Making a Case for Cases

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Four years ago, we undertook a revision of the first year biology course at our high school. We did this for two reasons: first, the curriculum we were using was not effective for all our students. For many students not labeled as "high-achievers," the content we were teaching was not engaging, and it was a struggle for them to maintain satisfactory grades. While those labeled as "high achievers" demonstrated adequate performance levels, our guess was that many of them were for the most part "program- and pedagogy-proof." We also were growing frustrated by the fact that when our students asked questions which went beyond the boundaries of the biology curriculum we were teaching at the time, we felt we had to put their questions aside, telling them that these issues would be dealt with when they took chemistry or physics.

At about the same time as our discontent was growing, so was a movement in our state, as well as in the nation, to re-vision the science curriculum with an expanded focus on the diverse audience this curriculum should serve. In Michigan, an article appeared that identified 10 key issues in science education (Education Extension Service 1992) and paralleled the kinds of changes we wanted to see take place. Unfortunately, there were no programs or textbooks that addressed these issues. We had a choice: we could either wait for the textbooks to address these issues, or we could develop a responsive curriculum ourselves. We chose to do the latter, and out of this conviction grew a new full-year integrated science course in which we used two large-scale case studies as vehicles for our students to use their developing understanding of concepts in biology, chemistry and physics in order to solve scientifically-based problems (Richmond & Striley 1994).

Here we share with readers the way we used the first of these case studies—the cholera epidemic, present and past—and the ways in which using one of these case studies allowed us to address critical objectives in science curriculum for all students.

Defining the Big Issues

What follows is a list of the issues that guided our initial thinking and helped define where we wanted to be as teachers, as well as how we assessed where we stood with regard to the curriculum we were using.

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1. *Science for the Best and Brightest vs. Excellence and Equity for All.* As noted above, we felt we were doing a disservice to most of our "average" and at-risk students. The need to find ways to reach these students was made even more imperative in light of our move several years earlier to include students with special needs in regular subject matter classes.
2. *Breadth vs. Depth.* We were speeding through our prescribed curriculum, sacrificing understanding for number of topics covered. We began to feel that if we covered less, we might do a better job with what we did teach.
3. *Separating the Teaching of Science Process & Content vs. Bringing Them Together.* We had not always done a very effective job teaching process or bringing process together with content so that our students would see process and content as equally important aspects of the scientific enterprise. In addition, we tended to teach process-related skills out of context, not in response to particular needs—and the result was that these skills were not considered relevant by our students. We came to understand the value of integrating the two, in our laboratory activities in particular, and in teaching skills only when they were needed to solve a problem.
4. *Teaching the Basics vs. Teaching Higher-order Knowledge and Skills.* This problem arose from the detailed life science curriculum established for our school. As a result, we felt pressured to "cover" the large number of objectives in the time we had. Gradually, we realized that in our effort to provide such coverage, our students were often the losers, as there existed no framework within which we could focus on teaching the most important scientific ideas and principles while also providing students with the tools to develop higher-order skills.
5. *School Learning vs. Authentic Learning.* What our students were learning between 7:30 and 2:30 was usually left behind when they departed school grounds. We wanted them to be able to see and use ideas they learned in science class in the experiences and decisions they would face in their lives outside of school.

