Commentary

Ethical Conduct in Science—the Joys of Teaching and the Joys of Learning

by Paul M. Treichel

Stories to tell about teaching experiences: if they could be taken together—the successes and failures, surprises, and disappointments—they would go a long way toward explaining why we are teachers and why we continue to derive satisfaction from our profession. I have a story to tell about events last semester in my second-semester general chemistry course, Chemistry 104. To begin, let me introduce the cast of characters. Leslie Frye and Meredith Sessions were students in my class whose contributions to this paper will become apparent; Jeremiah Miller was their TA.

Chemistry 104 (and the course that precedes it, Chemistry 103) is a typical non-major general chemistry course at a large university, with 300-student lectures and TA-taught discussion and lab sections. Among other things, a high level of formal organization is desirable when teaching such a course. In my course, the students take a quiz during most weeks with the topic listed in the course syllabus.

When I planned the course, there was not a convenient match to a lecture topic for quiz #6, so it was listed only as a "Surprise Quiz". When the appropriate time arrived, I raised the issue of its content with the class, "Last year the surprise quiz was on the laboratory…" That idea was met with a chorus of negative responses. So I continued, "I came prepared with alternatives; how about a take-home quiz?" That sounded a whole lot better, and mentioning that we had never had a take-home quiz dissuaded only a few members of the class from this idea. So it was settled.

One of my other interests is scientific ethics; I have had a role in promoting this issue on campus. Among other things, I teach a graduate seminar course on the topic. Scientific ethics hasn't made major inroads in the undergraduate curriculum in most schools, although there is some interest in this topic at the undergraduate level (*1*–*3*), and some good materials are available (*4*, *5*). A quiz on scientific ethics would take the students by surprise, but it would be well within in the bounds of the course.

Quiz #6 consisted of three case studies, all on the handling of numerical data. Each was written in the context of an experiment that students had done in the laboratory. The case studies, presented in the following paragraphs, described hypothetical exploits of two general chemistry students named Able and Baker. The cases were identified with the generic labels *trimming* (dropping data from a data set), *forging* (changing the data), and *cooking* (manipulating the data). The students were directed to select the case study in which the described actions were least defensible and to construct a paragraph identifying the ethical issue and explaining their choice. Only one point would ride on their selection; they would get two points for a well-constructed argument supporting their choice, and seven points for a well-written paragraph. They were encouraged to discuss their thoughts with other students.

Case 1: Trimming

Able and Baker have been assigned to carry out an experiment confirming Boyle's Law. This involved measuring the volume of a gas sample at various pressures. In all, they collected 12 different sets of data. When they met after class to graph the data, however, they discovered that two measurements were way out of line. After deliberation, they decided that they must have made an inadvertent error in these measurements—perhaps in reading the meter stick or maybe just in writing it down in their notebook. Recopying their data onto a new sheet to turn in, they decided that the best course of action was to simply drop the two sets of "erroneous" data. Thus, their written lab report contained a neat table of the satisfactory data (10 sets of P–V data), with their graph showing all points lying on the line. They didn't mention omitting data in their report.

Case 2: Forging

Later in the semester, Able and Baker encountered the heat-of-reaction experiment. Here, they measured the rise in temperature in a coffee-cup calorimeter and calculated the heat of a reaction between an acid and a base. By this time, they had become pretty capable in lab. Preparing solutions took little time, and they were able to carry out the reaction between HCl and NaOH solutions in triplicate. Later that evening, they calculated the heat of the reaction. Two of their three determinations gave almost identical results, but the third was about 20% lower (about 10 kJ/mol). They thought briefly about dropping the third value and reporting only the two results. But they figured that three determinations would look better than two in their report. Plus, the TA might see from their data sheets that they had done the experiment a third time and would figure that they screwed up. So instead, they decided to simply change the data. They scratched out the final temperature in the errant data set and wrote in a value that was 20% higher. Using this number, they recalculated the value for ΔH, and it was close enough to the first two values to pass any reasonable inspection.

