Unlocking Knowledge We Know the Students Know

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Information travels in two basic forms, language and pictures, and it is no surprise that when the use of language for information transfer fails, investigative professions resort to the use of pictures. Sometimes the use of pictures can deliver information that is not easily conveyed or obtained by other means. For example, it is possible to quickly diagnose color blindness by simply viewing a series of specially designed psuedoisochromatic images (Figure 1). Through the use of ink blots (Rorschach technique), psychologists make use of visual perception to unlock subconscious information and develop an understanding of the personality of their subject. Chemistry is replete with images and it was thought that a similar approach could be used to generate an interrogative situation that uses little or no language and does not require the examiner to prompt the candidate. The aim here is to trigger a particular learned response in our subjects hoping that the image provided would convey a specific meaning to the student. Significantly, an exercise based on images alone may shift the balance in favor of students who have superior visual perception and possibly those with language problems and specific learning disabilities (e.g., dyslexia, dysgraphia, dyscalculia).

Written Questions

For many years my department has been offering the graduating students general unpreviewed questions on inorganic chemistry as part of their final assessment. These questions are designed to target their basic understanding of fundamental chemistry and were derived from the numerous courses taken during their four years in the department. Typically these are a series of straightforward questions such as "Describe the importance of hydrogen bonding in chemistry" or "Discuss the bonding in simple metal carbonyl compounds."

The students are normally offered a free choice of topics, typically six topics from eight, and are expected to draft an answer to each question in five to ten minutes. Invariably these questions were poorly answered and the average grades were low. This outcome was highly frustrating as the teaching group responsible for these topics had documentary evidence about the students from their earlier years indicating that they did know the answers to these questions. It is evident that the students had not unlearned the material but had allowed the mental links to the answers of these simple questions to dissipate. From an instructor's point of view it is highly disappointing that the seminal importance of bonding theory, spectroscopy, and so forth to general science was seemingly being lost on these graduating students.

Pictorial Questions

We decided to approach the same topics using visual cues. The following year's examinees were provided with images (Figure 2 and Figure 3) instead of questions, with a simple directive to "give a detailed explanation of the diagram". The visual trigger seemed to tap into different levels of consciousness and the answers forthcoming were full and expansive. For example the question on hydrogen bonding (Figure 2), which many students in previous years struggle to make a full link with water, released a wide range of descriptions based on the polarity of the bonds, the strength of

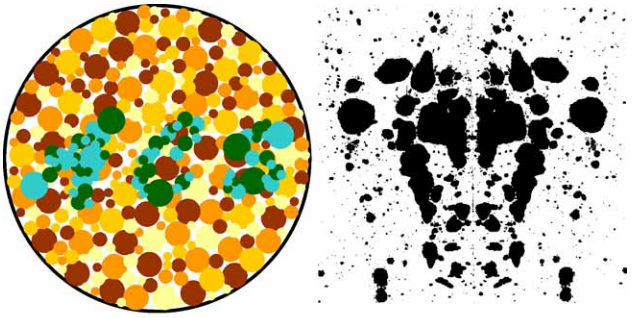

Figure 1. (left) A stylized psuedoisochromatic plate used in the diagnosis of color blindness. The hidden message is "ACS". (right) An ink-blot diagram in the style of the Rorschach technique.

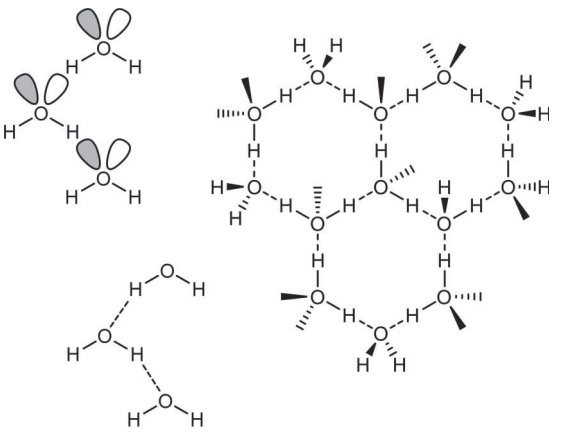

Figure 2. A visual, "ink-blot" method of asking the question, "Describe the importance of hydrogen bonding in chemistry."

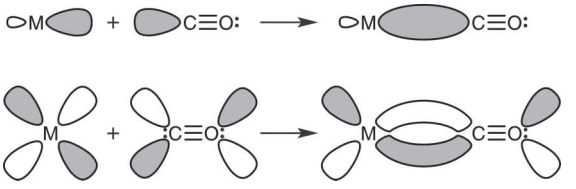

Figure 3. A visual, "ink-blot" method of asking the question, "Discuss the bonding in simple metal carbonyl compounds."

