inventio
creative thinking about learning and teaching

Spring 2004 ▪ Issue 1 , Volume 6

Have You Seen the Dog, Yet? Getting students to the link between information and meaning requires motivated learning.*

by: Brian P. Coppola

Introduction

At the University of Michigan, we began using the subject matter of organic chemistry as the basis for introductory instruction in chemistry in 1989, the study of which students start in either the first or second semester of their first year (Ege, Coppola & Lawton, 1997; Coppola, Ege & Lawton, 1997). In shifting from the *de rigeur* one-year course in general chemistry, we were also knowingly transferring a passel of academic myths and associated anxieties surrounding organic chemistry to our first-year students (Gmelch & Felson, 1980). Consequently, within the first week of each academic year, I offer an evening seminar for those students who want to hear my battle-worn advice about what sorts of learning strategies might be useful for the instructional goals my colleagues and I have in mind (1). Finding effective ways to counter the make-or-break urban legends about "the pre-med weed-out course" is an interesting pastime for organic chemistry professors (2).

The "learning how to learn" seminar is not all about defense strategies, however; I have in mind a number of general epistemological ideas about learning that I want to connect with my subject matter, and this vehicle (organic chemistry) differs considerably from students' past experiences in high school (general) chemistry. The biggest challenge in teaching general chemistry, and one that is backed up by a rich research literature, is helping students to connect the underlying conceptual knowledge about chemistry in the mathematics problems they learn to do with their ability to solve these problems successfully (Beall & Prescott, 1990; Nakhleh & Mitchell, 1993; Nurrenburn & Pickering, 1987; Pickering, Nakhleh, Nurrenburn & Miller, 1990; Sawrey, 1990; Francisco, 2002; Tan, Goh, Chia & Treagust, 2002). Encouraging students to look past the surface features for how we represent information (an algebra word problem) and to appreciate the deeper meaning (chemistry understanding) is a problem in semiotics.

Appreciating semiotic relationships sit at the core of most, if not all, of our knowledge systems, and are certainly one of the things that characterize more expert understanding in chemistry (Kozma, 2000; Kozma, Chin, Russel & Marx, 2000; Kozma & Russel, 1997). Organic chemistry is different from general chemistry in its representations, which are not mathematical but rather pictographic and more strongly linked with textual elaboration (Hoffmann, 1988). The semiotic challenge is to propel students past the lines and letters of molecular structural drawings to the underlying explanatory and predictive model of the structure-reactivity relationship. I think I have made this point most strongly and most obliquely, both at the same time, with my homage to René Magritte (Figure 1; Ege, Coppola & Lawton, 1997).

