Promoting Conceptual Understanding of Biotechnology:

Writing to a Younger Audience

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We recently received a number of positive responses from our tenth-grade biology students after using a new writing activity during our biotechnology unit. One of our students, Tony, had this to say about his writing:

> *It made me concentrate more on it [biotechnology]. I had to concentrate because I had to make it so that I could understand it and explain it to seventh-graders. I felt like I had to learn it, so I just did.*

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Students in all four classes (N = 73) indicated that their writing was instrumental in learning difficult concepts. In this article, we share our lesson procedure, report students' perspectives, and provide examples of their written work.

According to the National Research Council (1996), scientific literacy involves the ability to apply scientific knowledge defined by the content standards. Developing quality understanding of science concepts is an important goal for our students to achieve; however, it is often difficult to know which activities best suit this purpose and how to appropriately structure these tasks for optimal success. Written work provides a record of understanding, and we found that offering students guidance during the planning process helped make the activity a useful event. To assist students in planning their writing task, we incorporated techniques that the writing experts, the English teachers, use. Drawing on suggestions from researchers describing the

benefits of diversified writing tasks (Glynn & Muth, 1994; Hand & Keys, 1999; Hand, Prain, Lawrence, & Yore, 1999), we created an activity that required students to explain biotechnology concepts to a real-life audience. We chose a younger audience so that students would avoid parroting back what they heard from us, and instead be compelled to use "simpler" language as a means to construct their own understanding of these concepts.

Focus Concepts

The three focus concepts in the biotechnology unit were:

1. DNA is the hereditary material found in all living cells.
2. DNA contains a code that instructs cells to produce proteins influencing organisms' traits.
3. Social and ethical issues arise from genetic engineering.

The first two concepts are specific content knowledge, while the third concept was intended to address the societal impact of DNA manipulation, exposing students to the controversies surrounding genetic engineering. We covered this information with students during lectures, laboratories, and online activities. Students also accessed scientific publications, newspaper articles, and the Internet to further research the topics for their writing. After we introduced the task, we provided a series of planning activities to guide students in their research efforts and in developing a focus for their writing.

Sequence of Planning for the Writing Activity

The sequence of planning experiences for the activity is outlined in Table 1. Maintaining the humorous atmosphere of the classroom, we introduced the task to our tenth-grade students with a handout (Figure 1). The purpose of the task was to write a textbook explanation to an audience of seventh-grade students in the school, who would review the final drafts. With the assistance of the English teacher, we asked our tenth-grade students, as a class, to discuss the components of a good textbook and then gave them a template highlighting the major points (Figure 2). We encouraged them to use appropriate

Table 1. The Sequence of Planning Activities for the Writing Task.

TIMELINE	STUDENTS' EXPERIENCES
Day 1	Challenged with the writing task (Figure 1)
Day 1	Visited by the English teacher to discuss the template for the task (Figure 2)
Day 2	Researched in groups (Figure 3)
Day 3	Planned presentations in groups
Day 4-5	Presented to class for feedback
Day 5	Refined ideas according to feedback from members of the class
Day 6-7	Wrote first draft for feedback
Day 8	Reviewed feedback and wrote final draft
Day 9	Reviewed assessments from seventh-grade students and teachers

Comprehensible Textbook Inc.
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High School
Room 108

Dear Author:

We would like to retain you to write an explanation about your biotechnology topic for seventh-grade students. Write the explanation that covers the topic of your choice. The explanation will need to be 500 words or less. Pictures and diagrams can be used if they will help explain your topic to your readers.

The explanation needs to be written so seventh-grade students are able to understand the concepts you are trying to communicate. Remember your market and write the text in age-appropriate language.

Your work will be evaluated by our editorial staff, but more importantly by your readers. We will be surveying your readers for their feedback considering your work.

Sincerely,

Charles E. Oily
CEO C. T. Inc.

Figure 1. Handout Introducing the Guidelines of the Textbook Writing Task.

Purpose
- ✓ Inform
- ✓ Interest reader

Guidelines
- ✓ 500 words or less
- ✓ Quality not quantity

Audience
- ✓ Seventh-grade science students to support each heading.

Specifics
- ✓ Use headings for different sections.
- ✓ Include an introductory thesis statement for each.
- ✓ Use bullets and/or numbers to highlight main points.

Reminders
- ✓ You should not argue a case.
- ✓ You should present all pertinent information related to the topic.
- ✓ You must use language appropriate for the audience.

Figure 2. Template of the Major Components of the Textbook Writing Task.