6. *Learning Community vs. Isolation and Competition.* Previously we had concentrated our efforts on being the agent for our students' understanding of material; we did not appreciate that some of the most effective teaching might go on among peers. We grew to understand that it is imperative for us as educators to help our students learn how to work together cooperatively as a team, as this is a skill that is highly valued in the working world, science-related or not.
7. *Disciplinary vs. Interdisciplinary Knowledge.* As we have already noted, sometimes a student asked a question related to a topic we were discussing that would require explanations outside of the discipline of biology. Because of the compartmentalized curriculum, we would have to say, "Sorry, but we cannot go into that right now," weakly attaching to this apology the promise that they would undoubtedly deal with this issue in a future science class (if, in fact, they took other science classes). We wanted to be able to answer their questions, not to segment their knowledge or lessen their appreciation for the integrated nature of science. Worse, if we continued to sidestep their questions, we ran the risk of having them feel their inquisitiveness was neither relevant nor valued.
8. *Test-Driven Curriculum vs. Outcome-Based Curriculum.* We were testing our students on concepts we thought were important with no thought about how to help them reach these goals. We became convinced that it was critical to teach by first finding out what our students knew and taking them from where they were to where we wanted them to be. Any effective curriculum, in our minds, should be developed around what our students brought with them to the classroom as well as what we wanted them to know.
9. *Teaching in Isolation vs. Support Systems for Teachers.* While this is not an objective for our students, experience has told us that it is an essential prerequisite for creating and maintaining effective curriculum. In our case, we had a good support system at our school as the result of our whole-school commitment to professional development activities. This support was in the form not only of grants, which provided us with time to collaborate, but in the form of community and university collaborations, which provided us with intellectual stimulation and peace of mind that the innovations we were developing would for the most part be received by parents with open minds.
10. *Scheduled Delivery of Curriculum to Students vs. Patient Creation of Curriculum with Students.* We wanted to come up with a curriculum that students needed, based on their questions. This student-centered approach meant that we might not always be in the same place at the same time each year because our students change and their questions change. We believed that using case studies would allow us the flexibility and opportunity to achieve this goal.

Setting the Stage

Why did we select cholera as the focus of one of our large case studies? We held several faculty meetings to identify a topic or theme that might be useful and engaging. We wanted to select something kids did not know much about; we wanted something topical; and we wanted something that would require them to learn the content objectives we were responsible for, primarily cell biology and the nature of scientific investigation. One colleague suggested that water could be a theme, as it lends itself to interdisciplinary issues and units. Another mentioned that he had a copy of a video (see below) which had as a focus the discovery and treatment of the cholera epidemic in London in the 19th century. Cholera seemed to meet our criteria. We were fairly certain that none of our students would know much about the disease; our planning was taking place at a time when a major cholera outbreak was being reported in the news around the country and the world; and it was a wonderful disease to use in order to teach the cellular biology and scientific process objectives for which we were responsible at this grade level. We were off!

The Scenario

What follows is a brief description of the shape the cholera case study has taken over the past four years. Readers should keep in mind that the story and direction change from year to year, as our students and their questions change. That said, here is the way the cholera story typically unfolds.

We introduce the cholera case study as a mystery set in the present day, using the recent outbreak in South America and the United States to set the problem in contemporary context and to engage the students. We then extend the problem back in time to 19th-century London, when the disease first reached epidemic proportions. We introduce students to the problem by sharing with them segments of "The Day the Universe Changed." This PBS program, through historic reenactment and narration, traces the discovery of the source of the "bad water," the cause of the massive and recurring epidemic, and of an effective treatment. The first question that always comes up is: "What is the cause of this disease?" We ask the students where they would look if they wanted to find the cause. They immediately say that if it was caused by an organism, the cholera patient would have to be examined. We say that since we don't have a cholera patient handy, where else could we look? From this point it is a very short leap to the observation that since some of the symptoms are vomiting and diarrhea, it would be worthwhile to look at these products. While this prospect does not sound very pleasant, you might imagine that to high school students, such exploration has a certain appeal.