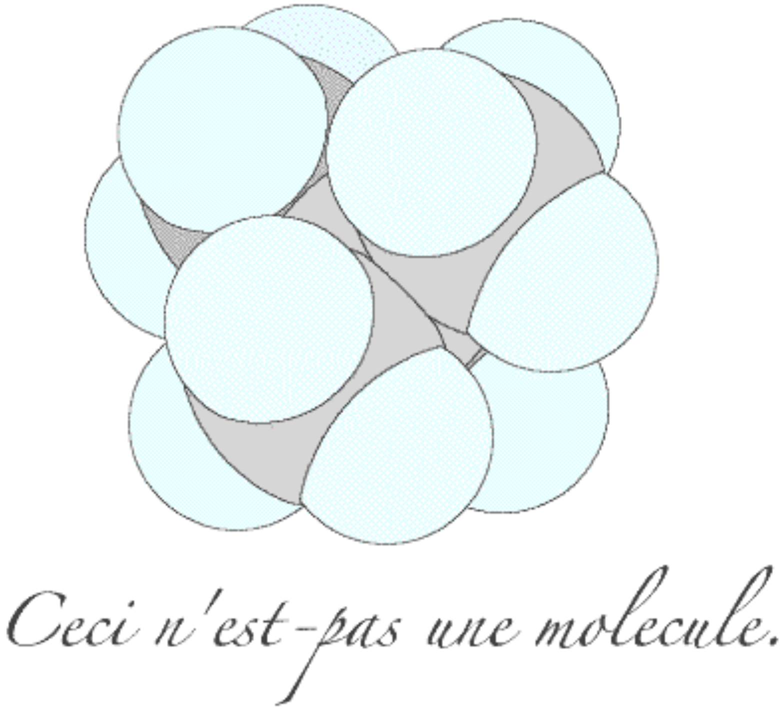

Figure 1

These are heady ideas to try and introduce to first-year college students, and only more *apropos* given that "getting an A" is the surface feature to which they are sometimes paying the greatest attention while I am attempting to make annoying academic points about learning and education.

Persistence and Puzzles

Another attribute of expert learners is persistence, which is a key concept in theories of human motivation (Weiner, 1985; Csikszentmihalyi & Csikszentmihalyi, 1992). Learners need sufficient and different surface examples to begin to see the patterns of meaning we call understanding. And these patterns of meaning are never simple straightforward inferences from the information. As learners, we are always constructing our understanding by seeking and creating meaning (what we often call the "big picture") by grouping, ungrouping, and regrouping the interconnections and relationships between individual ideas.

There is a great deal of intellectual risk, at the cost of ego, in backing away from a perceived or imagined pattern, even when all of the pieces do not quite fit. Or worse, students sometimes believe that they are simply incapable of seeing any pattern at all because of a fundamental inadequacy in themselves ("I just cannot do chemistry…"). A person might make the conscious decision not to invest the energy to persist, and that is a different situation. I have observed extremely capable students who are unaware that they must actively move back and forth between the smaller and larger concepts, constantly checking and rechecking the internal consistency of the picture they are constructing.

One of the important themes that appears in my instruction, then, is to provide the kind of language and examples that students can draw from in order to persist even when the immediate feedback is discouraging. The sincere advice that some faculty members give to students ("stick with it," "wrestle with the problems") is not too useful because it does not suggest either how or why one might stick or wrestle with something. Surely, this advice is based on faculty members' own experiences as students: it is as naïve as it is genuine, and derives from their own (un)naturally high persistence as learners in their subject areas. Psychologically, however, individuals do not persist because of their satisfaction with the fight; individuals persist because of their ability to envision and believe in a goal that cannot yet been seen (Pintrich, 1995).

As I said before, describing these goals to a group of first-year college students is difficult to do in the abstract.

These students lack the necessary experiences from which to create appropriate analogies. Activities typical of intrinsically motivated behavior, such as sports, music and art, are not great choices because so much is made of natural talent that it reinforces the idea that some folks just cannot be expected to “get it” unless they already “have it.” Instead, I use a series of visual puzzles as metaphors for the kind of persistent grouping and regrouping of data that are necessary for successful problem-solving or analysis, and tie these directly to some simple chemistry examples so that the transfer question is not left quite so open to chance.

*Dedicated to memory of Paul R. Pintrich (1953-2003).

The Eye and "Hi!"

The images in Figures 2-5 are taken from the area of visual perception and cognition, and they are meant to represent an assembly of facts, and their relationships, that we might have as instructional goals in our courses (Coppola & Daniels, 1996). It is mindful of the Gestalt notion of closure [that is, the human tendency to fill in gaps in order to construct understanding, analogous to our ability to perceive motion from 60 frame-per-second film (Street, 1931; Hunt, 1993)] where I posit that the individual (surface) facts of an argument are represented by the isolated shapes of these closure examples.

Figure 2

In order to see an animal represented by the shapes of Figure 2 (Street, 1931), an observer needs to consider the relationships between the individual pieces of information in the context of prior knowledge and experience. Of course, Figure 2 is not a metaphor for a very sophisticated discipline, with its few, well-defined "facts" (shapes), but it begins to get the 'big picture' idea across to students. That is, one cannot derive the facts from just the big picture, and the facts need to be considered in relationship with each other in a particular way in order to appreciate the big picture; this is a synergistic relationship.

