Some Heretical Thoughts on What Our Students Are Telling Us

Roald Hoffmann and Brian P. Coppola

There is a time, twice a year, when those of us who teach introductory courses sit down in a comfortable chair, pour ourselves a middling portion of single malt Scotch whisky, and begin to read the comments that students write about our teaching. For the overall ratings, numerical in nature, we can bear to wait—the computer will dutifully compile these single point undifferentiating indicators.

What we settle down to read are the "free-style comments," where the students are encouraged to write (anonymously, of course) what they think of the book, the exams, and, of course, of the lecturer. Many, not all, universities give students the opportunity to express themselves in this way. Some of us have learned to avoid asking silly questions with predictable responses, such as "What is the best part of the course?"

So we sit down, perhaps turning on some Chopin to complement the whisky, and face those student responses. Many are positive, as (with a trace of mild astonishment) "I didn't think I'd like chemistry, but Prof. Coppola made it fun!", "I actually enjoyed going to the lectures," or "I didn't get a very good grade, but I sure learned a lot." It's not always easy for a student (or us) to say a word of praise, to give thanks graciously harder still.

Positive feelings generally wash over us leaving small marks. Happiness is often diffuse. But pain is sharp—the small pain of a torn cuticle, the stronger incapacitating pain of a broken bone. Or, negating the validity of the familiar litany "sticks and stones..." the mental anguish of reading an evaluation such as "Prof. Hoffmann spends all his time on digressions, relating chemistry to politics, history, God knows what else. Who cares how hemoglobin or catalytic converters work? I want to know what's on the MCATs." Or "I got an A by memorizing equations and doing exam problems that were exactly like the problems that I had seen on the previous tests..." Or, "As far as I am concerned I did not need to go to class."

Now this hurts—ergo the whisky and music; it hurt last time too... Our reaction comes in part from this inability to weigh appropriately emotional praise and criticism. Differentiating among the negative comments, we can easily forgive the simple nastiness of resentment released under cover of anonymity. We are more wounded when the students condemn exactly what we are most proud of in the educational process: we finally got this course right! More than merely the course contents, that neutral list comprising the syllabus, we more importantly developed the spirit of our science (chemistry in culture, and chemistry as culture, as it should be at a liberal arts university) and the process of its construction (stressing understanding and discovery). We finally understood (and thought we succeeded in communicating) that multiculturalism embraces all part of the university experience, and is as inclusive of intellectual constructs, such as chemistry, as it is of the traditional social ones. Then to get such comments really, really hurts.

We could counter, and lash out at the immature young people, at societal pressures and at all the things that make for their wrong attitude toward learning. Better we release our anger on them than on those dear to us... Or we could take another sip of the Lagavulin and reflect on what we can learn from the students' comments, from just those comments that wound

Roald Hoffmann is a professor in the department of chemistry, Cornell University, Baker Laboratory, Ithaca, NY 14853-1301. Brian P. Coppola is a lecturer in the department of chemistry, University of Michigan, Ann Arbor, MI 48109-1055.

most.

As teachers, we invest a great deal of our professional intellectual lives trying to see beneath the surface of what we encounter. What drives our curiosity is trying to understand core phenomena or motivations that give rise to what we see. That is, we try, even if we don't always succeed, to be attentive and insightful learners. For we believe that a high road to effective teaching is to be a good learner when analyzing a students' work or perspective. (Coppola and Daniels, in press) This is as satisfying an intellectual challenge as authorship or laboratory research.

An effective analogy that one of us (BPC) has created for demonstrating that anybody who takes on the "teaching" role must think (to learn) before despairing about ignorance, is given here:

> You are teaching multiplication. To probe the students' mastery of the subject, you give an examination. To which one student provides the following answers:
>
> 2 x 2 = 4
> 1.1 x 11 = 12.1
> 3.5 x 1.4 = 4.9
> -1 x 0.5 = -0.5
> -3 x 0.75 = -2.25
> 2 x 4 = 6
>
> What do you do? You can shake your head and say "How can a student who can multiply noninteger and even negative numbers make such a mistake?" Or you can decide to learn from what the student's response is telling you. And revise your educational strategy accordingly.
>
> The student has done nothing wrong, except...to think that multiplication is addition.

