing activities can be integrated into science classrooms in a way that addresses curriculum, provides alternative, authentic means of assessing student understanding, and motivates students to become actively involved in the learning process.

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Resources

Web quests

The WebQuest Page- http://webquest.sdsu.edu Teachnology- www.teach-nology.com/teachers/lesson_plans/ computing/web_quests/science/ Science web quests- www.can-do.com/uci/k12-lessons.html

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Straits, William. "Mystery Box Writing. " Science and Children. (Nov 2005): 33-37. General OneFile. Gale. West Salem High School. 17 June 2010 http://find.galegroup.com/gps/infomark.do?&contentSet=IAC-Documents&type=retrieve&tabID=T002&prodId=IPS&docId=A139757254&source=gale&userGroupName=wsalem&version=1.0

Byline: William Straits

My search for integrated writing and science connections began years ago when I was teaching seventh- and eighth-grade science at a school for dyslexic students. Like any class, the interests and abilities of my students were all across the board. However, one characteristic all the students had in common was a reluctance to write.

Although I was the "science" teacher, it was critically important that I help students develop writing skills along with content, so I made a point that our hands-on science experiences would be accompanied by a related writing lesson. Science, I happily discovered, provided students with a purpose for writing, made it meaningful, and motivated these normally reluctant writers to pick up their pens.

One of my favorite science writing activities that grew out of this experience is what I've come to call the "Mystery Box" activity. It can be adapted successfully for use in myriad ways-as part of individual, small group, or whole-class instruction-and at various grade levels from elementary through middle school. (I know, I've almost tried them all!) I encourage you to try it with your students, too.

What's in the Box?

The activity begins when I bring a mystery object or organism into the classroom, hidden in a box. Typically, I select items that will introduce a new unit of study or that relate to the unit we're currently studying. I also sometimes use this as a means for revisiting topics covered earlier in the year. (I notify students when it's a review organism/object; they are otherwise safe to assume that it relates to the day's topic.)

I have used beetles, spiders, screws, and various plants for this activity (see Figure 1 for additional suggestions). I also use models-answering questions as if they were the real thing, but I include a discussion of the use of models in science. For example, after revealing a toy airplane I'll ask, "How is this like a real airplane?" and "How is it different from a real airplane?" and then we'll discuss why scientists often use models to represent objects and processes in science (e.g., "Why did I use a model airplane instead of a real one?").

Figure 1. Ten "get-you-started," never-fail mystery organisms/objects.

Organism/Object

Notes

Mealworm

These are readily available, yet often completely unfamiliar. Useful for introducing life cycles.

Goldfish

Often students will focus on terrestrial animals. This activity is great for introducing young children to aquatic organisms.

Tree seedling

The idea that a tree can fit in the box often doesn't occur to students. This mystery organism segues nicely into lessons on (plant) growth.

Magnet

The classic U-shaped magnets seem to work best initially; you can challenge students by using different shapes.

Model of a volcano

In my experience, students sometimes need a little more direction with Earth and space science topics-be ready to give some hints.

Thermometer

More appropriate with older children, although primary grades can be successful if they know the mystery object is something you use to learn about weather.

Rock

This is a fun one. Because there are so many different types of "rocks," responses sometimes lead students away from the answer. (e.g., "Yes, it is magnetic." (Magnetite), "It is pink." (Rose Quartz), "No, it's not heavy for its size." (Pumice))

Globe

Readily available mystery space science object. A relief, rather than a political one, works best at the science writing center.

Any body part (or model thereof)

Helps students to think of body parts, locations, and functions. Works great as a review-students will identify the mystery organ, bone, facial feature, body part, etc., fairly quickly.

Water

Like rocks, this object can be tricky: It moves-"it must be an animal." It conducts electricity-"it must be made of metal." And, it connects to many topics within the science curriculum.

The activity occurs in two phases. The first phase introduces the organism/object to the students and focuses on science-process skill development. Specific skills applied during the mystery organism/object activity include questioning, predicting, interpreting information, observing and recording observations, and critical thinking.