The role of prior knowledge, which is a core ideal of constructivist epistemology, is also clear in one’s ability to understand these images, and how one might be sorting through whatever image-based information exists in the brain. I discuss the value of expressing viewpoint and shared assumptions by using Figure 3 (Street, 1931).

Figure 3

Even though it is as unsophisticated as Figure 2, the implied message for Figure 3 is nearly indecipherable until we, as instructors in this metaphorical discipline, share an important viewpoint in order to make our discussion of the subject matter (the spots) meaningful (more about Figure 3 in a moment). Numerous alternative interpretations can be inferred, on the other hand, as viewers persist in their belief that there is actually something they will eventually be able to understand.

Although the significance of this point can be made with any discipline's jargon, it is chemists, perhaps more than any other group, that base their intellectual work on a representational system for objects that is meant to connote physical objects that cannot actually be seen (namely, molecules). As chemists, we are remarkably comfortable with the notion that "H-O-H is water" than we ever would be that "T-A-B-L-E is a table". Of course, we chemists understand that letters are used to represent atoms and that lines have been used to represent chemical affinity since before the discovery of electrons, but these are clearly learned associations and not at all imbedded in the use of letters and lines. Bransford and Stein (1984) use clever textual passages to make this same point. In the case of Figure 3, by the way, knowing that it has been printed upside down is critical to understanding what was implied by its author (I wonder: how long did you persist?).

In chemistry classes, I purposefully write "HI" on the board and explore the distinctions between questions such as "What does HI mean?," "What could HI mean?," and "What could HI represent?" Inference and implication play significant roles in understanding all communication. The validity of "hydroiodic acid" relative to "a greeting" or "the middle of 'ship'" as responses to the HI questions depends not only on context, but also on the how well an ascribed meaning has been learned.

The Spots are Never Changing

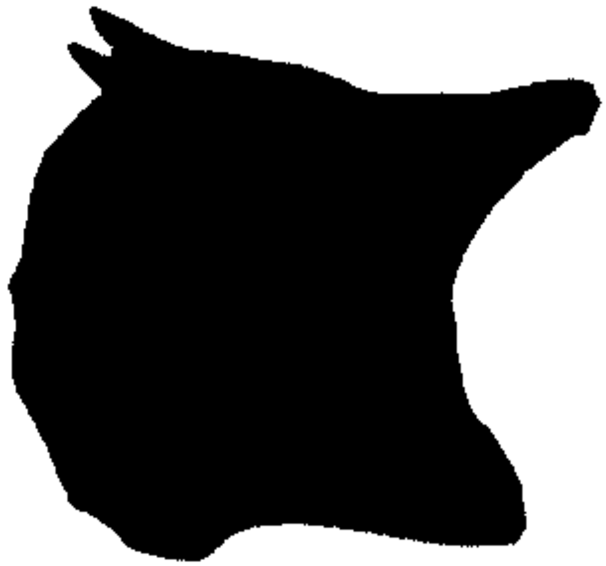

Figure 4

Figure 4 is often the first figure I show to a group, with two objectives in mind. After collecting different interpretations of the shape in response to the question "What is this?," I can describe the role of inference, representation, and the observer's prior knowledge in suggesting this is anything other than 'projected blotch(es) of light impinging on your retina, etc.' The importance of contextualization is illustrated after showing Figure 2 and asking an audience to suggest what is represented by the topmost fragment. A remarkably unanimous and loud reply of 'a cat's head' contrasts nicely with the debate and uncertainty originally surrounding Figure 4, even though Figure 4 is simply the 'cat's head', isolated and rotated.

