UC DAVIS

"Building" 3D visualization skills in mineralogy

Sarah J. Gaudio, Cecilia N. Ajoku, Bryan S. McCarthy, Sarah Lambart

sarahgaudio@gmail.com

Motivation: Providing a new set of experiential learning activities for students struggling with 3D-visualization

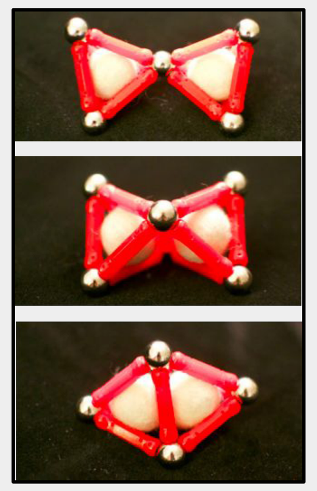
Description of Activity Modules

Module #1: Making Connections

Exploring connectivity of polyhedral units

OBJECTIVE MODULE #1: Provide students a conceptual understanding of Pauling's rule for connectivity in ionic solids using Magnastix®. After completing this module students will:

1. Be able to recognize and illustrate the different ways in which polyhedra are connected to one another.
2. Develop intuition about how changes in connectivity affect intercationic distance.



Type of Connectivity	Distance between cations	Percent difference maximum
Corner-Sharing	~5.0cm	100%
Edge-Sharing	~3.0cm	~60%
Face-Sharing	~1.75 cm	~35%

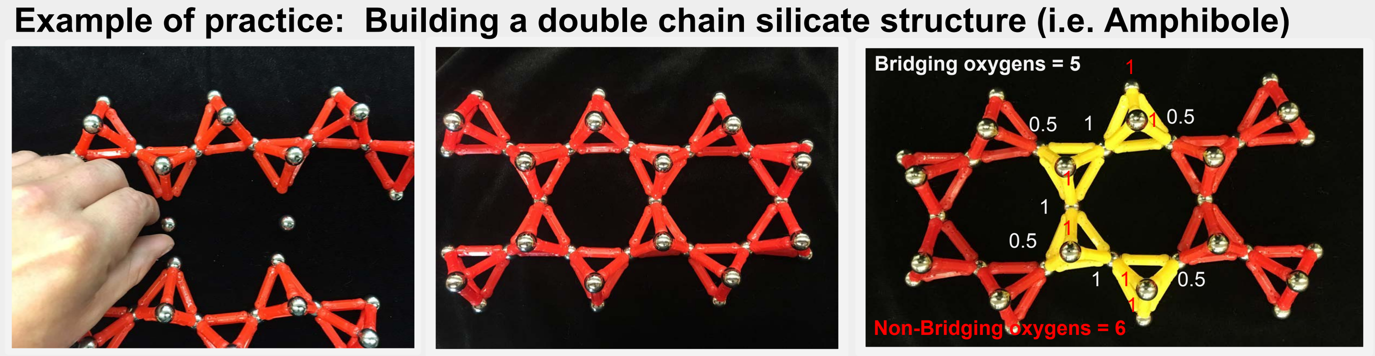
Module #2: Polymerization of Si-O Tetrahedra

Exploring polymerization, Pauling's electrostatic valency principle and the chemical formulae of silicate minerals

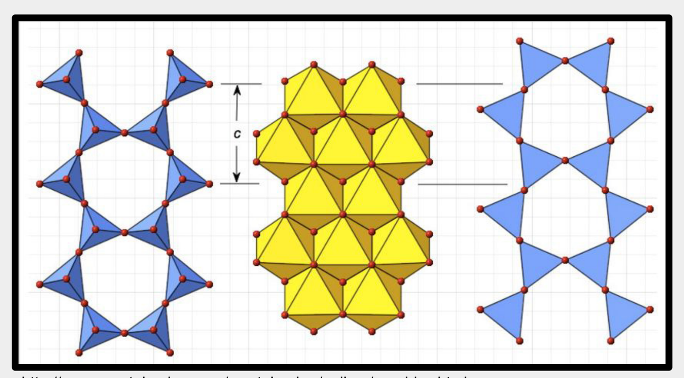
OBJECTIVE MODULE #2:

1. Construct polyhedral units that represent Si-O tetrahedra,
2. Learn to visualize (and draw) structures produced by varying the number of corner- sharing connections between these tetrahedra (intertetrahedral linkages or Si-O-Si connections),
3. Learn how the number of intertetrahedral linkages controls the silicate portion of the chemical formula of silicate minerals using Pauling's electrostatic valency principle.