In the second phase, students complete language arts tasks that relate to the mystery organism/object at a writing center. Specific language arts knowledge and skills can include: comparing and contrasting; identifying parts of speech; and developing concepts through concept map(s) and/or definition diagram(s).

Start With Questions

When the activity begins, students will want to ask very specific questions (e.g., "Is it a soccer ball?" "Is it a kitten?"). In challenging students to determine the contents of the mystery box, I tell students they may ask me three types of questions:

"Does it ____? / Can it ____? (verbs),"

"Does it have ____? / Is it a ____? (nouns)," or

"Is it ____? (adjectives)."

These "yes or no" questions help students gather information that will inform their inferences of what is in the mystery box. A typical exchange might be something like this:

Student 1: "Is it alive?" Teacher: "Yes, it is alive."

Student 2: "Can it move?" Teacher: "Yes, it can move."

Student 3: Does it have six or more legs?" Teacher: "No, it doesn't have six or more legs."

Student 4: "Does it have four legs?" Teacher: "No, it doesn't have four legs."

Student 5: "Wait a minute, does it even have legs?" Teacher: "No, it doesn't have legs." Students: (groan)

Student 6: "It's a snake! Is it a snake?" Teacher: "No, it's not a snake."

Students: (more groans) Teacher: "Ok, write (draw) what you think the mystery organism is."

Throughout this exchange, students (or I) write the information (e.g., "alive," "can move," "does not have six or more legs," etc.) on one of three pieces of chart paper, listing verbs, nouns, and adjectives each on a separate piece. After students record their guesses, I call on students for more questions, periodically stopping to record new guesses. The number of questions between guesses depends on the accuracy of the guesses. If the class seems far from finding the answer, I'll answer several questions before asking for guesses; if they are narrowing in, I'll provide less information between guesses. Used at the beginning of a unit, this exercise helps students to activate relevant prior knowledge and gives me a great idea about what they know about the topic before instruction.

When conducting this activity early in the school year, I usually have to answer between 10-15 questions before students begin making inferences as to what object is in the box. Students usually figure out the object in 45-50 questions total. By the middle of the year, as students' questioning and critical-thinking skills improve, inferences and drawings are made after the first five questions, and the mystery organism/object is found out in just a few minutes, sometimes in as few as 8 or 9 questions. Interestingly, it's been my experience that rather than waning, enthusiasm for this activity grows as students become more adept at using these science process skills.

I Think / I Infer...

As students ask their questions, I periodically ask them to stop and draw or write predictions based on what they know so far:

"I think/infer (I use "think" and "guess" with primary-level students and "infer" with older students) that the mystery organism/object is _________." We learn about inferences using the "Earthlets" chapter of Picture-Perfect Science Lessons: Using Children's Books to Guide Inquiry (Ansberry and Morgan 2005).

I also ask, "Are we 100% certain?" Although many students, especially younger ones, will be extremely confident in their responses, none will be absolutely certain. I then point out that scientists can never be 100% certain either-that's why they keep doing science, asking questions, and getting more information." I then ask, "If we want to get a better idea of what the mystery object is, what should we do?" It delights me to hear a class of young scientists reply, "Ask more questions!"

At the end of the questioning phase, the object in the box is revealed, and the list of verbs, nouns, and adjectives collected in the questioning phase is gathered for use in the next phase of the activity-the writing center.

After a bit of practice, students become very adept at asking illuminating questions and honing in on the mystery organism/object. If the class is about to identify the organism/object too quickly (i.e., the word lists are insufficiently developed), I will "outlaw" noun questions, forcing the class to in effect expand their description of the organism/object. Students, particularly students in upper elementary grades, come to see this outlawing as something to be proud of ("Yeah, we got you Mr. Straits!") and strive to solve the mystery.