Figure 5 (Carraher & Thurston, 1966) is a much better metaphor for a sophisticated discipline. In most groups of 30 or more, 1-3 people will immediately perceive the image originally captured by this high-contrast photograph. Like the students in our classes who 'connect' with us right away, any subsequent discussion of details will serve to reinforce the picture we now collectively share.

By using Figure 5, I hope that the other students begin to understand why I am constantly returning to the 'big picture' in class, since much of the well-intended discussion about the details will be lost without this shared understanding. Figure 5 has been especially effective with faculty members, particularly when I congratulate the few who have seen the image and then whisk away the overhead while exhorting a need to get on to the next topic on the syllabus because there are a lot of topics I am supposed to cover!

With students, I linger with Figure 5, reminding my persistent learners that they have all the facts they need, and that for the most part they are engaged in grouping, ungrouping, and regrouping against their prior knowledge. I will ask those who have seen the imbedded image to perhaps think of some lesson they might use to help those around them to see what they can see, along with the not-so-subtle reminder that the facts (i.e., the spots) are never changing, only the way they are being grouped (i.e., understood in relation to each other). I help another fraction of the group by mentioning the Dalmatian dog in the center right-hand side of the image.

The lesson that sticks is simple: ‘When you run into difficult or challenging material, I want you to add an alternative to throwing up your arms, resigned to your inability or the inadequacy of your situation. Instead, consider that you need to change your viewpoint, to group things differently, perhaps to develop new strategies and alternative viewpoints — and to work with others, especially in taking the teacher’s role, because we assess learning, first and foremost, by asking students to take on the instructor’s role four times each semester, by providing explanations to questions that we call an exam.”

Every year, a subset of students connects with this pictorial metaphor for persistence. I learn about this months later, when a student comes to my office (as they do) after working unsuccessfully to understand a topic, and chooses to express this frustration with one version or another of the delightful phrase: "I just haven't seen the dog, yet."

References

Notes

1. There are a few different ways for the students to get different takes on this advice. The Study Guide that accompanies their textbook has a longer and more detailed version of the "advice talk" (Coppola, 1999, 2003), the course pack of sample exams uses another version of the talk as an introduction, and the course web site (http://www.umich.edu/~chem210) contains yet another. The leaders in our Peer-Led Study Group (PLSG) program are also encouraged to spend time on learning strategies and course philosophy as a part of their work (details about the PLSG program, which is administered and organized by the University of Michigan's Science Learning Center, can be found at http://www.umich.edu/~slc).

2. Being the instructor of a course people love to hate is an annoying cachet. Imagine walking into your first day of class (and this happened in 1998), with red-colored flyers plastering the desktops, put there by you-know-which kompany (sic) that offers those MCAT review kourses (sic), on all of which are printed in big block letters "Don't Let Organic Chemistry Keep You Out of Medical School."

References:

Beall, H.; Prescott, S. (1994). "Concepts and Calculations in Chemistry Teaching and Learning" *Journal of Chemical Education, 71,* 111-112.

Bransford, J. D.; Stein, B. S. (1984). *The IDEAL Problem Solver.* New York: W. H. Freeman.

Carraher, R. G.; Thurston, J. B. (1966). *Optical Illusions and the Visual Arts.* New York:Reinholt, p. 18. Permission for use granted from the photographer, Ronald C. James, who originally published the image in Life magazine (Life, February 19, 1965 Vol. 58, No. 7).

Coppola, B. P. (1999). "Learning Tips for Students." In, Seyhan N. Ege, Roberta W. Kleinman, and Peggy K. Zitek "Study Guide for Organic Chemistry, Structure and Reactivity, 4th Ed." Boston: Houghton Mifflin; pp. xiii-xxii.

Coppola, B. P. (2003). "Learning Tips for Students." In, Seyhan N. Ege, Roberta W. Kleinman, and Peggy K. Zitek "Study Guide for Organic Chemistry, Structure and Reactivity, 5th Ed." Boston: Houghton Mifflin; pp. xxii-xxiii.