Teachers and students meet in the classroom to fulfill the terms of a tacit covenant of instruction. There is more to it than being paid to teach—we sacrifice whatever else we could be doing during that hour when we teach, or even when we read their comments, to confront a simple question: "Am I being understood?" We learn from books and other media (oh, how imperfectly via these comment sheets!) at our convenience, but in classrooms teachers and the taught come together for just the kind of feedback that is unique to our conversational profession. All classroom pedagogy revolves around ways for the faculty to learn "Am I being understood?" Students want to know this too: "Are we being understood?"

Even when we feel we finally got the course right, in teaching the spirit of the science and the process of its construction, a good number of students tell us what we don't want to hear: that they got along fine by memorizing formulae, and they don't want all those digressions about science in the real world and in culture.

So...we force ourselves to listen to students who have confronted the subject matter and ideas we have so painstakingly (and, we hope, eloquently) provided. But the students have not constructed the same understanding that we have... of the subject, its ambience, and its process. This may be sad, but it is true, as those comments of theirs so painfully reveal.

Of course we understand that our own appreciation continued to grow after the first—or tenth—time that we turned our thinking to the subject. And especially it grew when we finally needed to teach it. We do not expect novices to surpass us in their first round. But we must also not dismiss what we may learn from their unique perspective as less experienced learners. We listen unwillingly, for we are sure that we are right. But we try, because they are right, also. In collaborative communities, the distinction between who is the "teacher" and who is the "learner" becomes blurred, if not wholly imaginary to begin with. Here's what we think we hear:

The students are telling us that you don't have to understand everything in chemistry to learn and use the science.

Yes, we'd like them to understand, and we have designed our course so as to emphasize the process of understanding. But learning in chemistry is (a) a curious mixture of proof (real proof), and of belief (accepting on faith, trusting that someone else has proved, or that proof might be forthcoming if one advances in the subject). And that learning is (b) sequential, in an intriguing, intellectually inconsistent way—it proceeds by first understanding something, then memorizing something else, then using the mathematical expression of what was understood in a rote or algorithmic (yes, unthinking) way so as to solve a real problem. We develop a tacit tolerance for the fundamental inconsistencies that define the edges of our understanding. All this, mixed up with occasional necessary bouts of memorization and a nomenclature that has pretensions of being systematic.

As mature learners, we include as many strategies as we can in our arsenal for inquiry. Progress does not occur because we have excluded memorization, but rather because we recognize when memorization is precisely the most effective strategy to use. As much as we would like to enact a truly Socratic dialogue with undergraduates, the reality of teaching thousands of students has made this impossible. It may be that the only potentially authentic thinking in on-your-feet creative situations we place

students into are our examinations. Regardless of any rhetoric we provide in class, our examinations transmit the learning objectives that are targeted for comment by students.

Let's take an example: We derive the ideal gas equation, PV = nRT, by historical or experimental appeal to the individual Gas Laws (of Boyle, Charles, and Gay-Lussac). We and the students "understand" the formula (how limited that understanding is, how unreal the ideal, becomes clear in a physical chemistry course). We see the formula in our minds, its beauty in the chemistry and physics it so succinctly summarizes for us. We go on to use it in a myriad problems, from balloons to equilibria, from determining molecular weights to thermodynamic cycles. And in using it we do not go back in each instance to the derivation. We use it as we need it, as a formula.