When a class is unable to identify the organism/object within the allotted time, students often analyze questions and answers looking for the information that led them astray. Occasionally, this leads to some great debates. "Do chrysalises move?" "Does water move?" "What color is a chameleon?" Sometimes after revealing an organism/object that had stumped the class, we'll brainstorm questions that the class should've asked. I highly prize this analytical thinking.

The "reveal" brings up an important misconception about the nature of science to address: Scientists are not able to "look into the box" and find an absolute answer, they must always keep asking questions. Cutting the activity short and not revealing the mystery organism/object is a good way to initiate this discussion.

Inspired to Write

In the second phase of the activity, small groups of students work independently at a writing center. Like all learning centers, the writing center is a designated area of the classroom where students are provisioned with the needed materials and provided time and prompts to explore a particular topic. Each week we spend 30-45 minutes in "centers." Over the course of the week, students complete five centers, of which a student favorite is the writing center. This arrangement allows me to work with a small group of students each day-addressing specific student needs and allows students opportunities to work independently as well as collaboratively. These opportunities are valuable not just in terms of learning the subject matter, but also in developing decision-making, social, and investigative skills.

In the writing center, which has chairs and table space for three to five students to work, I typically post the vocabulary lists and place the mystery organism or object. I also provide various materials (e.g., paper, pencils, rulers, crayons, colored pencils, magnifying glasses, diagram templates (Venn, concept map, definition map), and students' previous work (examples of haiku, riddles, etc.). This center becomes a place where students can purposefully apply the various techniques and writing genres we are studying in language arts.

Figure 2. Suggested writing center activities.

Create a fictional story using vocabulary lists.

Write haiku or other poems using vocabulary lists.

Write "I am a (mystery organism/object)" riddles.

List as many observations of the organism/object as possible.

Draw a picture of the organism/object.

Research organism/object and list 10 facts about it.

Make a Venn diagram for characteristics of the organisms/objects from the past two weeks.

Make a concept map(s) for the anatomy/composition or (and) behavior/uses of the organism/object.

Make a Definition diagram for the organism object:

A. Dictionary definition B. Important facts from vocabulary lists C. Examples of the organism/object D. Your personal definition of the organism/object E. Important facts you discover on your own F. Negative definition

Typically, rather than assigning a specific writing task, I offer students a choice from three or four tasks, including story writing, creating a concept map, and others (see Figure 2). I keep a record of the types of work each student selects and encourage them to try others, either through discussion with the student or by only offering the avoided options.

The student work examples, shown in Figure 3, demonstrate the flexibility of the assignment. Some students embrace the assignment as an opportunity to write creatively, others as a chance to display their understanding of science vocabulary and concepts. Some choose to do both, writing creatively and incorporating science concepts. Subsequently, my assessment of these assignments includes a combination of language arts and science goals. Is the drawing accurate? Are the observations detailed? Does the Haiku follow 3-5-3 convention? Do the fictional stories demonstrate creativity? These questions are all equally important as I evaluate student work.

Figure 3. Student examples.

It's No Mystery

I bet many teachers use some kind of "Mystery Box?" activity as a science lesson at some point in the school year. By using it routinely as part of my science lessons and by adding the dimension of incorporating a writing assignment into the experience, I've discovered these activities can greatly develop students' abilities to ask questions, make inferences, and think critically-and to motivate even the most reluctant students to get writing. What a terrific combination!

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Resources

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Connecting to the Standards

This article addresses the following National Science Education Standards (NRC 1996):

Program Standards Standard B: The program of study in science for all students should be developmentally appropriate, interesting, and relevant to students' lives; emphasize student understanding through inquiry; and be connected with other school subjects and is aligned with several content standards.

Gale Document Number:A139757254

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http://find.galegroup.com/gps/infomark.do?&contentSet=IAC-Documents&type=retrieve&tabID=T002&prodId=IPS&docId=A139757255&source=gale&userGroupName=wsalem&version=1.0

Byline: Valarie L. Akerson and Terrell A. Young

Learning to write well is a long process that comes through teacher modeling, instruction, practice, and feedback. Luckily, the writing process can be used to improve science learning, too. Here are a few good writing suggestions that integrate science while helping students develop their informational writing skills.