Coppola, B. P.; Daniels, D. S. (1996). "Structuring the Liberal (Arts) Education in Chemistry", *Chemical Educator, 1* (2): S 1430-4171(96)02018-3. Avail. URL: http://journals.springer-ny.com/chedr

Coppola, B. P. ; Ege, S. N. ; Lawton, R. G. (1997). "The University of Michigan Undergraduate Chemistry Curriculum. 2. Instructional Strategies and Assessment", *Journal of Chemical Education, 74,* 84-94.

Csikszentmihalyi, M.; Csikszentmihalyi, I. S. (1992). Optimal Experience. *Psychological Studies of Flow in Consciousness*; Cambridge University Press: Cambridge.

Ege, S. N.; Coppola, B. P.; Lawton, R. G. (1997). "The University of Michigan Undergraduate Chemistry Curriculum. 1. Philosophy, Curriculum, and the Nature of Change", *Journal of Chemical Education, 74,* 74-83.

Francisco, J. S.; Nakhleh, M. B.; Nurrenbern, S. C.; Miller, M. L. (2002). "Assessing Student Understanding of General Chemistry with Concept Mapping", *Journal of Chemical Education, 79,* 248-257.

Gmelch, G.; Felson, R. (1980). "Can a Lucky Charm Get You Through Organic Chemistry?" *Psychology Today,* December; pp 75-77.

Hoffmann, R. (1998). "Under the Surface of the Chemical Article" Angewandte Chemie, 100, 1653; see also: *Angewandte Chemie, International Edition in English* **1988**, *27*, 1593.

Hunt, M. (1993). *The Story of Psychology* New York: Doubleday.

Kozma, R. B. (2000). "The use of multiple representations and the social construction of understanding in chemistry." In M. J. Jacobson & R. B. Kozma (Eds.), *Innovations in science and mathematics education.* (pp. 11-46). Mahwah, NJ: Lawrence Erlbaum.

Kozma, R. B., & Russell, J. (1997). "Multimedia and understanding: Expert and novice responses to different representations of chemical phenomena." *Journal of Research in Science Teaching, 34*(9), 949-968.

Kozma, R. B., Chin, E., Russell, J., & Marx, N. (2000). "The roles of representations and tools in the chemistry laboratory and their implications for chemistry instruction." *Journal of the Learning Sciences, 9*(2), 105-143.

Nakhleh, M. B.; Mitchell, R. C. (1993). "Concept Learning versus Problem Solving" *Journal of Chemical Education, 70,* 190-192.

Nurrenburn, S.; Pickering, M. (1987). "Concept Learning versus Problem Solving: Is There a Difference?" *Journal of Chemical Education, 64,* 508-510.

Pickering, M. (1990). "Further Studies on Concept Learning versus Problem Solving" *Journal of Chemical Education, 67,* 254-255.

Pintrich, P. R. (1995). "Understanding Self-Regulated Learning." In, Pintrich, P. R. (ed.), *Understanding Self-Regulated Learning.* New Directions for Learning and Teaching. No. 63. Jossey-Bass: San Francisco, 3-12.

Sawrey, B. A. (1990). "Concept Learning versus Problem Solving: Revisited" *Journal of Chemical Education, 67,* 253-254.

Street, R. F. (1931). *A Gestalt Completion Test. A Study of a Cross Section of Intellect.* Contributions to Education, No. 481. New York:Teachers College, Columbia University. Permission for use granted from Teachers College Press.

Tan, K. C. D., Goh, N. K., Chia, L. S., & Treagust, D. F. (2002). "Development and application of a two-tier multiple choice diagnostic instrument to assess high school students' understanding of inorganic chemistry qualitative analysis." *Journal of Research in Science Teaching, 39*(4), 283-301.

Weiner, B. (1985). *Human Motivation;* Springer-Verlag: New York.