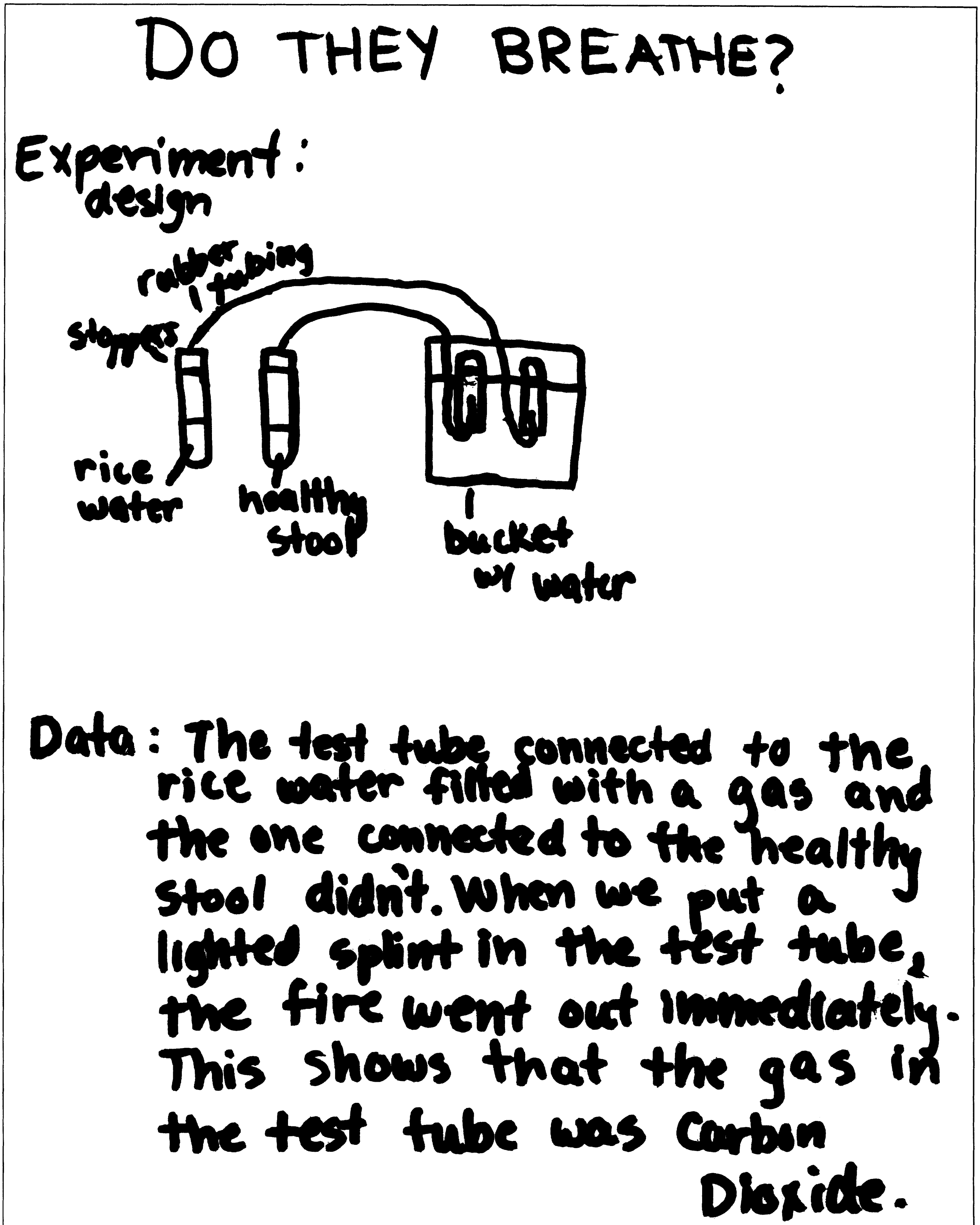
We continue to play out our scenario by telling them that while we do not have the vomit, we do have the stool, and we supply them with a flask containing a so-called specimen. This gets *everyone's* attention! We tell them it is called ricewater, due to the fact that the mucous flecks make it look like rice suspended in a watery fluid. We prepare this specimen by mixing together molasses and water, adding flakes of gelatin to simulate the mucous, and yeast to simulate the cholera-causing organism. When asked what they would do with the specimen, they claim they need to examine it, but of course, they cannot see anything with their eyes alone. Several claim they must use a microscope in order to visualize the small organisms they think are in the specimen. Those students who understand and can demonstrate they know how to use this tool do so; those who cannot are instructed in its use.

This is but one example of how we teach process and content hand-in-hand. Students examine the stool, see little bubbles or dots, and wonder if that is the cause. We continue to assess their understanding of the scientific method by asking them: "How could you prove this is the cause?" Many students want to compare this stool to a healthy stool. They ask us to get them a healthy stool, and we prepare a molasses and water mixture for this purpose. They examine the two mixtures, note the difference, and hypothesize that the tiny dots are the cause.

