Stereoscopic 3D in the Virtual Museum of Minerals & Molecules: Glitz, Bother, or Value?

ABSTRACT

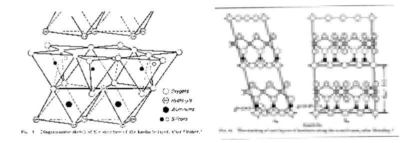
Molecular visualization is a struggle for both students and instructors. Two-dimensional (2D) print illustrations may show shading and perspective but lack other 3D cues. Computer-aided visualization adds interactivity to high quality 2D images on a computer screen, creating ‘2½D’, generally regarded as a marked improvement.

True stereoscopic 3D presents subtly different images to the right and left eyes. Stereo3D requires more preparation for the presenter and more equipment that may distract the learner, but more closely imitates viewing a physical object.

The questions: Is there a demonstrable difference in student learning between 2D and 2½D displays? …2½D and 3D? Is development of 3D capability really worth the trouble? Are there some students who will benefit more than others?

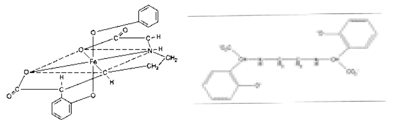
Introduction. In the natural world, function often follows form. Understanding the three-dimensional structure of microscopic natural objects is often the key to understanding their functionality. However, illustrations conventionally used to demonstrate that structure, such as those used in textbooks, often miss the mark.

For example, a standard illustration of a layer silicate structure (below) is ‘anatomically correct’ and an example of beautiful draftsmanship. However, it is difficult to imagine that it is very educational if judged by the results if one were to task a student to repeat it, describe it, build it, or in any way produce a product that demonstrated deep understanding of its three dimensional nature.



Typical textbook 2D illustration of phyllosilicate structure. Here, two views of kaolinite, a soil-forming mineral of environmental significance.

Some textbook illustrations are apparently so uninformative and un-educational that errors may persist over multiple editions, escaping the eye of authors, instructors, and students for years! This figure of a metal chelate, a chemical compound in which the form/function relationship is particularly obvious (below, left) was taken from a 1970s textbook and reproduced in another title in two subsequent editions. When errors were brought to the attention of the authors, the figure was replaced with another (below, right) that completely ignored the form aspect of a chelating agent that imparted its functionality.

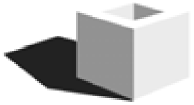


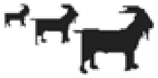
A chelating agent shown in 5th and 6th editions of a popular textbook (FeEDDHA, left) and the substitute used in 7th ed (EDDHA, right) to correct the two errors in the earlier editions. Although the errors have been corrected, the form/function relationship has been lost.

What is there about these figures that is so uninformative? Perhaps most obvious—they lack the visual depth cues that allow the mental construction of a three-dimensional object from a two-dimensional representation. Done cleverly--with shading, perspective, and other monocular depth cues—such images may be considered to be 2½D images.

Monocular Depth Cues (after Lipton, 1997)

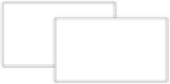
Light and shade provide a basic depth cue. Objects may look solid or rounded by shading them. Cast shadows can make an object appear to be resting on a surface. Bright objects appear to be nearer than dim ones.

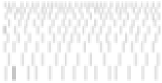




Relative size involves the size of the image of an object. Since objects appear larger when they are closer, and smaller when they are farther away, memory helps the viewer make a judgment about the distance of familiar objects.

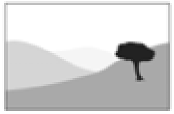
Interposition is so obvious it is easily taken for granted. An object interposed between the viewer and another object is perceived as closer to the viewer.

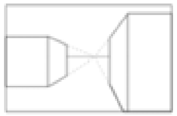




Textural gradient is a depth cue in which the texture of an object is more apparent if the object is closer to the observer.

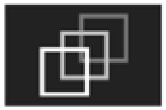
Aerial perspective is the diminution in visibility of distant objects caused by intervening haze. Often, distant vistas will pick up a bluish haze because of the scattering of red light by the intervening atmosphere.





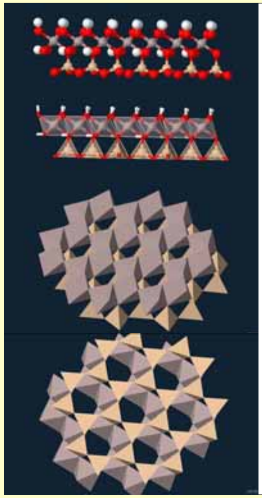
Perspective, sometimes called “geometric,” “rectilinear,” or “photographic” perspective, is the relationship between foreground and background objects. Particularly if perspective cues such as lines receding to a vanishing point are present, this Is the most important extrastereoscopic depth cue.