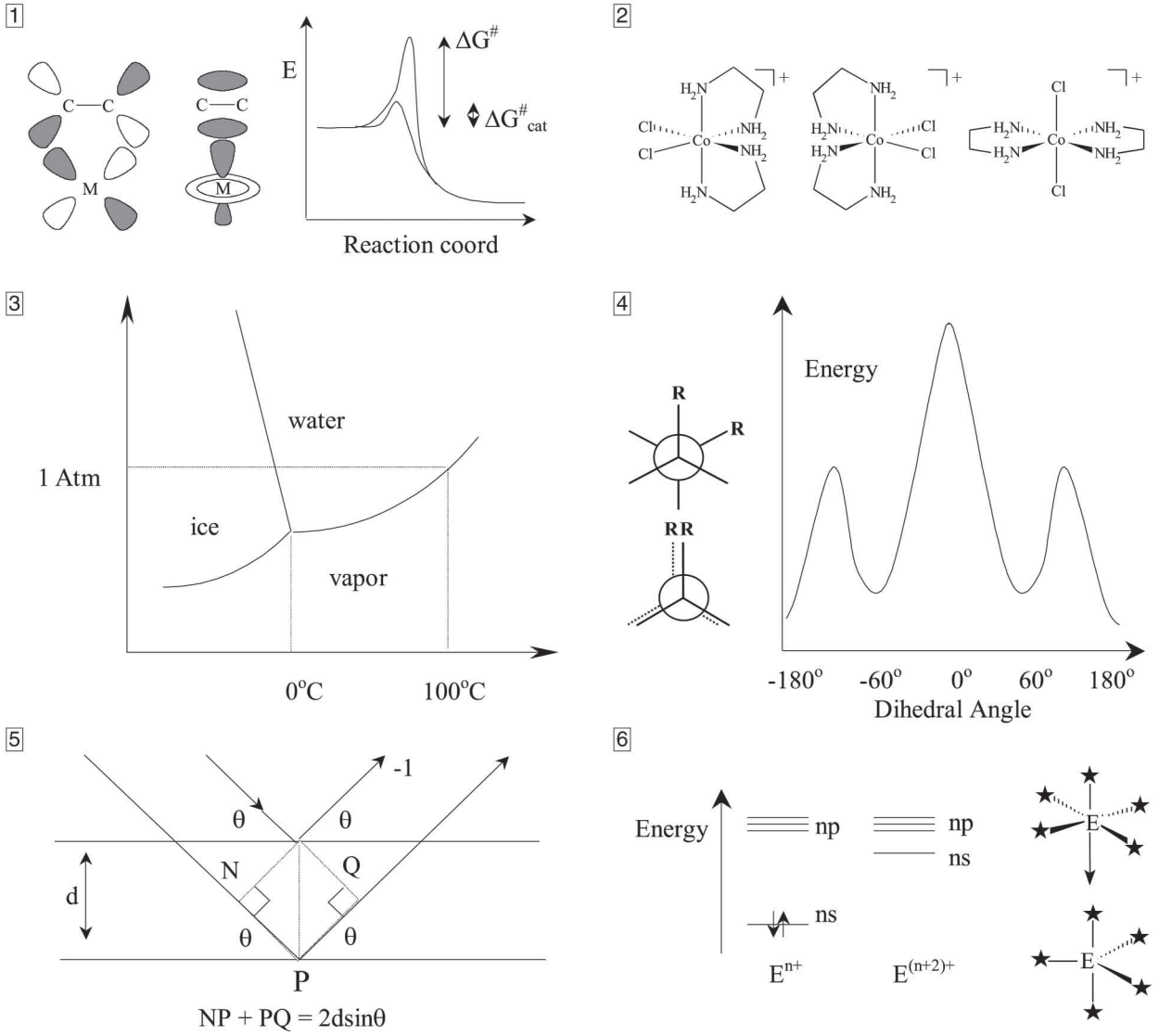

Figure 4. Six pictorial representations of seminal chemical concepts.

the bonds, and encompassed the relative densities of water and ice. Similarly the bonding descriptions of metal carbonyls (Figure 3) moved quickly to the type of bond, the orbitals involved, the C−O bond length, and the effect of ligation on the ν_{CO} infrared stretching frequencies. In effect the scope of the answers exceeded that expected and the overall performance of this set was a significant improvement over previous classes with the same grade profile.

Discussion

This attempt to elevate the grades of a failing assessment delivered unprecedented success. In its examination mode, responses to six diagrams from ten were required. In an alternative incarnation the exercise could be used as a midterm or class test for fourth-year students or new graduate students if significantly more diagrams were available. Ten diagrams that can be used are shown in Figure 4 (larger formats are available in the Supplemental Material[W]). The diagrams provided reflect the author's interest and those engaged in physical or organic teaching would need to supplement the list with diagrams of their own. However, the design of the diagrams must be simple, suggestive, and devoid of text. Complicated diagrams make it too difficult to isolate the question that connects with the examiner's projected answer. It is best if the students have seen these diagrams or something like them previously.

Instructors must bear in mind that with the element of surprise there can be no fixed answer to the "question". Instructors must be prepared to act in a responsive mode to what is written or said in class. Since there is no language base from which to direct the manner in which the student tackles the

question, the answer reflects their personal view of the topic. This type of response provides information on the impact of the teaching and in turn requires more of the instructors as graders. Furthermore, this type of question is designed to tap into different aspects of the students' thought processes and one should not be surprised if the exercise grades the class differently, just as there may on occasion be a graded discrepancy between a student's practical and paper marks.

Not only did the pictorial format increase the students' performance, but it can also be helpful to students with specific learning difficulties. It is now common practice to provide extra time in examinations to allow students with learning difficulties to read and understand the questions. We have become tolerant of simple physical aids that assist these students. We provide notes on colored paper and in extra large fonts. In some cases we even provide scribes during classes and examinations. Although many of these teaching innovations benefit students with learning disabilities, the examination still disadvantages them. Allowing a candidate extra time only ensures that they have time to read the question again; it does not mean that they can unravel the meaning contained in it and that they actually understand it. Furthermore in examinations of long duration extra time is not really a help but a hindrance to students with learning disabilities. They can easily become mentally exhausted before their allotted time expires. Although efforts are being made to offer help, in many instances we still remain unable to unlock the talent submerged in some of these individuals. Removing the language component from a question allows it to acquire a different sense, one that may suit students with specific learning disabilities most notably dyslexia. In effect this type of exercise may help negate a learning disability. However, by offering it to the whole class we can effectively level the playing field for this special group without making artificial and irrelevant compensations.

[W]Supplemental Material

Twenty pictorial representations on various chemical topics are available in this issue of *JCE Online*.