Letters

Mystery Molecules or What's in a Name?

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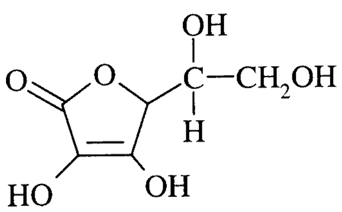
Reading Tina Overton's paper "creating critical chemists" [1] suggested to me that readers might be interested in a strategy I use to try to do this.

I teach biochemistry to a group of about 35 second year students at Delaware[2]. The subject depends on basic concepts in general and organic chemistry. Despite my students' exposure to courses in those areas, a frustratingly large number seem to have difficulty applying useful concepts to unknown structures, a problem not helped by their seeming inability to remember what they once knew. For several years now as a way to reconstruct their forgotten knowledge and build confidence from fragments retained by different students, I have begun most classes by drawing the structure of a relevant "mystery molecule" on the board. This initiates a short game that lasts several minutes. A typical dialogue with the class might be:

Professor *Can anyone identify this molecule?*



Student A (Hesitantly) *I'm not sure, but it might be glucose.*

Professor *What makes you think it might be glucose?*

Student A *Well, it has six carbons and sort of looks like a sugar.*

Professor *Is there any reason that it might not be glucose?*

Student B *I don't think glucose has a double bond.*

Professor *Notice the substituents. What is a double bond between two hydroxyl groups called?*
(No student response.)
(Circling the functional group) *Has anyone heard of an enediol?*
What other observations do you have?

Student C *I thought glucose had a six-membered, rather than a five-membered ring, and I didn't think it was a lactone?*

Professor *Does everybody know what a lactone is?*
Can you come to the board and show what you mean?

Student C (At the board.) *Lactones are cyclic esters.*

Professor *Thank you. Let me see a show of hands.*
How many of you think this molecule is glucose?
(No hands go up.)

Professor *How many of you think that molecule is not glucose?*
(Less than half of the class raise their hands.)

Professor *How many of you are not sure?*
(The majority raise their hands.)

Professor *Given this structural representation, how would you go about identifying this molecule?*

Student D *I'd figure out the atomic formula and look it up in the Merck Index.*
(Within a minute or so, the molecule is identified as ascorbic acid, but the game is not over.)

Professor *Ascorbic acid, Hmmm, I don't see a carboxyl group. Why do you think it is called an acid?*
Puzzlement prevails but upon reflection some student will usually ask, "*Does it have a dissociable hydrogen?*"

Professor *Good. How might you decide which one?*
(Pointing to hydrogen bonded to carbon.)
Would this proton be dissociable?

Student E *No.*

Professor *Why not?*
(And so on until someone shows that one of the protons on the enediol is likely to be acidic.)

Professor *Another name for ascorbic acid is vitamin C. Why is vitamin C important in your body?*

Student F *I thought it was supposed to be an antioxidant?*

Professor *Chemically, what does that mean? Is that the same as a reducing agent?*

Student F *I think so. It gets oxidized to dehydroascorbic acid.*

Professor *Can anyone suggest a structure for dehydroascorbic acid?*

As can be seen, this game can be continued further and be played with any molecule. Equations also work. Sometimes, when answers are not forthcoming, the questions can be turned back to the students to discuss in groups or look up before the next class. The effect is that after several classes, many students start thinking about molecules as more than something with a structure and name to memorise. It helps to create critical chemists[1]. By seeing a variety of principles applied to different molecules in a context, students begin to gain confidence that they possess some relevant understanding and can apply general principles without knowing the name. They can appreciate the "*difference between knowing the name of something and knowing something,*" a lesson Richard Feynman learned early on about birds (and other things) from his father[3]. To reinforce that I value this type of thinking and understanding, I often include a mystery-molecule question on my examinations and ask students to predict or rationalise its chemical properties. Such an approach fits in nicely with the problem-based learning approach used in my course[4] and the constructivist ideas of how people learn[5].