Depth Cuing is the name of a technique used in computer graphics in which the intensity of the object is reduced in proportion to the distance from the viewer.



Motion parallax is a depth in the cue provided in moving image displays and can be achieved through the rotation of an object. A familiar example is seen from a moving car when telephone poles move past the viewer more rapidly than the distant hills.

Starting in 1998, I began work with molecular visualization software that put research-grade, interactive 2½D images into web browsers as part of the **Virtual Museum of Minerals & Molecules**, virtual-museum.soils.wisc.edu. Over time, the software functionality has improved—most noticeably with the substitution of Jmol, an open-source, Java-based applet—and now standard polyhedral representations are available as well as ball&stick.

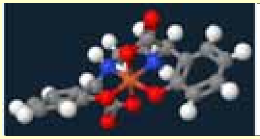


Four screenshots of kaolinite from the **VMMM**, reflecting ball&stick (*top*) and polyhedral representation, as well as investigation of motion parallax by user interaction by dragging the mouse across the display.

In particular, the transition from atoms as ‘balls’ to tetrahedral and octahedral units is evident in the second panel with translucency.

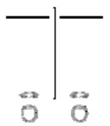
Rotation of the polyhedral views reveals that the polyhedra in each layer are assembled in near-perfect hexagons, and the layer of tetrahedra and the layer of octahedra neatly bond to each other.

Molecules and minerals that may be represented by such techniques range from natural to synthetic, organic to crystalline, low-molecular weight molecules to proteins with thousands of atoms.



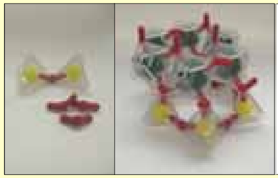
Screenshot of FeEDDHA from **VMMM**, using most of the monocular depth cues. When live on a computer screen, object rotation presents motion parallax as well.

The Questions. Almost as soon as the VMMM project began, questions as to whether students indeed *learn* better with the 2½D displays than the 2D displays previously encountered. As time passed, I became interested in the possibility of constructed true stereoscopic displays—using LCD shutterglasses or polarized lenses—that would present different images to right and left eyes (below). Would students learn better with 3D than 2½D? How could I tell? Would all students respond similarly?



In true stereoscopic viewing, right and left eyes perceive slightly different images which are processed as depth cues. Here, lenticular stereoscopy is shown but modern alternatives include page-flipping with LCD shutterglasses or dual projection with polarized lenses and polarized glasses.

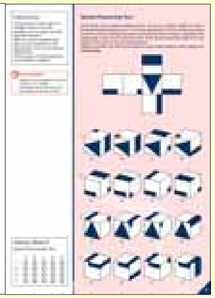
The Method. A ‘best-practices’ lesson on phyllosilicate structure—focusing on kaolinite—will be constructed and rendered into 2D, 2½D, and stereo3D displays. Soil science and environmental science students will be randomly assigned one or another of the lessons. Afterwards, students will be asked to engage in object assembly of a kaolinite unit cell, using a polyhedral model kit and a simple set of instructions. Results will be timed and videotaped, and subsequently evaluated. Parallel tests of spatial visualization ability will be administered.



The Polyhedral Model Kit (Institute for Chemical Education; MRSEC, UW-Madison) makes object assembly from individual tetrahedra and octahedra possible, *if* real 3D understanding of form has been acquired. (Unit cell of kaolinite depicted on the right.)

Expected Outcomes. It is likely that the depth cues added by 2½D display will enhance learning compared to 2D. The effect of adding stereo3D to 2½D is less certain. Furthermore, it is likely that students with advanced spatial visualization abilities will benefit less from 3D displays than others.

Spatial Visualization Ability refers to the ability to mentally manipulate 2D and 3D figures. It is typically measured with simple mental rotation and cognitive tests and is predictive of user performance with some kinds of user interfaces. At right is a practice test in which a cube is mentally assembled from a 2D plan. The Kit of Factor-Reference cognitive tests produced by ETS includes cognitive tests like the VZ-1 (Form Board), VZ-2 (Paper Folding), and VZ-3 (Surface Development.)



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