How to...

Write to Learn Science

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You write it all, discovering it at the end of the line of words. The line of words is a fiber optic, flexible as wire; it illuminates the path just before its fragile tip. You probe with it, delicate as a worm.

—Annie Dillard
from *The Writing Life*

When asked why he became a scientist, the famous nuclear physicist Robert Oppenheimer replied, "Because my teachers allowed me the exhilaration of my own discovery." That statement haunted me. When I read it, I had been a science teacher for nearly two decades. My teaching style allowed little personal discovery on the part of the student; I was the sole owner of all the right answers. The exhilaration of discovery in my class had been washed away in a flood tide of commercially prepared worksheets and cookbook laboratory exercises.

Learning units typically began with an overview of fundamental principles followed by a focus on the details. I taught science as a body of knowledge, and tested my students on their knowledge of details. Those who were good at memorizing scored high, but only a few expressed any real understanding of the principles. I needed to find a way to focus on concept understanding and give my students the exhilaration of their own discovery.

The solution lay with expressive writing—the writing one uses to think through a problem. Anyone who has ever written a letter, a page in a diary, or an entry in a journal understands that the physical act of putting pen to paper uncovers ideas the writer was not aware of previously. Writing exercises both sides of the brain. More importantly, if the writer has ownership of the subject, the writer understands more deeply and retains what he or she has discovered for a longer

period of time. By replacing passive learning with active learning, through writing and cooperative learning techniques, I became a facilitator of learning instead of a spouter of information. My classes became student centered. The student-centered approach could be successfully used with students at all levels of ability. My enthusiasm for teaching was renewed. I no longer looked forward to retirement.

This book describes classroom-tested activities that effectively use expressive writing to further concept comprehension. Writing helps students think through problems. As they write they have a sense of what they already know and, more importantly, what they don't understand. This book also offers options for effectively managing writing evaluations without becoming swamped with paperwork.

Teaching and Writing: Similar Endeavors

The writing process is much like the scientific process. The scientist first hypothesizes, then experiments, and finally revises his or her thinking. Most writers, as they work through a piece, initially put pen to paper without much concern for anything more than getting ideas down. Writers complete several drafts of a document as they attempt to get the material into a form appropriate for the intended audience. As Donald Murray, author of numerous books about writing, says, "The process is first a prevision, then a vision, and finally a revision."

Successful writers know their audience. They accept the audiences for what they are, not for what they should be. The primary reason many writers receive rejection slips is their failure to address the particular audience required by the periodical. By the same token, each class of students has its own personality. Skilled teachers take the time to know their students and present lessons designed for those audiences.

As a teacher, I was the toughest audience in the world for my students' papers. Many students saw me as the judge, jury, and executioner. Early on during my teaching career, the students and I would be obsessed with form rather than substance, product rather than process. Students would ask: "How long does this have to be?" "Does spelling count?" "What do you want me to say?" "How many points is it worth?" Many of them turned in third-rate reports that sounded as if they had been taken from the encyclopedia, textbook, or Internet. Student writing showed little evidence of creative thinking in the process, and their own voices never emerged from the text.

Successful writers "hook" their audience with an opening that makes the reader curious and anxious to see what follows. I needed to start every learning unit by getting students to ask questions and encouraging them to take the risk of getting involved. If I'm successful the students will assume some of the ownership of the subject matter. If they assume some of the ownership they must also assume some of the responsibility for learning. In my beginning years of teaching almost all of the responsibility was mine, not the students.

A successful writer shows, not tells. The effective writer does not write, "The landscape is beautiful." Instead, he or she describes the landscape, allowing the reader to decide if it is beautiful or not. By the same token, a good science teacher engages students by using hands-on, open-ended experiments that require the students to make decisions.

The successful writer does not show off to the reader. He or she never uses vocabulary or information merely to indicate a command of such things. Instead, vocabulary serves to make a point clearly and to present information in a way that doesn't talk down to the reader. The successful teacher must apply the same principles to get information across to the students.

The successful writer is a master of the craft, a professional. The teacher must be nothing less.