Example of practice: Building a double chain silicate structure (i.e. Amphibole)



Identification of repeat unit in the double chain is easy when highlighted by contrasting Magnastix® and when analyzed with Pauling's principle of electrostatic valency, one can calculate the silicate portion of the general amphibole formula. In figure 2c, bridging oxygens are indicated with white numbers, while non-bridging oxygens are indicated with red numbers.



http://www.crystalmaker.com/crystalmaker/gallery/graphics.html

For a double chain silicate the unit in figure 2C must be doubled as illustrated in figure 2D; therefore, there are:

Si = 4*2 = 8
Bridging oxygens = 5*2 = 10*0 excess charge = 0
Non-Bridging = 6*2 = 12*-1 excess charge = -12

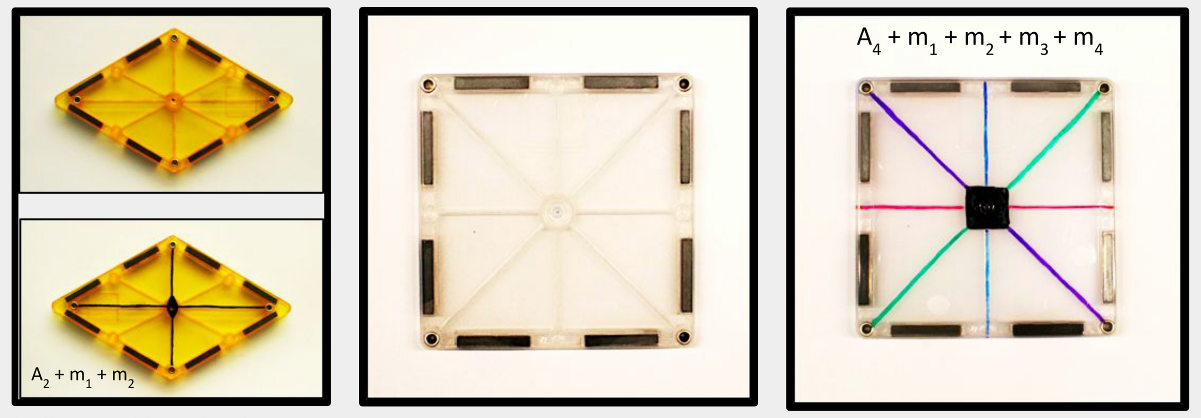
So the silicate portion of the formula is:
$(Si_8O_{22})^{12-}$

Modules #3 and #4: Symmetry in 2D objects and patterns

An exploration of rotational and mirror symmetry in polygons and mirrors, rotations, translation, and glides in 2D patterns

OBJECTIVE MODULE #3: Determine the symmetry of elements of shapes.

Example of practice : Diamond and Square



A diamond has 2 mirrors (2m) and one A_2 rotation axis.

B) A square shape has 4 mirrors (4m) and 1 4-fold rotation axis (A_4).

OBJECTIVE MODULE # 4: Create 2D patterns with different types of symmetry elements:

Part A: Determine the types of shapes that can fill 2D space.