Science Journals

There is perhaps no better place than a science journal for students to develop informational writing skills. Daily journal prompts are one way to encourage students to write expansively about developing knowledge (see Figure 1 for sample journal prompts).

Figure 1. Sample journal prompts, followed by examples of typical student responses.

TREES

What do you think is a tree? How is it different from other plants? I think a tree is wood and leaves. Trees are bigger than plants.

What do you think a tree is made of? Trees are made of wood and leaves.

What are the parts of the tree? Draw a tree. Leaves and the wood trunk (later in the unit they add other parts, such as roots)

(After we find a tree to "adopt") What is our tree like? What is special about our tree? How do you think our tree might change over time? Our tree is big. It is special because it is ours! It has big leaves.

Why do you think trees are different shapes? Why do you think their leaves are different? Because the leaves catch the sun in different ways.

(After several weeks) How does our tree look different? How does it look the same? The trunk still looks the same. It is getting leaves!

What different shapes of leaves did you find? How can we sort our leaves? I am putting the big ones together, then putting the spikey ones, and then the skinny ones.

What things can you tell me about a tree now? How do you think it is different from other plants now? Trees are a kind of plant.

In journals, students make records of what they are doing in investigations-they organize data by creating tables and write observations based on their investigations. They record, via drawing and writing, characteristics of what they are observing (i.e., what a pill bug looks like and how it reacts in different settings). In using the journal in this way, students learn that making records of actual observations is something scientists often do and is a useful kind of nonfiction writing.

Beyond recording observations, students can use journals to write inferences based on their observations. For example, if students observe that pill bugs prefer walking on dirt, they could infer that the dirt is more like their natural environment-thus making meaning of their observations. Students will find that inferences made from early observations may change as they make more observations. This tentativeness in inferences is an intrinsic part of the nature of science, but by making the recordings in their journal students can track their ideas over time and note any observations that lead to a change in inference.

Observations vs. Inference Charts

Another tool that supports science learning while developing informational writing skills is the observation vs. inference chart-we've used this chart successfully to introduce primary students to the distinction between observation and inference. On the chart, one column is labeled "Observations" and the second is labeled "Inferences." During a class discussion following an exploration, the teacher records student observations under the "Observations" column and then asks students to make inferences about what those observations mean on the "Inferences" column.

For example, after students have had time to observe snails up close, the teacher would collectively record students' observations (i.e., "the eyestalks move when I touch them") on the chart, then ask students to infer the meaning behind the observation (i.e., because they are trying to move them out of my way-to keep them safe." The teacher can record the response on the inferences side.

After a few examples, students will begin making good distinctions between observations and inferences, and they can be given similar smaller charts for individual or small groups of students to record their observations and inferences about other investigations on their own.

Student-Authored Books

Figure 2. Sample chapter from a student-authored book, "What Is a Scientist?"

To gain simultaneous insights into a content area, research, and literacy, students can research and write their very own book on a theme, such as "A Book about Scientists." Individual students or small groups can research subtopics-"What do scientists do?" "How do I become a scientist?" "What do scientists do in their spare time?"-and write chapters for the books (Figure 2). The chapters usually begin as notes from research or interviews of scientists.

Once the chapters are compiled, students then create a table of contents and a reference list to demonstrate that nonfiction writing must be based on accurate information. Next, students can illustrate the chapters with their own drawings.

Afterward the book can be published for their classroom enjoyment. Publishing a book is another good place to reinforce accuracy in writing in terms of spelling and conventions and the process of writing. Prior notes that students take can be written in draft form to be edited by the students later as they work on the computer to type their chapters.

We keep copies of our student-authored books in free reading-time tubs, so students can revisit their work, encouraging both recall of information about scientists and the importance of writing informational text.