The First Week

Building Trust

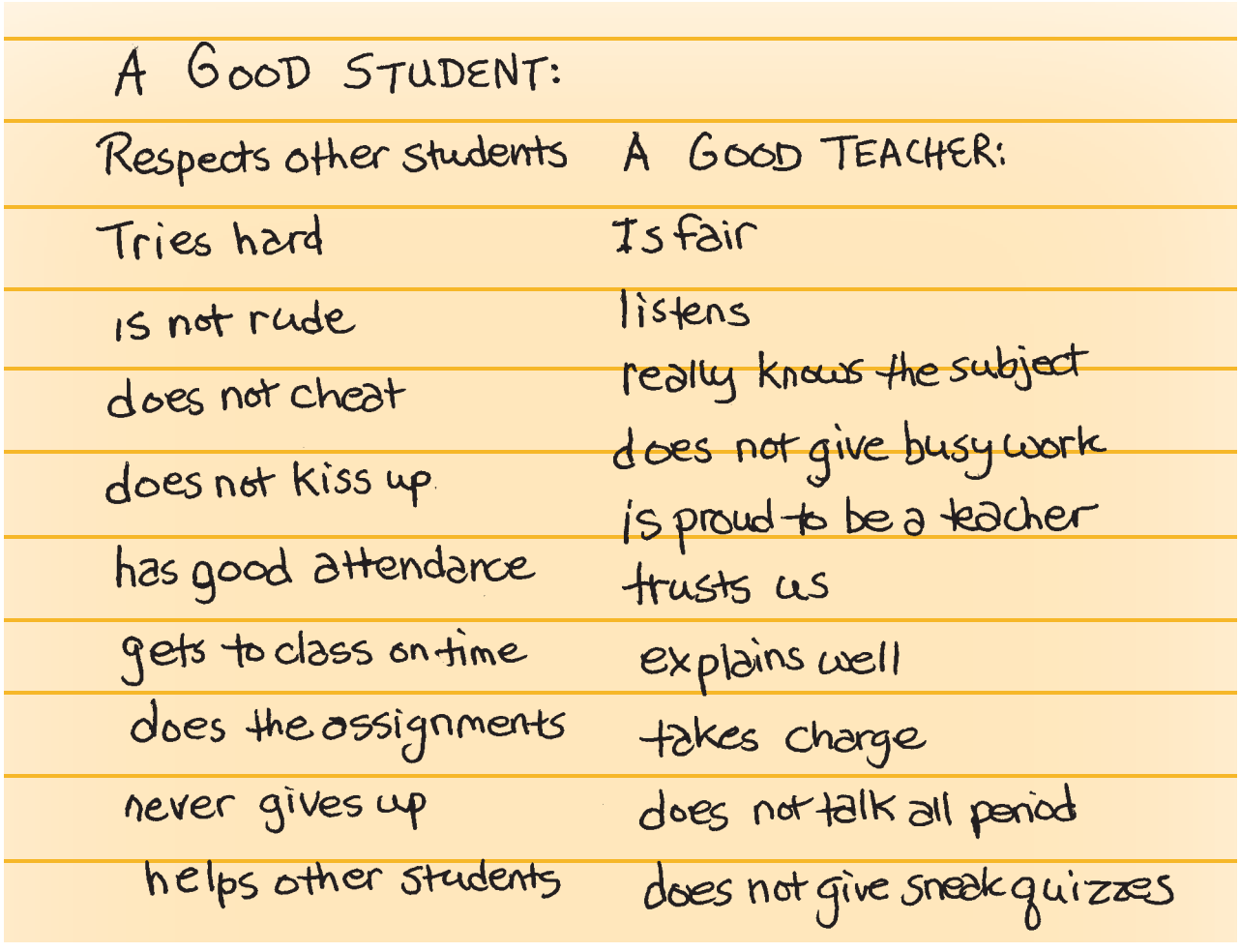
In my first years of teaching I was too anxious to hand out the textbooks and get going. I taught biology, the study of life, and I had only one school year to do it. I didn't know my students until after the first test when many of them received grades that discouraged future effort. I realized I needed to know my audience as individual students instead of as period one, two, three, four.

It took me several years to develop a new approach. By getting my students to write openly about their work in science, I was able to help many of them experience the joy of their own discovery. Even though I am now retired, I still regard this process as something very much a part of me, in the present tense. Here's how it works.