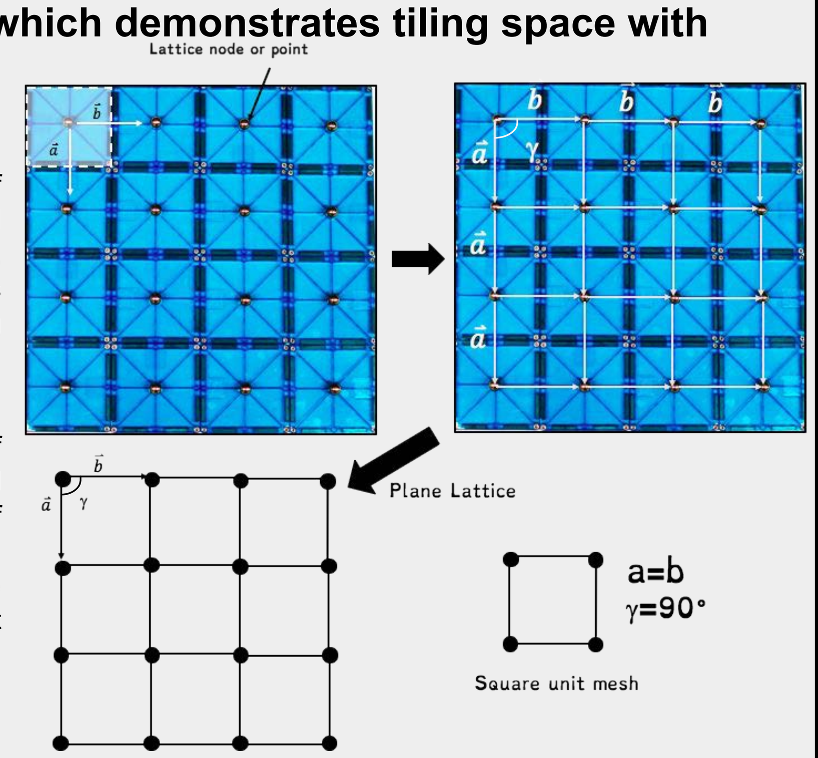
Part B: Learn how symmetry is described and reported for different types of patterns.

Part C: Exploring glide symmetry in 2D patterns

Example from part B which demonstrates tiling space with a square shape.

Square tiles are the motif (outlined in dashed white line and highlighted in transparent white), because they are the unit that is repeated through space along translation vectors $\vec{a}$ and $\vec{b}$.

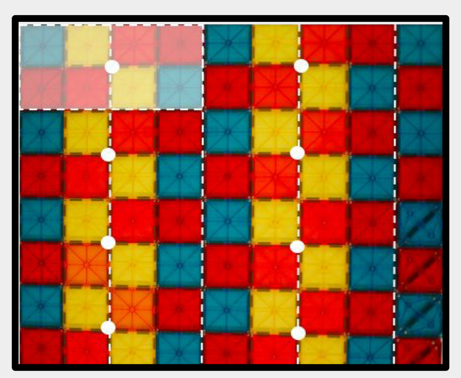
The symmetry center of the motif (or the point through which all symmetry elements of the motif must pass), is called a **lattice node.** Lattice nodes may also be described as points of equivalent symmetry in a pattern.



Example from part C demonstrating glide symmetry

The motif has glide symmetry a A_2 and the plane lattice is rectangular [$A_2 + m_1 + m_2$].

Pattern has a whole has has 2 vertical glide symmetry elements, no mirrors and 1 A_2

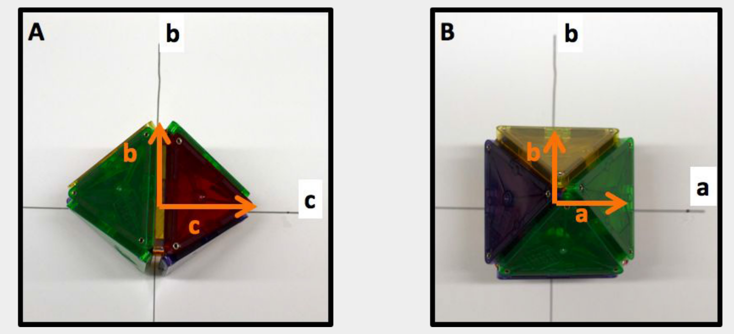


Module #5: 3D Symmetry and Indexing Crystal Faces

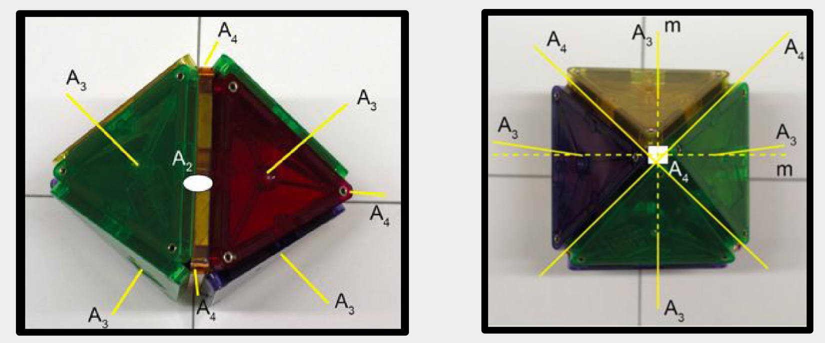
Identifying symmetry elements and Miller indices of crystal faces

OBJECTIVE MODULE #5:

Part A: Identify elements of symmetry on 3D shapes in order to locate the crystallographic axes



Step 1) Using simple shapes such as a cube and octahedron, showing that crystallographic axes are not always parallel to the crystal face.