1. Overton TL 1997 Creating critical chemists *U. Chem. Ed.* 1 28 - 30
2. White HB, 1992 Introduction to Biochemistry, A Different Approach *Biochem. Ed.* 20 22 - 23
3. Feynman RP and Leighton RM 1988 *What Do You Care What Other People Think?* (Norton)
4. White HB 1996 Addressing Content in Problem-Based Courses: The Learning Issue Matrix *Biochem. Ed.* 24 42 - 46
5. Johnstone AH 1997 "...And some fell on good ground" *U. Chem. Ed.* 1 8-13

Reflecting on learning

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In the last issue of University Chemistry Education four articles in particular (those by Garratt, Overton, Bailey, and Kee and Ryder) described different strategies for encouraging students to engage actively in the learning process and develop various skills needed by professional chemists. Strangely, none of the authors referred to the importance of encouraging their students to engage in reflection on what they had learned and the way they had learned it.

Most teachers understand the value of reflection with reference to more traditional teaching: the student who reflects on mistakes and on feedback on a piece of marked tutorial work learns more than the student who forgets the entire exercise the moment the work is handed in. However, where teaching is intended to lead to the development of skills, the need for reflection can be overlooked. Learners are often provided with an opportunity to experience a situation which requires the use of specific skills, without actually being given the opportunity to reflect on how they performed, and what they have learnt. This may actually be counter-productive, since it may reduce confidence by exposing the learner's lack of skill, without helping the learner to develop that skill, or bringing to light other positive qualities which can be developed further.

The value of reflecting on a learning experience was brought home to me at a Project Improve workshop run by Maskill and Race, where participants were introduced to some of the materials developed by them as part of their FDTL funded project.The exercises focused on communication skills in a variety of contexts. Maskill and Race emphasised that the exercises they have developed include an explicit component of reflection by the learner on what and how they have learned. For example, in one exercise all participants were provided with a single piece of information about a fictitious public health problem; once all the information had been shared between the group, conclusions could be drawn. Drawing the correct conclusion was of secondary importance. The most valuable learning opportunity was the subsequent discussion, which ranged over issues such as the group dynamics, the influence of the seating arrangements, and how we had organised the information as it was revealed. Maskill and Race very effectively demonstrated that it was the process of reflecting on the exercise that enabled the participants to learn from their experience, and identify ways in which we could improve on our performance when next faced with such a situation.

Reflection can and does take place even without being explicitly designed into a teaching exercise by a teacher.This may be particularly likely when new materials or teaching strategies are being used because there is pressure on the teacher to evaluate the effectiveness of innovations. The evaluation process, involving feedback from students, may encourage exactly that reflection which plays a valuable role in the learning process.

Reflection may also be involved during activities involving group work, especially in those examples I referred to above taken from University Chemistry Education where group work is followed by plenary discussion sessions involving learners and teachers.

I therefore accept that a degree of reflection is frequently a natural part of most learning opportunities. My point is that it is too important a part of the learning experience to be left to chance, and should be explicitly included in discussions of teaching.

Laboratory work does not interest students

From Professor Alex Johnstone,
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I recently attended a meeting of university lecturers in chemistry on the subject of 'New Approaches to Undergraduate Laboratory Work'. We discussed various ways of increasing the effectiveness of this aspect of the curriculum. But we spent little time thinking about the students' view of laboratory work. The importance of this was forcibly made to me as a result of my involvement with the training of probationary university staff.

Last term I ran three courses and workshops on 'Teaching and Learning in Laboratories' which were attended by a mixture of Chemists, Physicists, Biologists and Engineers. As a preliminary part of the 'warm up' discussion, I asked each group to indicate if they had enjoyed their undergraduate experience in laboratories. Of the 50 young lecturers, only two admitted to having enjoyed their time in undergraduate labs (and these two were not chemists!).

When questioned further about how they were going to square this with inflicting the same experiences on the next generation of undergraduates, there was much disquiet. There were the usual mutterings about *"Science is practical and so they must do practical work"* or *"It is good for them"* or *"How else will they obtain research skills"*.

This was a good curtain raiser for the later parts of the course and forced us to question the experiences we had undergone and think about how things could be better. We ranged over the demands of the conventional labs in terms of time pressure, in ways students have of 'easing the pain' and boredom and in their dodges to make teachers believe that they were learning.

All of this points up the need for rethinking what goes on in labs. Nobody was suggesting that there should be no labs, but there was a genuine concern that in order to make this extremely costly form of teaching and learning effective and educational we need to maintain the interest and enthusiasm of the students. My unscientific 'survey' suggests that we are not even doing this for the most academically minded students who end up as university lecturers. How do you suppose the rest of them feel?