They use their textbooks—which we refer to periodically—to obtain information about Koch's postulates in order to investigate whether these tiny dots are the cause. In order to do this, they first must investigate the characteristics of life. The students generate these characteristics and hypothesize whether or not the tiny dots are living. There is usually some disagreement among class members, and uncertainty about whether such disagreement is acceptable. We reassure them that scientists—and teachers—disagree all the time. We then ask each group to investigate two characteristics of life (one of which is always breathing) in order to obtain evidence that supports or refutes their hypothesis. They design controlled experiments, carry them out, and collaborate with other groups in the class to gather and interpret results.

The designs vary in sophistication (see Figures 1a–1c for examples of designs to test breathing and reproduction), but the results obtained support the same idea. Because some in the class will recognize that a positive result with respect to the presence of CO_2 doesn't necessarily confer living status, students investigate other characteristics of life. Some will do three experiments, some four. We provide them with sufficient time to conduct two experiments (some groups do up to four), then stop and share results. Once all groups report their results, they conclude that the thing that causes cholera is alive.

What follows quickly on the heels of these tasks is the question—again, generated by the students—of how this cholera-causing organism kills you. Going back to the symptoms of the disease, students realize that to understand more about the cause, they have to look at the digestive system, and so we investigate digestion. We take some time to assess what they know about the system, first by asking them to diagram, in groups, what happens to a Big Mac when it is eaten. Not surprisingly, we find that there are numerous misconceptions about the organs and processes involved. We look at each step of the process, examining both physical and chemical digestion and the role of acids and enzymes. Students design experiments to find out what (e.g. protein, fat, starch) is digested where, for example, by making use of enzymes and acids located in digestive organs. In carrying these experiments out and in sharing and



Figures 1a–1c. See pp. 338–340 for examples of experiment designs created by three different groups of students to investigate whether the sample of an unidentified substance hypothesized to cause cholera is living or nonliving. Here in Figure 1a students designed an experiment to determine if the substance breathes. Note: Students learn that BTB (bromthymol blue) is a color indicator used to detect the presence of carbon dioxide. If appropriate, we also let them know that BTB is a pH indicator; they have opportunities across the year to use BTB in other contexts as well.