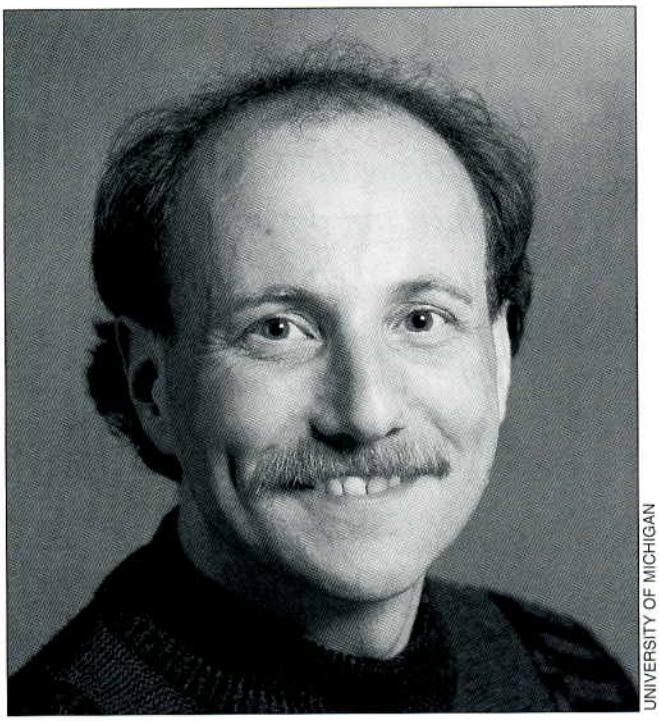
The reason we shouldn't get angry at students who says they got by "just memorizing the formula" is that they are just shading their response-very probably they understood a lot, but then chose to emphasize the formulaic use. We think that as much as we value *sophia* and understanding, that knowledge and learning also involve a component of suspending understanding, or at least pushing it into the background. We ask the reader to recall the problems of 25 years ago with "the new math" in primary education.

There's an even broader lesson, we think:

You don't have to understand everything in order to (a) operate as a normal successful human being in this world, or (b) even to do creative work of the highest degree.

Once again, we have to begin by saying ever so clearly that we value real understanding, that knowledge is an absolute good. And the special contribution from formal education, schools and universities is centered, we believe, in their being the place where connections between general educational and professional training objectives are constructed and maintained. Elsewhere in life, other imperatives, often economic, dominate.

However, it is clear that technical training is of great pragmatic value even in the absence of the connections forged at a university. Practice and experience suggest that this is the way of the world: we usually learn to use technology's products quite separately from the underlying context, and we can make successful and productive, humane, contributions without even being aware of any appendant knowledge. Driving an ambulance to an accident site does not require a cognitive awareness of the thermodynamics of combustion; the thermodynamics operate just fine without us. We use calculators to help us do arithmetic, and we choose to need to understand how learning arithmetic allows us to make the necessary judgements about the outcomes of button-pushing, while at the same time we choose not to understand things about batteries, liquid crystal displays, the manufacture of silicon chips and the marketing of calculators. Performing a specific task on an assembly line can be done well when the laborer is completely unaware of the other tasks on the line or even the object being assembled. Sometimes that is the learner's choice, quite democratic and informed, also.



Professor Brian P. Coppola.

Let's jump to the creative act in our science. The synthesis of a new antitumor agent, the perfection of a new industrial process that avoids the use of a harmful solvent, may both involve a heterogeneous catalyst. The catalyst does something reproducible, taking, say, an olefin, and epoxidizing it specifically on one of the two olefin faces. We may have a vague idea how this works on the molecular level, but should we suspend use of the reaction until we really understand the catalyst mechanism? That would be just as silly as to ask Archie Ammons to tell us the metallurgy of the keys of the ancient typewriter that he uses before he writes a poem.

The pressure to understand everything betrays a simplistic reductionist world view. As one of us has expounded (perhaps tiresomely) elsewhere, reductionist (or vertical) understanding is just one way of knowing the world. The other (call it horizontal) way is to understand the world, quasi-circularly if you insist, in terms of the concepts that have evolved in the field under consideration, concepts as complex and seemingly poorly defined as what one is trying to understand. (Hoffmann, 1995). So a telephone that makes a call to an ambulance is accepted as a communication device, working or not working, able to place a call here but not there.