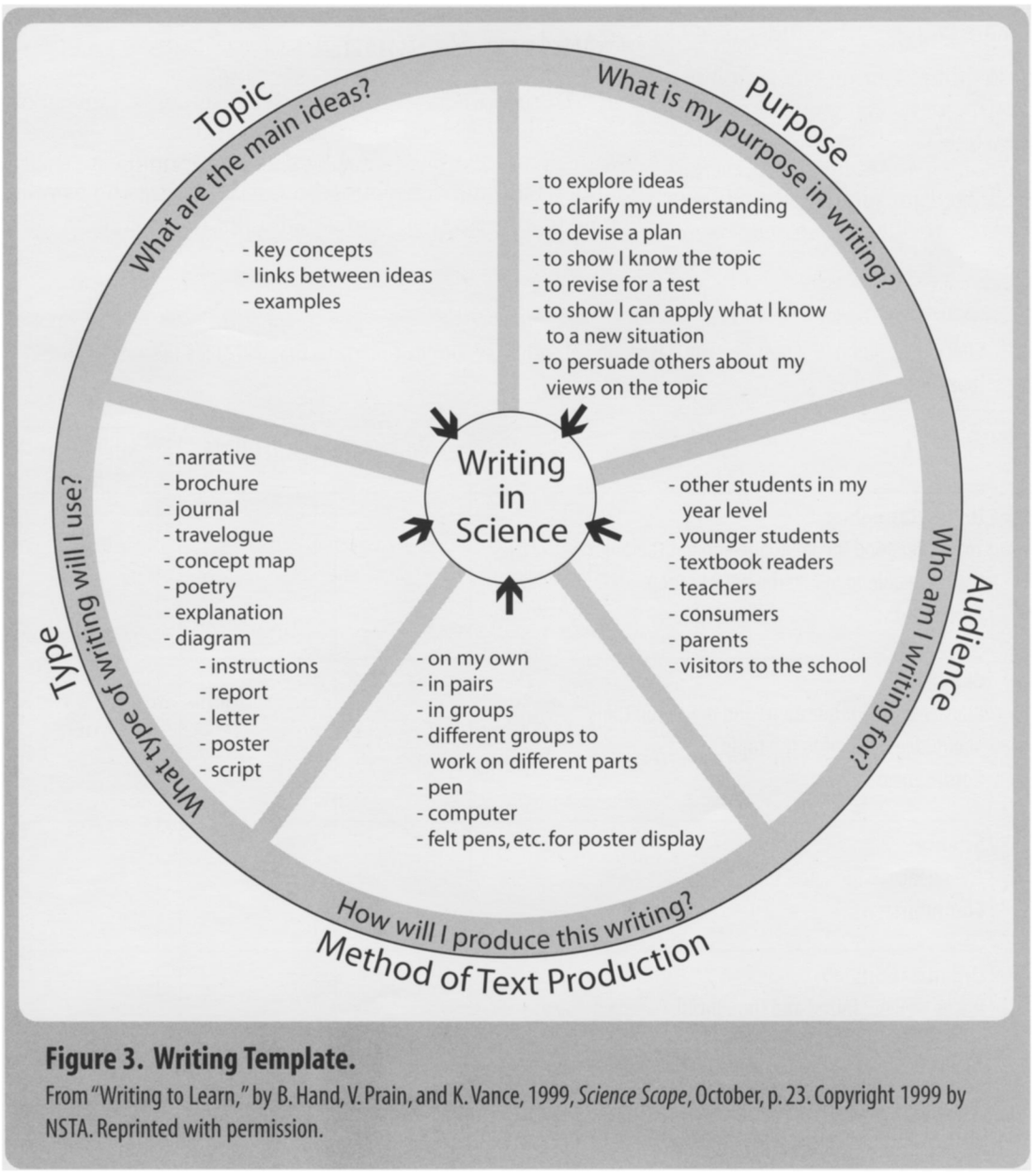

Figure 3. Writing Template.
From "Writing to Learn," by B. Hand, V. Prain, and K. Vance, 1999, *Science Scope*, October, p. 23. Copyright 1999 by NSTA. Reprinted with permission.

language for seventh-grade students and to make the topic interesting by including visuals and explaining their relevance in the text. The real-life application of the task resulted in several students consulting their younger siblings. We suggested that students use headings for different sections, include introductory sentences, and highlight important information. The writing task was limited to 500 words and we reminded students that a textbook author would not argue a case, but present pertinent information about the topic.

The topics for the writing task included:

1. Genetically Modified Organisms for Food
2. Biotechnology and Agriculture
3. Biotechnology and Medicine
4. Biotechnology Regulation
5. Gene Therapy.