Case 3: Cooking

Able and Baker passed Chem 103 and continued on in 104. In their second experiment of the laboratory, they determined the kinetics of crystal violet oxidation by measuring the concentration of this colored compound at different times. To measure the concentration, however, they first had to prepare a calibration curve. This involved measuring the amount of light absorbed by solutions of known concentration and then preparing a graph of concentration vs absorbance. The unknown concentrations would be determined from this graph, so the measurements on the standard solu-

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tions had to be reliable. Collection of this data was done by hand, point-by-point, and then entered into a spreadsheet program for analysis. (Note: this description predates our current procedure. We now collect and analyze data using a computer.)

Two nights later, while Able and Baker were in the Chemistry Computer Lab working up their data, they ran into a problem. The first four measurements of absorbance plotted up nicely, giving a straight line, but the next four points were way off the line. Interestingly, all of these absorbances were too high, and the last four points traced out a straight line with a different slope. For awhile, Able and Baker were puzzled as to which data to use, but then they remembered that midway through the experiment, they had broken the tube in which the absorbance measurements were made. (In fact, they had even made a note of this in their notebook.) Clearly the problem must have been with the new tube obtained from the stockroom. They decided that the logical way to deal with this problem was to impose a correction factor. So they decided to multiply each of the absorbance values obtained using the first tube by a factor of 1.04. Both sets of data were then used to plot a nice straight line. However, they decided not to mention their correction factor in their report because it was just too hard to explain.

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The story might have ended at this point, but for an interesting development. In an offhand comment, Jeremiah told his class that anyone who submitted their answer in iambic pentameter would automatically get a 10. Several students took this as a serious challenge, with very witty verse as the

A story of two chemists that went wrong…
To hear about it just follow along.
I do believe the trimming case is bad
and cooking is dishonest just a tad,
but most importantly there is some blame
in forging—that's the culprit in this game.
To drop data might prove hypotheses,
but in the science world it's just a tease.
Yes, Kotz and Treichel state it on page eight:
considering results could indicate
you weren't quite ready in guessing what you guessed
since reproducible results are best.
If Able boy and Baker made mistakes,
then reproducing them would leave them baked.
They said the problem was in their measurement.
In fact, it made the line they graphed quite bent
and since the same mistakes will not come out
the same a second time—surely I doubt.
Now this is not a practice to support.
Investigation though can't be cut short.
they've done some other things of which I say.
Chem 104 had not brought luck their way.

Case three, you know, I would not recommend.
Repeating Baker's scam would bring impend-
ing doom upon your lab group and their grade,
so into ethics of this case we'll wade.
We all know human error's just a fact,
no matter if it's CO_2 or lac-
tic acid; getting it exact is rough,
especially if your TA's tough…
This time they realized what the problem was,
but most important's what the scientist does
when she or he can see they've made a mess
with numbers: just a little, more or less.
There's not so much they could have done by then
except report the errors clearly when
they gave the TA what they had to show
and Able could have come clean then, but nooooo.
their data was not really off that far
though when some heard of it they might cry "l'ar!"
The changes that they made were logical
and in attempt to make the graph not dull
mathematical deduction seemed a plan,
but of deception Treichel's not a fan.
However, I will back their reasoning
about the broken tube in questioning.

I shan't stop here with worst case still upon
us, of these two dudes I am not so fond.
You see by now it's forging I will guess:
the case I think has most little defense.
That scheme was dirty, rotten, and grotesque.
In labs of these guys I would not invest.
After finishing calorimetry,
they noticed that their values weren't on tee.
they changed the ten's to twelve's and gave no proof
or reason, logic, explanation, scoop…
There were no notes inside the boy's reports.
For this type of a crime we need "chem court".
Their main concern was looking like they'd done
a good job, but lab's not all games and fun.
They did not care 'bout doing the job right.
Over this issue I must stand and fight!
"They simply changed the data," said the sheet,
with no regard saving making it seem neat.
Liars, liars, pants on fires they are.
Considering the facts I'd say it's par
the course that they should have to take the bar,
and with lawyers they would fit right in.
I guess in that career they'd surely win.
Move over Dowe, Cheatum, and then How—
The firm of Able/Baker is around!