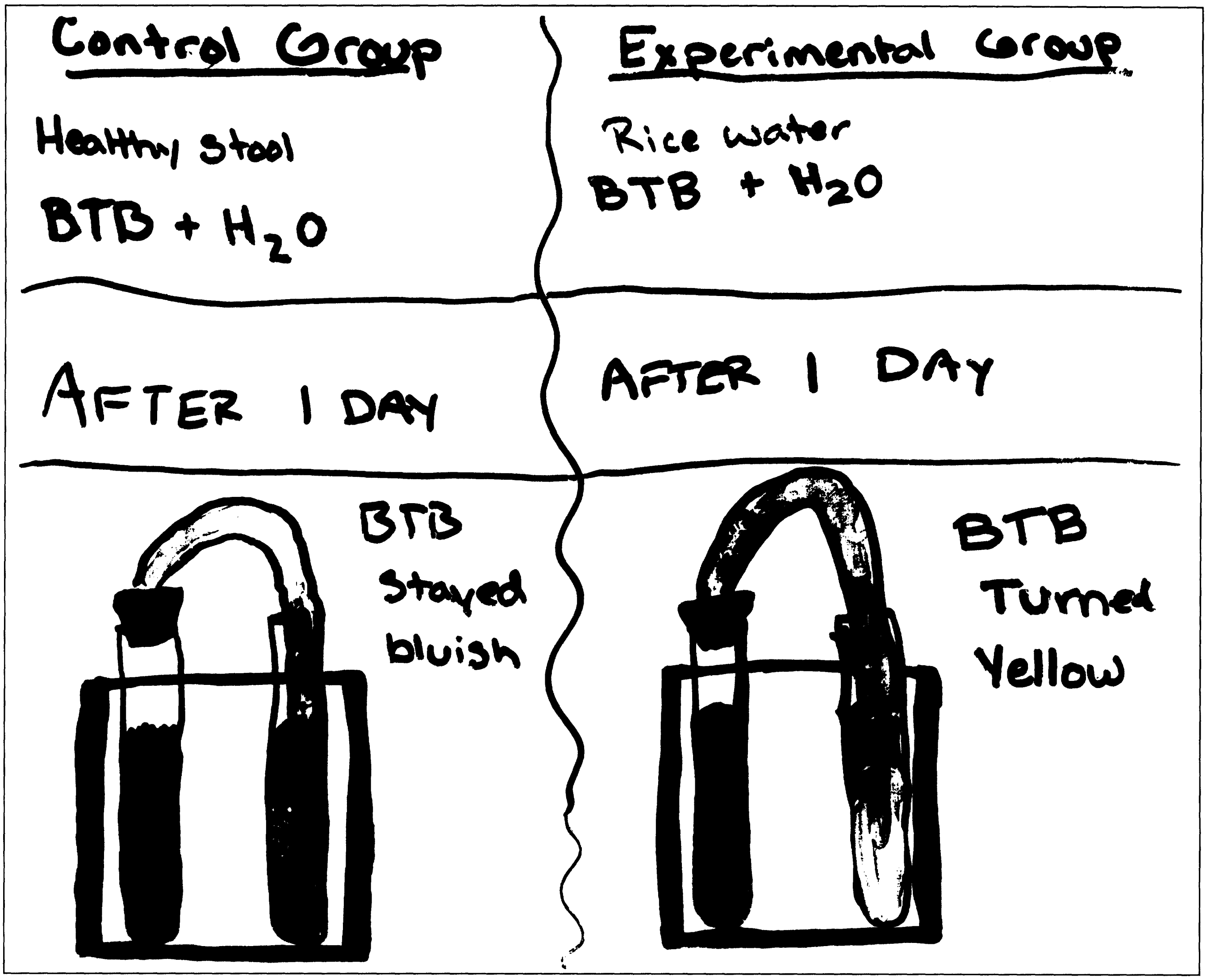


Figure 1b. Here students designed another experiment to determine if the substance breathes. Note: BTB is a color indicator used to detect the presence of carbon dioxide.

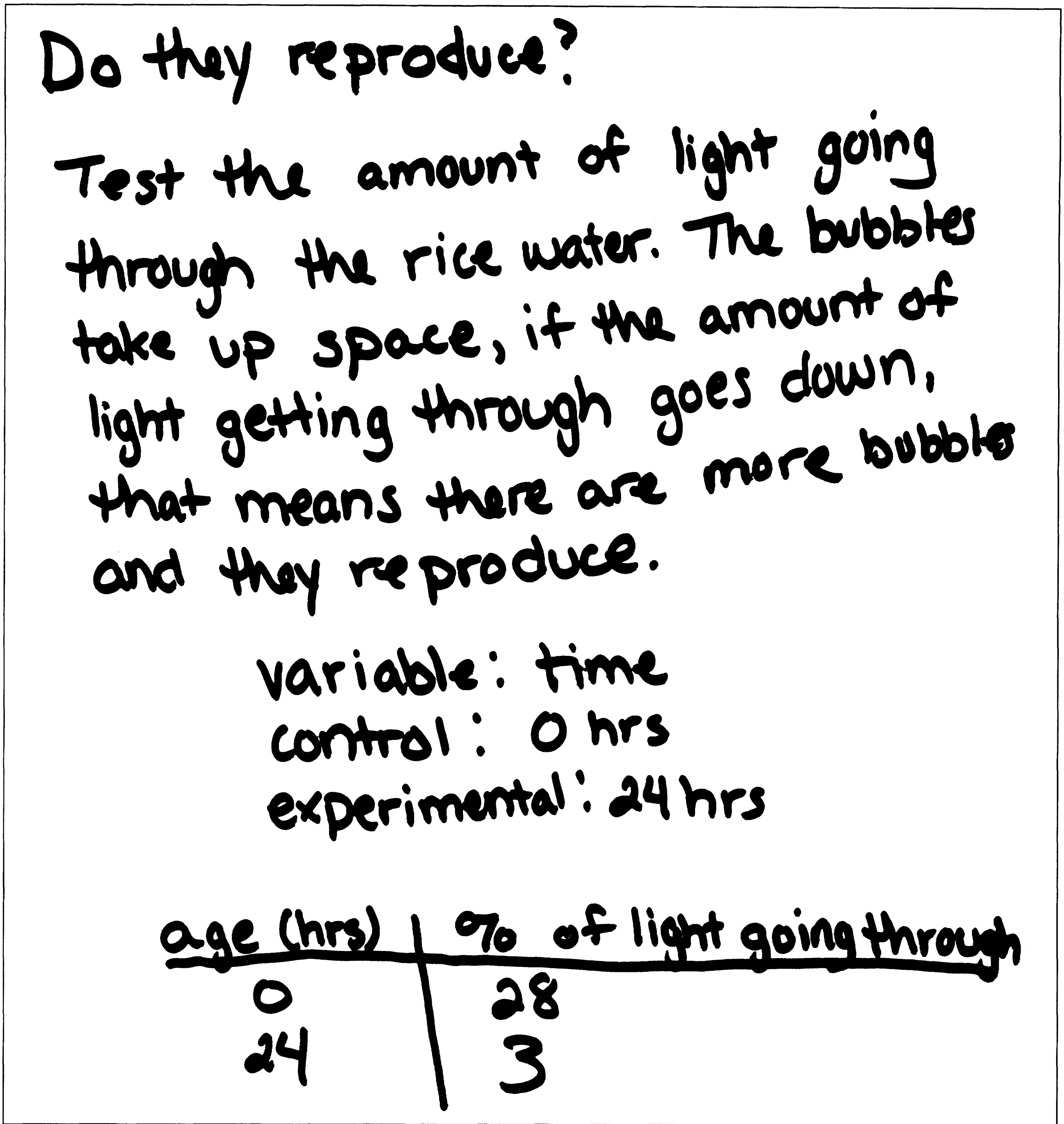
comparing their data with those of other groups, many misconceptions are corrected.

