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ABSTRACT

Writing can be a rich source of information for science teachers who wish to take their students' present understandings into account as they plan and carry out instruction. The responses students give when asked to explain in writing what happened in an experiment can help the teacher address particular student's misunderstandings. Even writers of low ability can demonstrate conceptual understanding of scientific concepts. The writing need not be lengthy--a few lines can be quite informative. Students who demonstrate in their writing different levels of understanding can benefit from a range of experiences in a lab designed for the whole class. Using writing in this way can enhance teachers' understandings of their students and enhance students' understandings of science. (RS)

Center for the Study of Writing

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CENTER FOR THE STUDY OF WRITING

USING STUDENT WRITING TO ASSESS AND PROMOTE UNDERSTANDINGS IN SCIENCE

by

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During the seventies and eighties educators have become increasingly aware that students often pass through their science classes without attaining the kinds of understandings they are expected to have—broader and deeper understandings of the sort that would enable more students to pursue careers in science, and that would enable all students to become better informed citizens. At the same time, there has also been increasing recognition that the outcomes of instruction in science are determined, in part, by the various prior understandings and ways of thinking that students bring with them. Even in relatively homogeneous classes, different students may interpret the same demonstration or laboratory activity in very different ways, and what they ultimately get out of the activity may well depend on the teacher's ability to make contact with the different understandings they already have, as a first step toward helping them go further.

Some teachers have suggested that a particularly good way to get in touch with students' thinking is through their writing (Soriano, 1989; Wotring, 1981). This idea receives strong support from our own research on writing and learning in science. The data from our current project indicate that writing can be a rich source of information for teachers who wish to take their students' present understandings into account as they plan and carry out instruction. To illustrate how teachers might use writing in this way, we will share some examples from our research and consider their implications for teaching.

The first examples come from two tenth graders, Ernie and Aaron, who were writing about an experiment they had done on the buoyancy of various objects in two clear liquids, labeled "A" and "B." At the beginning of the experiment, two small toys, a tire and a top, were found to sink in a container of liquid A. However, when some liquid B was added, the top rose to the surface, while the tire remained at the bottom. Among other things, the students were asked to explain in their writing why that happened. The answers that Ernie and Aaron gave to this question are shown in the following excerpts, and they suggest two different levels of understanding, both of which are still incomplete.

Ernie

> . . . The reason (I think) the tire and top sank at first was because they were heavier. The molecules of A were not dense enough to support the object.
>
> I hypothesize that the molecules of B are more dense than those of A. . . . The top was lighter than the mixture, and floated when B was added. The tire was heavier than the mix, and remained sunken. . . .

Aaron

> . . . The tire stayed on the bottom because the substance of liquid B didn't have anything in it to make the tire float but it did have something in it to make the top float (such as an ionic compound). . . .

Ernie seems closer to a complete understanding of buoyancy than Aaron. He attributes the floating of the top to a physical property of liquid B—which he refers to in terms of both density and weight—and, with his notion that a liquid must be dense enough to "support" a given object, he suggests a mechanism for buoyancy that is both physical and general. Aaron, on the other hand, seems inclined to attribute the floating of the top to some unknown *chemical* property of B, and the effect of that property on the top seems rather magical. His use of the "make . . . float" construction does not suggest any sort of mechanism, and there is nothing very general about his explanation either; rather, it seems that specific objects simply require different chemicals in order to float. What comes through in Aaron's writing is corroborated by the interview we conducted with him while he performed the experiment. The top, he hypothesized, had a kind of molecule in it such that "when the other substance [B] was added, it just took away its weight or something."

Although Ernie's understanding seems more advanced than Aaron's, his writing also indicates that his understanding is still incomplete in some important respects. His idea that the *molecules* of a liquid must have a certain density suggests that he is thinking of density not as weight per unit of volume, but as the concentration or thickness of the liquid. In fact, when Ernie used the term "denser" in our interview with him, we asked him what it meant and he replied that he thought it might mean "more molecules per square inch." With a model of buoyancy based on this conception of density, Ernie could say that a liquid must be dense enough (i.e., thick enough) to support the weight of a given object, but he could not make a direct comparison between object weight and liquid density. That would explain why he cut short the weight comparison in the first sentence of the excerpt and discussed liquid density instead. He did write, later, about the objects being "lighter" or "heavier" than the liquid, but at that point he was taking advantage of the fact that such weight terms are commonly used with reference to thickness (e.g., "heavy cream"), as well as weight.

To help Ernie attain a more complete understanding of density as weight per unit of volume, it would seem important to have him think about what an object *does* to a liquid as it is gradually immersed, i.e., that it displaces the liquid, or pushes the liquid out of its way. Another thing for him to consider is exactly how *much* liquid is displaced when the object is fully submerged, i.e., a volume equal to the volume of the object. Ernie might then be asked what property of the object determines whether or not the force of gravity will cause it to displace its entire volume in the liquid, i.e., its weight.[1] Finally, there would be the question of how heavy the object must be to displace an equal volume of liquid, i.e., at least as heavy as the volume of liquid being displaced.

In this way, Ernie might be led to an understanding that both the thickness of liquids and the heaviness of objects can be expressed universally as weight in relation to volume, so that one can predict exactly which liquids will "support" which objects. It should be noted, however, that this scientific concept of density depends in turn on the concept of volume, which itself is still difficult for many tenth grade students. It probably was no mere slip of the tongue when Ernie defined density in terms of molecules per *square* inch, because we have additional evidence in our data that he was inclined to think of space in terms of area rather than volume (as were several other students we have seen). Consequently, it would be important to help Ernie clarify his understanding of volume as well as density.