Students were divided into five groups composed of five to six individuals. As a group, students chose the topic to write about, the only condition was that each class, as a whole, cover all five topics.

A writing template (Figure 3, Hand, Prain, & Vance, 1999) was

provided to help students structure their writing. They discussed the template with one another; however, each student was required to hand in a separate outline of the task and an individually-written product. The template helped students realize the demands of the activity. In addition to informing seventh-grade students about biotechnology, many students identified a self-directed purpose: as " ... so I can learn more about biotechnology" and " ... to demonstrate my understanding." We required students to explain the three focus concepts in their writing; organizing the "topic" portion of the template was the most demanding. We tried not to be too prescriptive and, instead, encouraged discussion of this section with their peers. When students expressed confusion, we asked them to identify what it was they needed to do, suggesting consultation with group members, thereby directing students back to their peers. While this was different from our usual response, this action emphasized that the responsibility for learning and decision-making was the students'.

Students researched in groups during one 50-minute class period. On the following day, each group presented an outline of ideas to the whole class and each individual contributed to some portion of the 5-minute presentation. Students were encouraged to question the presenters, and all students were provided Feedback Forms (Figure 4) to critique the group presentations. Students had an opportunity to refine their ideas by reviewing the feedback about the content of their presentations; they listed five improvements before writing their first draft. The discussions during the planning process were essential, stimulating students to think about the task, how they would approach it, and what would make it successful.

While students worked in groups during the planning portion of the activity, each submitted his/her own individually written product. Two class periods were reserved for writing the first draft. We provided written feedback to each individual on his/her draft, identifying missing concepts, as well as pointing out spelling and grammatical errors. Students completed their final drafts during one full class hour, these drafts were given to seventh-grade students to review. The seventh-grade students used a Feedback Form similar to the group presentation form; however, the language was modified to a "chatty" seventh-grade level and the students were asked to compare the writing to their textbooks. The feedback provided by the seventh-grade students was much more powerful than any teacher feedback, comments, or grades. We witnessed a transformation as classroom activity was converted to reality, involving a real-life application of students' work. Writing to an audience of seventh-grade students contributed to learning; this is evident in the responses of our tenth-grade students.

Student Responses

During interviews, tenth-grade students indicated that writing helped them understand the focus concepts, particularly when they had to communicate their understanding to a younger audience. Wrestling with how to express their understanding caused students to

Check the column that best fits your description of each area. Provide comments that will guide the authors in making corrections.

CRITERIA	WEAK	ADEQUATE	SUPERIOR
Understandable: You understood the language and got the point. You were able to follow the presentation. **Comments:**			
Complete: It answered your questions and made you think about ideas related to the topic. **Comments:**			
Science: The science made sense to you. **Comments:**			
Organization: It was well organized and thoughtful. **Comments:**			

Figure 4. Feedback Forms Used To Critique Group Presentations.

engage in more mental work than they would under our previous curriculum. Terry, who was normally difficult to motivate in science, explained:

> *I actually had to go in and figure out what it was really trying to say instead of just "oh yeah." I actually had to dig deeper so I could explain it better to the seventh graders ... if I wasn't talking to [them] I could have just wrote down the vocab. words and not have to explain them and ... I wouldn't have had to dig as deep. I could have just stayed at the surface.*

Surprisingly, this type of response was more common than we anticipated. Students felt they had to think about the concepts to simplify the language for their readers. Several students let us know why they thought the writing task was better than other assignments. For example, Harry commented:

> *For a study guide you are just filling in the blanks and that is fairly simple ... writing things out you have to know everything about it. Study guides are just short answers; they are pretty easy. You can get them done in about ten minutes. For the paper you have to take time and actually work on it for a while to get everything in there and correct.*

We were particularly impressed with Laura's response:

> *I mean it is one thing to write the same thing over and over but it is another thing to rewrite it but change the format like change the wording and stuff like that. I think it's more changing the wording and rewriting that really helps people learn than writing notes over and over. I mean if you can write something articulate enough to convey it to someone else then I think that helps you not only absorb the material but it helps you learn. Use this same basic process on other assignments so then it really helps you to have a better ability to communicate.*

From interviews, we discovered that students were aware of their own learning and we were surprised at their ability to describe how that writing helped them to learn.