By this time, we can step back from the design process, because students are very good at creating and carrying out their own experiments. We help them focus instead on the implications of their findings. Once they realize that something affecting the digestive system is responsible for the major symptoms of cholera and combine this with their knowledge of digestive processes and cholera symptoms (e.g. vomiting and diarrhea), they also begin to understand (some more quickly than others) that it is in the intestine that water is not being reabsorbed.

Our attention is then drawn to cells because understanding more about the cells lining the intestine (or cells generally) would tell us a great deal about how this water was lost. This leads to questions about the structure and functions of cell membranes. We share several demonstrations of diffusion in the absence of a membrane, and students then answer the question of how diffusion occurs when a membrane is present. Students investigate this by determining which nutrients can/cannot diffuse across an artificial membrane. From here, we proceed to a discussion of osmosis, and the ways in which food molecules (nutrients) are similar or different. This leads to a discussion of why certain food molecules cannot pass through a membrane, connecting this issue back to our previous discussions about digestion. Students then investigate how large food molecules might be broken down in order to pass through a membrane. The experiments our students design on osmosis and diffusion are often better and more sophisticated than the ones you usually find as examples in textbooks.

After these experiments, the students' attention typically is drawn further into the functions of cells, as they want to know not only how cholera stays alive and gets its energy, but how our cells get the energy to carry out their functions as well. This leads us into a study of cellular respiration.

The very last problem we look at is how we can help cholera patients. The students recognize what is lost


Do they reproduce?

Test the amount of light going through the rice water. The bubbles take up space, if the amount of light getting through goes down, that means there are more bubbles and they reproduce.

variable: time
control: 0 hrs
experimental: 24 hrs

age (hrs)	% of light going through
0	28
24	3

Figure 1c. This design is for testing whether the substance reproduces.

through cholera: primarily electrolytes and water. We ask them to hypothesize what should be in the fluid they lose, both urine and stool, and in light of this, how these patients would need to be treated in order to stay alive. Students examine a commercially available oral rehydration therapy solution that is used in the treatment of cholera. Some students think sugar should be present because humans need energy for cellular functions; they check for glucose, and sure enough, glucose is present.