Custom ABC Books

For younger primary grades, have students collectively create informational text in the form of an alphabetical or counting book. Students will not only be practicing writing and research content; they'll be learning how to gain information from nonfiction text and group it into categories.

Start out by reading examples, such as George Ella Lyon's (1989) A B Cedar: An Alphabet of Trees, George Shannon's Tomorrow's Alphabet (1996), or Kathy Darling's Amazon ABC (1996), then assign a content area to students or have them pick their own content area. Next, assign individual students a letter or a number. Each will research information related to that content and write an informational page that relates to their assigned letter or number.

For example, primary students might study organisms, and each child in the class could be assigned a letter of the alphabet and select an organism to study that begins with that letter, such as the student who gets "L" studying lemurs. That student would then write an informational page about the lemur, illustrate it, and when all pages are complete, the teacher would compile the book as a class alphabet book. Teachers can involve their students with similar projects related to nonfiction counting books (see Resources). April Pulley Sayre and Jeff Sayre's One Is a Snail, Ten Is a Crab: A Counting by Feet Book (2003) is ideal for intermediate students, as readers are required to count, add, and multiply the feet of various creatures. Using Counting Wildflowers (McMillan 1986) as a model, a first-grade teacher can take digital pictures of animals on a class field trip to a farm. Students can then record information about what they experienced on their field trip.

E-mails to Scientists

Finally, students can pursue science learning by writing to real scientists. Most appropriate for older elementary students, having students e-mail a scientist provides an opportunity for students to compose their own questions about science content. Or, students could interview scientists about how they became scientists and the kinds of work they do. Students could use these e-mail conversations as a basis for a nonfiction report on that scientific specialty. They could even be required to ask the scientists how they use writing in their work!

Teachers can find contact information for scientist e-mail pals by contacting local universities and science labs. For instance, Indiana University houses a science outreach office in their college of arts and sciences with staff whose purpose is to make contacts between university science faculty and K-12 education. A similar office is located in Washington State at the Pacific Northwest National Laboratory's Office of Science Education, which not only provides scientists to visit classrooms and interact with students but also provides professional development opportunities for teachers. Teachers can find similar opportunities for contacts with scientists in their own local areas.

Reports and Other Uses

Nonfiction writing can also be used to help students develop understandings of science as inquiry, as students record observations, inferences, and results of investigations, and write formal reports to share with peers. Students can also use writing to design their own investigations, leading to a further understanding of investigations as recommended by the National Science Education Standards (NRC 1996).

Writings Are Assessments

Incorporating various nonfiction writing activities such as those suggested above not only facilitates students thinking about science content, but it also results in material/work that can help teachers assess student understanding.

For example, observation vs. inference charts can be used to capture a picture of what the whole class understands about a given topic. If a student records an observation of an investigation exploring whether pillbugs prefer light or dark environments as "pillbugs love the dark," the teacher will know that the student is confusing the observation with an inference. The teacher can then ask the student to describe how he or she knows that pillbugs "love the dark." When the students states that it is because pillbugs tend to stay in the dark side of their environment the teacher can point out to the student that moving to the dark side is the observation and the inference is that they "love the dark."

Similarly, individual journal writings can be used to assess what individual students understand about a science content area. In a unit exploring electrical circuits, students could be asked to respond to a journal prompt of "How do you think electricity works?" several times throughout the unit. Initially the student may respond with something like "electricity is lightening," whereas later in the unit the student may respond with something like "electricity makes things work," and finally the student may respond with something like "electricity works through a complete circle-a circuit." Thus, the teacher can track the development of the student's idea over time, from less informed to more informed views.

Whether supporting content learning, guiding teacher instruction, or furthering the development of students' literacy or science process skills-or all of the above-nonfiction writing opportunities are an essential aspect of science learning from which teachers and students benefit in many ways.

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Connecting to the Standards

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

Teaching Standards Standard B: Teachers of science guide and facilitate learning.

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