So that's my choice; it's what I'm sticking with
Over this I hope you're not in a tiff!

—Leslie Anne Frye

outcome. Since space in this journal is a prime commodity, only two are presented here. A poem by Leslie Anne Frye, presented on the previous page, exhibited the more sophisticated writing. The second, shown below, is a whimsical piece titled "Running Backward on the Hamster Wheel of Science" by Meredith Sessions.

This story concludes with several general comments. Ethical conduct in the sciences covers a wide scope. In graduate and postgraduate training, a wide variety of topics is included; some of them are quite personal, and most are applicable to the ongoing research experience. Not all of these issues are relevant for undergraduates, of course, but a few are especially germane to the general chemistry curriculum. The handling of data is surely one of these; students in general chemistry labs carry out a number of different experiments in which they do exactly that. At the University of Wisconsin–Madison and, I suspect, at most colleges and universities, our students are given little guidance on what is considered appropriate practice in data handling. So the door is open to introduce this material. The challenge will be to find an effective means of integrating it into the curriculum and balancing the time and effort committed to this topic with other important parts of the curriculum. The example here is one way to carry this off, relating scientific ethics directly to laboratory material and linking it to writing, another course goal. There are other ways, of course. All three case studies are a good basis for discussions on ethics in laboratory work. Our department is making plans to introduce exercises in scientific ethics into the laboratory curriculum next semester, with case studies being the vehicle.

How important might the addition of scientific ethics be to the general chemistry curriculum? Less than two weeks after the ethics quiz, a scientist teaching in the University's Biocore program contacted several faculty members who teach general chemistry. (Biocore is a popular honors curriculum taken by second-year students who are interested in a biological science). Quoting from the email message: "We recently had the very disturbing situation in Biocore with multiple cases of students changing data to fit what they wanted it to be…I am puzzled because there is no motivation to change data. Biocore students are not graded on their results but on how well they analyze their results…" A common denominator for this group of students was that they all had previously taken chemistry courses, hence the contact to our department to open a dialogue on this issue.

And what were the results of this quiz? It will probably be obvious that forging (Case 2) is the least defensible. For some students, however, the decision between the last two cases was apparently not straightforward. More than 15% of the students picked Case 3. Why? Distilling the arguments presented, it seems that four data points were changed in this example, whereas in Case 2 only one data point was altered. By any account, this curious result is sufficient evidence to explore some of these issues further.

Returning to the title of this article: this episode illustrates what teaching and learning are all about. As teachers we need to be creative, and we seek to inspire creativity in our students. Within such successes lie the joys of the profession.

References

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Running Backwards on the Hamster Wheel of Science

Our naughty little lab mice, Baker and Able,
Did their worst deed in the second Treichel fable.

Their first crime, in contrast, seems much less severe:
They had their six points, almost in the clear.
Some day in a lab though, they'll use this technique,
And cut from a graph a critical peak.
Negligence suits will abound left and right,
And with blood on their hands, they'll lie sleepless at night.

Though it is wrong to correct for bad data,
And to drop lousy points and not mention it lata',
The third story sounds better when we remember the fact
To compare data to them, graphs must be correct.
And they know just the problem and what change to select,
To cancel the little old test tubes effect.

Of course it'd be better done over again,
But Able and Baker are two lazy men (Assumption).
As UW grads, expectations are tall,
But they'll be sucking down money, doing nothing at all.
They carefully changed their graph's correlation
To get anywhere near the right concentration.

There was no such excuse when Able and Baker
Played their sly game of new-data-maker.
On the third case at least, they changed things to find truth
In the second, for pride's sake, they lied through each tooth.
Imagine these mice when they're full-fledged lab rats;
Making up data to improve their own stats.
Further convolution, fueling dispute,
Two little stones in science's boot.

—Meredith Sessions