After completing these experiments, the class revisits the following questions:

1. What is the cholera organism like?
2. How does it get into the body?
3. How does it cause symptoms?
4. How does oral rehydration therapy work?
5. What is the role of antibiotics in the treatment of the disease?
6. What are reasonable methods of disease prevention?

Students use these questions to develop individual concept papers.

Conclusions

To what extent do we think we have been successful in achieving our objectives?

1. We feel that, in our heterogeneously grouped classrooms, all of our students are challenged when they are asked to design experiments, and they work to their potential. For example, those students enrolled in accelerated courses such as AP History, Advanced English, and Advanced Math, design experiments that are more complex and more sophisticated than those not enrolled in such courses. However, the simpler experiments still address the concepts and processes we are trying to convey, and we observe the same amount of effort and engagement in both groups of students.
2. By using case studies such as cholera, we are able to go into more depth with a single concept, and are still able to teach the science objectives we have responsibility for teaching.
3. Using case studies allow us to help our students make more connections. As we were nearing the end of our cholera story, we asked the students what they liked best about the work we had been doing to date, and a significant number reported that not only did they love the story line, but this was the first time they had been able to make connections to their other science nonscience classes. The more connections our students can make, the more likely it is that they will remember this information and the more useful it will be in situations that demand problem-solving approaches.
4. We are integrating process throughout our teaching—in lecture, in discussion, in lab—and it is being enacted in whole class and small group interactions. We also are teaching skills in the service of process and only when they are needed, not before. For example, when students need to test for the presence of certain electrolytes in fluid, they may say, "I think there is potassium in this solution. How do you test for potassium?" Then, and only then, do we introduce the flame test. Or if they think there is glucose present, we show them how to test for glucose. When they want to know how to do it, they learn it. When you tell them they will use it later, there is no reason for them to learn it now.
5. By using this case study, our students define the problems and design their own experiments. We are not giving them the questions. Rather, they are uncovering them by virtue of their own curiosity, and their different approaches and different results make them feel their contributions have value.
6. Our use of case studies allows us to make effective use of group work. In order to arrive at reasonable conclusions, our students must work cooperatively and collaboratively, both within their own group and across groups. They learn to share data in order to arrive at more effective and powerful conclusions than they could have arrived at by working alone.
7. This case study allows us to treat a problem in an interdisciplinary fashion. In order to understand cholera, it is not only important to bring the concepts of biology and chemistry to bear on the disease but also mathematics (e.g. epidemiology, statistics), history, and politics. We also ask our students to engage in a significant amount of written as well as oral reflection, from the writing of lab reports to the use of journals, concept mapping, group presentations, and in-class focus questions or quickwrites.
8. Our instruction is based on our students' questions, and our planning and assessment strategies reflect these questions, as well as the outcomes we, as a group, have developed. We have an overarching set of objectives for the course, but how we reach these usually depends upon our students. The knowledge they bring from middle school and junior high is changing as well, in large part as a result of the objectives upon which our new state science framework and resulting proficiency examination are based. One of these sets of objectives in particular,

"constructing objectives," focuses on the individual as a learner and that individual's ability to:

A. Ask questions about the world that can be answered by using scientific knowledge and techniques.
B. Develop solutions to problems or questions, interpret representations of scientific knowledge.
C. Remember key points and use sources of information to reconstruct previously learned knowledge rather than memorize details of what they study (Michigan State Board of Education 1991).

These are precisely the objectives which lie at the heart of our case-study approach.

We know that our students' abilities to design effective experiments, share and interpret data, and bring together what they are learning to build a cumulative series of investigations all improve significantly over the cholera case study, as does their ability to apply their knowledge of process in new situations (Richmond & Striley 1996). Their performance this year on the science proficiency exam—the first year of the new test—is well above the state average, and we will continue to carefully examine the areas in which they show strengths and weaknesses in order to determine how well we are preparing them to be scientific problem-solvers. It is both our students' changing knowledge base and questioning and our desire to best prepare them to be critical thinkers that keep us invigorated and challenged from year to year and help us to develop new ways of looking at concepts central to the understanding and doing of science.

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