During the first week of class, I strive to create an atmosphere of mutual trust and respect. The students need to get to know me, and I them. It's helpful if they begin to see me as a colleague, even a mentor, instead of just another teacher telling them what to do.

A key challenge is to make students feel comfortable with science, which many view as

FIGURE 1. Lists of What Makes a Good Student and a Good Teacher



difficult to understand and unimportant to their daily lives. I use a variety of writing assignments to help them build confidence in their abilities and to convince them of the relevance of science.

Classroom Rules

Students are more apt to follow rules if they have some say in determining what the rules will be. At the start of each year, I divide the students into lab teams of three and have them make a list of characteristics of a good student. They don't get very excited about that, but when I ask them to also make a list of the characteristics of a good teacher they are eager to get involved (Figure 1).

I summarize the lists, and in order to build trust, leave in such ideas as "lets us eat in class," "gives easy tests," "doesn't give homework." The following day, the students select 10 characteristics from each list. Some teachers who have tried this idea suggest that using only five characteristics is better. My faith is rewarded when the students develop the final list, which does not include the items mentioned above. The characteristics of a good student and a good teacher are written on signs designed by students. The signs are hung on opposite walls of the classroom to serve as guides.

We agree to strive for the high standards we have set. I grade them; they grade me. Once each month, they anonymously give me a letter grade

on a note card based on the criteria established on the teacher characteristic sign. They write a paragraph supporting their reasons for the grade. It's one of the best evaluations I get.

Getting to Know My Students

Day 1: What's in a Name?

After making a seating chart I ask my students to think about their names for two minutes. During this time they can doodle, cluster map the assignment, or close their eyes and think about it. This step is what the English teachers call a pre-write. It is an essential step if students are to write anything meaningful. I never give any writing assignments without a pre-write.

The students write anything they wish about their names for about six minutes. As they write I also write about my name. They then share what they have written by reading it aloud to the others at their lab tables. The exercise is relatively easy because students are writing about something they know and understand. It is amazing how much I learn about my students from this exercise. I am able to identify students who are apprehensive, have a low opinion of their abilities, and dislike school. These students would be likely to receive low scores on the first test, prompting them to give up on the class. That lack of initial success can cause them to become discipline problems as the semester moves on. By identifying these students early, however, I am able to ensure that most of them have a positive experience with the first test.

I read my essay to the class, allowing the students to learn something about me. This helps them see me as a person instead of a teacher or an authority figure.

Some alternatives to the "What's in a Name?" assignment are the following: "Give the world a grade today and explain why it should get that grade." "If you could be any animal in the world which animal would it be, and why?" "It is the year 2030. What are you doing?" The teacher also does the assignment and shares with the students.

One science teacher I know has the students write what they wish the teacher to know about them and what they wish to know about the teacher. The science teacher also writes, and shares, the assignment with the students.

Day 2: Learning to Be Observers

The students make a rough sketch map of the room and write a detailed description of something they observe in the room. They also express their feelings about what they see. The exercise provides insights into students' apprehensions and expectations as well as what they think of the classroom. For example, I found that a significant number of students, upon observing the preserved specimens in the glass cabinets, wrote passages such as, "Did you kill that little mouse and stuff him in that jar?" The specimens were a distraction. I placed them all in the back room and brought them out as they learned biology. It made more sense.

Day 3: Student Autobiographies

Students write short autobiographies of themselves as scientists. The teacher writes his or her own autobiography and reads it to the class. The teacher's piece serves as a rubric for the students' efforts. Sharing the autobiographies provides the teacher with an awareness of what type of science instruction the students have had previously, and more importantly, how the students felt about their experiences. The students discover that the teacher is qualified, but had a similar experience when first trying to learn science.

The following is a typical example of a student autobiography:

Science is boring. I am taking biology because it is part of the college prep program, but I hope to be a model or an actress some day so I don't see

what this class will do for me. I never got real good grades in science because I don't like it. My sister always got good grades in science, though. In the fifth grade we learned about the solar system and that was sorta interesting.

Day 4: Why Are We Here?