As for Terry:

> *When you actually have to write it down and redraft it and think about what you are writing, it helps a lot more. You are just not writing it down and maybe remember a few things, you are remembering all of it because you write it down a few times, read over it, change things, read over again, all that stuff.*

Students' comments reassured us that the writing task promoted learning, which was not simply a novelty effect, as Tim explains:

> *Because when you are just listening to someone talk about it, it gets boring. You don't want to listen, and you just don't really pay attention. But when you are writing it yourself and getting the information you are taking it into your head a lot more, and you are keeping it in your mind because you are doing it over and over with the different drafts. And you get more information.*

Written Work

The following examples of textbook explanations illustrate the range in students' work. The first excerpt (which received a high mark) was taken from a writing sample on the topic "Biotechnology in Medicine:"

> *DNA or deoxyribose nucleic acid, controls every aspect of the cell, from protein production to physical characteristics. It tells the cells how to grow, which is how hair color, eye color, and skin tone come about. DNA is also in all living things, so it's no wonder that scientists and doctors have developed new, ground-breaking biotechnology procedures in the medical field.*
>
> *Many of the procedures involve changing the DNA sequence to produce a specific protein. A protein is produced by precise sequences in the DNA chain. Scientists have recently discovered that by changing certain sequences, they can get the cell to produce a different protein. They can change the sequences by using many unique tools, such as Ligase, Restriction Enzymes, a Gene Gun, and Gel Electrophoresis. Ligase is the "paste tool" of the genetic field. It binds together the DNA sequence after it has been changed. Restriction Enzymes are the "cut tool," which means obviously that they remove certain sections of the DNA sequence. Gel Electrophoresis is the "read tool." It is a simple process that reads the DNA sequence.*

Few writing samples were perfect in the sense of a technical textbook explanation. This was important because detailed, technical explanations were perceived to be beyond the comprehension of the audience. Instead, students took complicated concepts, concerning tools and techniques of biotechnology, and tried to reduce them to the most basic ideas, simplifying the explanation for their audience of seventh-grade students. While several writing samples received high marks, there were no perfect scores. In the struggle to reduce complex terminology, some essential features of the concepts were inaccurate or absent. However, this situation presented an excellent opportunity to further discuss and reflect on the way in which the writing communicated concepts. With reference to the excerpt above, while gel electrophoresis may help to "read" DNA sequences, this is more accurately described as a

technique used to separate regions of DNA by size. Due to the permanent record writing provided, we could identify some misconceptions held by particular students (see next excerpt). Overall, we were very impressed with the way in which most students simplified concepts, identifying their fundamental roles. We were enlightened by the way students' samples revealed how they were thinking about the concepts. Their written expressions provided various means for reflection, discussion, and idea consolidation.

Confusion was evident in several writing products. The next excerpt, from a sample on the topic "Genetically Modified Organisms for Food," received a lower mark due to inaccuracies, missing requirements, and less descriptive content of the major concepts:

Chapter 1. Genetically Modified Organisms for Food

1-1 Where is it done?

Genetically modified food is found in almost all countries, but the U. S. is one of the top countries in genetically modified food. Most vegetables are used, but all foods are effected. Scientific engineers are modifying food you eat and you might not know it.

1-2 Why is it done?

Some of the main reasons food is genetically modified is so it can be made cheaper, made easier, made healthier, grown better, and it can also taste better.

1-3 Who is doing it?

There are scientists that work for biotech labs that are modifying foods by putting proteins in the food to make it healthier. They do this by putting the protein in the plant or animal that produces the product or food. Scientific engineers are doing this, and there are a lot of people that are against it for different reasons. Most people are using it and not even realizing it.

1-4 What is it?

Genetically Modified Food or GMO for short is simply changing the DNA's composition of the plant or animal in this case. In other words it is changing the composition of the animal or plant to what they want it to produce. They do this by injecting the protein that they want in the organism so it will produce the food the way they would like it. It is done indirectly by putting the protein into the plant or animal and not directly into the food.

While this student may be aware of some reasons organisms are modified for food, he did not clearly demonstrate understanding of the term "genetically," even though he used it five times. It is apparent that he is unclear about the distinction between DNA and proteins, and their roles in genetic engineering–concepts essential to biotechnology. A low score also resulted from omitting a description of the tools and processes; had he attempted this, he might have clarified his explanations and his understanding.

Outcomes & Implications

We were very pleased with the genuine effort that students put into their writing activity. Writing to a younger audience and having the opportunity to plan their writing with group members allowed students to construct their own understanding of biotechnology concepts. Our tenth-grade students practiced literacy skills and demonstrated knowledge integration by communicating their understanding to seventh-grade students. Such teaching strategies help fulfill the science literacy standards put forward by the National Research Council (1996), and empower students to take responsibility for their learning.

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