As for Aaron, the fact that his understanding appears to be at a lower level than Ernie's leads us to think that a different instructional response would be more appropriate for him. It might be especially useful for Aaron to see that the buoyancy of various objects increases as more and more of a given compound (e.g., a salt) is added to water, and that the same effect can be achieved for a particular object with a variety of compounds. Aaron might well explain such observations by adopting Ernie's notion that the liquid is becoming *thicker* as more of a compound is added, and—for Aaron—that would represent progress toward a more complete understanding.

The examples from Ernie and Aaron may immediately raise some questions about the feasibility of using writing to assess students' conceptual understandings, when considered from a practical standpoint, so we turn to a few of those questions now.

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[1]The appropriate technical term for the property in question is, of course, "mass," but we speak of "weight" here in deference to our subjects, who rarely used the term "mass," and then did so in ways that showed considerable confusion as to its meaning.

How informative is it to look at writing done by students who are low in writing ability? Students like Ernie, and even Aaron, seem to be reasonably fluent writers, but other students still have enough of a struggle with "basic" writing that teachers might wonder about the ability of these students to articulate what they really think. Consider the following writing from Larry, a sixth grader whose writing (and thinking) resembles what we have found with some tenth graders as well.

Larry

> There was two types of water one was labbles liqued A and one was liqueid B. We put a tire and a little top in liqued A they both sank then we put some liqued B in and the top went up the top and the tire stayed at the bottom. I think the tire stayed down at the bottom because it was heavyer and the top was lighter.

Larry provides a fairly good description of what happened in the experiment, and his explanation is focused on a relevant physical property, i.e., weight. But he seems to attribute the floating of the top entirely to its being lighter than the tire, without explaining the role of liquid B, and therefore he seems to display a rather low-level understanding of buoyancy. However, Larry also displays some obvious problems with written English, so we need to ask whether there might not be more to his understanding than meets the eye in what he wrote. Once again, however, the apparent limits of the writer's understanding are confirmed by data from our interview, where it was possible for us to probe those limits at greater length and in greater depth, independent of writing.

Consider, also, the writing of Mickey, who was a tenth grader.

Mickey

> We had a Jar with a liquid called "A" we put a top & a tire into "A" & they sank we poured a liquid called "B" into "A" & the top floated up to the top but the tire staed at the bottom. This menes "A" was lighter then the top & the tire wile "B" is hever. . . .

Mickey was enrolled in a remedial reading class, and writing this piece was quite a struggle for him. Nevertheless, the comparisons he made between objects and liquids in terms of "lighter" and "hever" suggest that his understanding of buoyancy was more advanced than the majority of our subjects, and in fact the interview showed his understanding to be at a level higher than Aaron's but not quite up to Ernie's.

It probably should not surprise us that even students like Mickey and Larry can produce writing that contains significant clues as to their thinking. Any piece of writing requires the writer to make a number of linguistic choices, and many of those choices are likely to reflect the writer's understanding of the topic, even if they are not "good" choices from the standpoint of written composition or standard

English. However, this is not to say that all writing done by all students is equally informative, which brings us to the next question.

What kind of writing is informative, and how can I get students to do it? We can at least suggest some guidelines here by considering the writing samples involved in our own research—which generally turned out to be quite informative—and by examining the circumstances under which students produced them. The writing does not need to be lengthy; even a few lines can be quite revealing. The important thing is that students have an opportunity to say what *they* think, without first being given someone else's answer, which they then try to give back. Our subjects seemed to be primed for this kind of writing in that they did not write immediately after formal instruction related to buoyancy, but after having a chance to think and talk about relevant hands-on experiences. We also assured the students that, whatever they wrote, it would not be graded as to its correctness. It seems noteworthy, too, that we asked students both to describe and to explain what happened in the experiments they had performed. While explanation is the goal of science, some students seemed unwilling or unable to offer an explanation for what they had seen, but were quite willing to describe it and, in that way, to provide insights into their thinking.

How can I be sure that my interpretation of a student's writing is correct? The inferences teachers make about a student's understanding on the basis of some writing must always be treated as tentative hypotheses to be tested with additional data, including additional data from the same piece of writing and from other interactions with the student. If a teacher knows what *kinds* of partial understandings students are likely to have, then the range of plausible hypotheses may be narrowed considerably. The pieces of writing we have been working with generally contain multiple clues as to the writer's understanding, so that in evaluating a given piece, it is usually a question of deciding which of the plausible hypotheses seems most consistent with all the clues in the text.

When students' writing indicates that they are at different levels of understanding, should I respond by engaging them in different individual and small-group activities? Possibly, but not necessarily. Individualized instruction may be desirable and even feasible in some instances, but the needs of students at different levels of understanding can be addressed through whole-class activities as well. For example, a laboratory on buoyancy might include experiences designed for both the Ernies and the Aarons in a particular class, and the teacher might then try to monitor the lab by making sure that students at different levels of understanding are paying particular attention to those experiences that seem most pertinent to their current thinking. By including a range of experiences in a lab that is planned for a whole class, the teacher gains additional opportunities to see what individual students already understand, and to help them advance as far as possible.

To conclude, we should note that the use of writing to assess what students understand may pay an important bonus, because it is a common observation that engagement in the activity of writing can itself have a progressive effect on the writer's understanding, through a kind of re-thinking process. On the other hand, it also seems to be the case that not all writers—not even all fluent ones—actually use writing as an occasion to reflect on their thinking and rework it. But students are probably more likely to do that if they have experience writing in a context where they are subsequently led by others to think further about the ideas they have already expressed in writing. There is still much to learn about the use of writing to assess and promote students' understandings. Thus, in the interest of further exploration, we encourage teachers to try using writing in this way, to see how it enhances their understandings of their students, and to see how it enhances their students' understandings of science.

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