On the first day of school, at least one student will saunter into class and ask, "Why do we have to take this stuff? I hate science." It's a valid question, which needs to be addressed. The question becomes a focused writing assignment that not only answers the question, but pays dividends later when students attempt to write conclusions to laboratory exercises. The exercise also provides an excellent pre-write for argumentative essays about topics such as genetic engineering or nuclear waste disposal.

Students pair up sharing one piece of paper. One student takes the position that science is the most important subject in the school. The other takes the opposite view. For the next 10 minutes they argue on paper. They do not talk. Using a kitchen timer to announce when to exchange the paper is a good way of making sure each students gets a fair chance. Figure 2 shows an example of what students might say.

When the students finish, they underline the opposing student's best line, or "Golden Line." They read the Golden Line back to the author and say why they chose that line. I ask for volunteers to share their lines. The Golden Lines are placed on the board and provide a basis for student-owned discussion. The discussion is triggered by a search for the truth. The search-for-the-truth activity teaches students to defend their

FIGURE 2. The Search-for-the-Truth Activity

Student A	Student B
You have to know some science in order to get a good job.	Pro football players have a neat job and they don't know any science.
Not everyone can play pro football so you better learn some science.	Football isn't my thing, but playing drums is. Rock stars don't need to learn science either.
They need to know the science of sound and stuff about electronics, don't they?	OK, knowing electronics might help, but this is biology. Why do I need to know about bugs and stuff?
Maybe if you learned about bugs you could become an exterminator.	Who wants to be an exterminator?
Well, you need to know something about science for everyday life, like cooking your dinner.	My mom cooks my dinner and she's no scientist!

statements and to learn to write in a more specific way. When, in my early years of teaching, I wrote, "Be more specific" on their papers, I eventually realized I was not being very specific. As an example, a student might write, "Everyone should know science in order to get a good job." This line, after class discussion, might be revised to read: "Many of the better-paying jobs require some knowledge of science; it's probably a good thing to know." After several such exercises the students learn to write specifically.

The search for the truth is followed by a homework assignment. The students select a point of view: science is good, or science is a waste of time. They write a defense of their position. Their grade is not based upon which side they take, but on how well they defend their position. The question, "Why do we have to take science?" seldom, if ever, comes up again.

By the end of the first week, I have learned a lot about my audience, but now I am more than a week behind the district curriculum guide. No matter, I have established a foundation of trust that allows me to accelerate student learning as the semester progresses.

If the students are to have the exhilaration of discovery they must become explorers. The first requirement of an explorer is curiosity followed by the courage, or lack of common sense, to take a risk. William Zinsser (1988), in the preface of his book *Writing to Learn,* says, "I saw that writing across the curriculum wasn't just a method of getting students to write who are afraid of writing. It was also a method of getting students to learn who are afraid of learning" (p. ix).

Varying the Audience

Each learning unit should start by piquing student curiosity. For example: I may place a petri dish containing a small polychaete worm, scraped from a pier piling, in some saltwater on each lab table. The students ask, "What is this?" "What does it eat?" "Will it bite?" I do not answer their questions. Instead I remind them we have microscopes and urge them to make a personal list of what they observe. Their observations generate more questions, such as, "How does it eat?" "Why does it eat what it does?" "Does anything eat these worms?" During my first years of teaching, the students simply wanted me, or the textbook, to supply them with an answer they could memorize. This exercise gets them involved in the essence of science, that is, inquiry. They are hooked, ready, even eager, to learn more. The students get all of the credit if they make the list, and none of the credit if they don't.

A chemistry unit might begin by asking the students to observe the wall chart of the periodic table and make a list of what they observe. The students ask, "Do we have to learn all that?" "Who thought up this idea?" "What do the numbers at the bottom of each square mean?" They share what they observe, and are allowed to take items from other students' lists if they wish. The students then write a paragraph about what the periodic table says to them at the time and place it in their portfolio or notebook. Making the list prepares the student to write. Then they write, free of concern about grade because what they write are their own perceptions. The writing generates questions. Students are ready to learn more.

Note that the two exercises described above require the students to write to themselves, the easiest audience to address. After a few assignments addressed to themselves, the students gain the courage to try their ideas on a different audience. Too often, in many classes, the only audience the student writes for is the teacher, the most difficult audience to address.