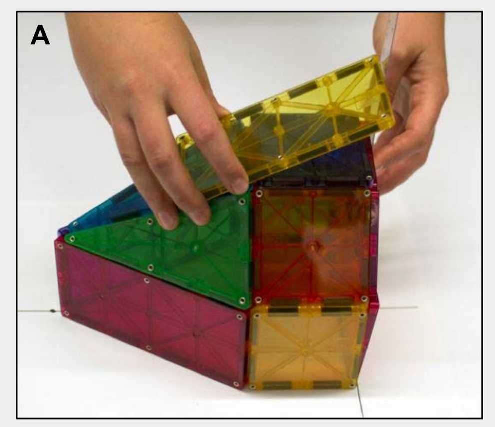


Step 2) Demonstrates that determining the symmetry elements of a polyhedron helps identify the orientation of the crystallographic axes.

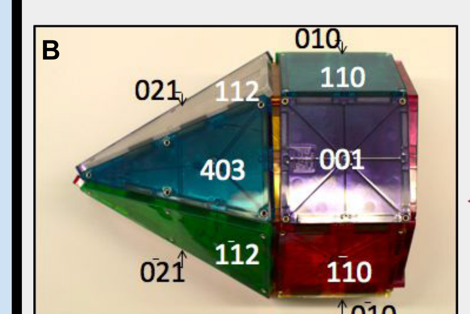
Part B: Miller indices

A) Conventional determination:

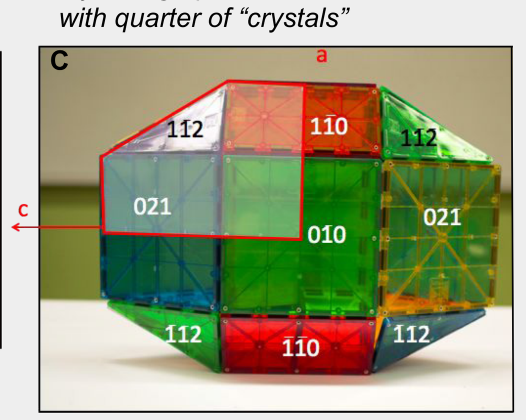
1) Location of the axes and calculation of the axial ratios
2) Measurements of the axial intercepts (Fig. A)
3) Calculation and normalization of the Miller indices.

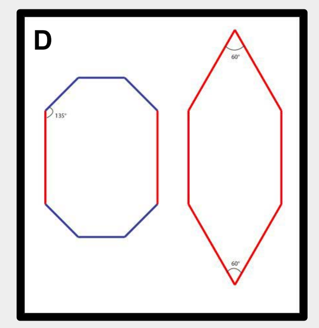


To facilitate the measurement on the crystallographic axes, students work with quarter of "crystals"



Birds-eye view of the section highlighted in red on Fig. ***C***





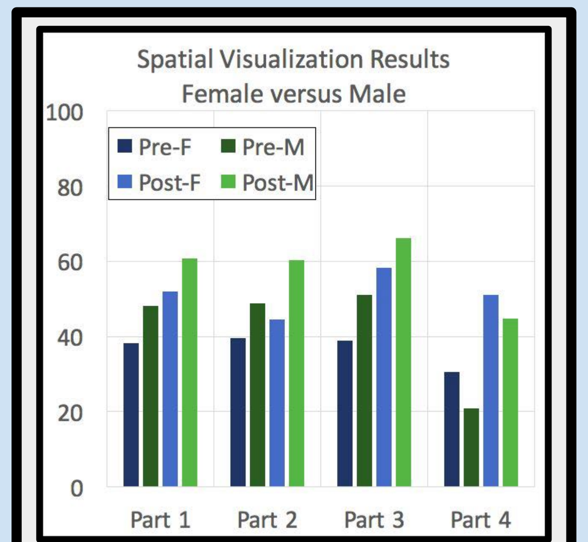
B) Additional activities:

- Develop skills in the areas of visual penetrative ability as well as spatial rotation (Fig. D)
- Develop intuition for labeling crystal faces without making measurements

Class Demographics

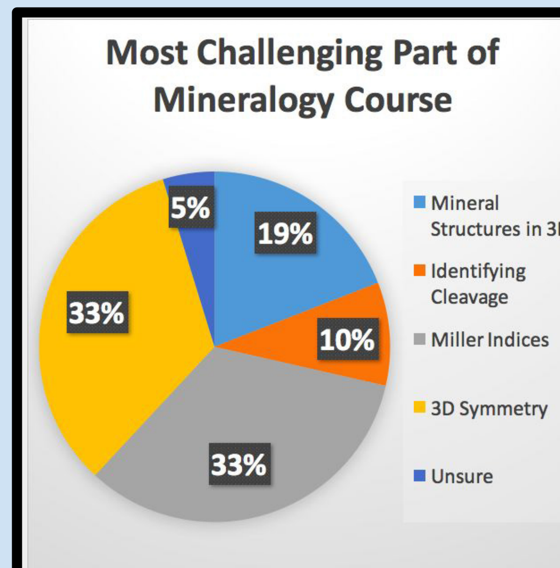
14 females / 25 males:
- 8 with structural geology background
- 21 concurrently enrolled in optical mineralogy

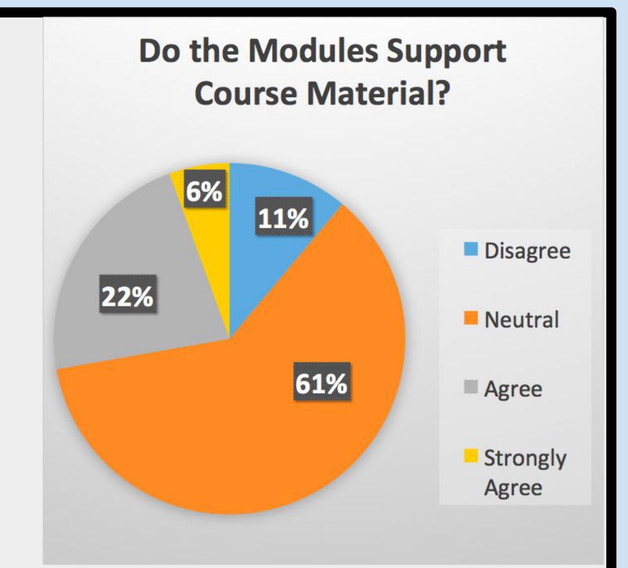
Assessment*

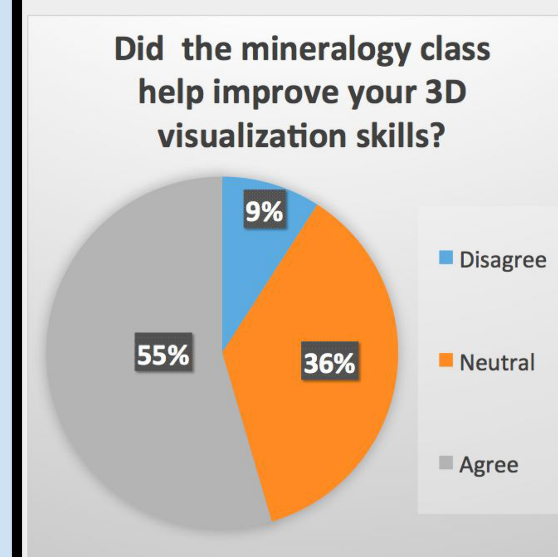


Part 1: Spatial Rotation
Part 2: Spatial Manipulation
Part 3: Visual Penetrative Ability
Part 4: Mineralogy specific spatial visualization questions.

Student Responses and Comments







Additional Statistics

-No correlation between course grade and performance on the assessment.

-No correlation between students' confidence in their answers on the assessment and their actual accumulative score or with any single part of the test.

-No correlation between test answer confidence in pre-course assessment and post-course assessment; however, students attempted more questions in post-course assessment.

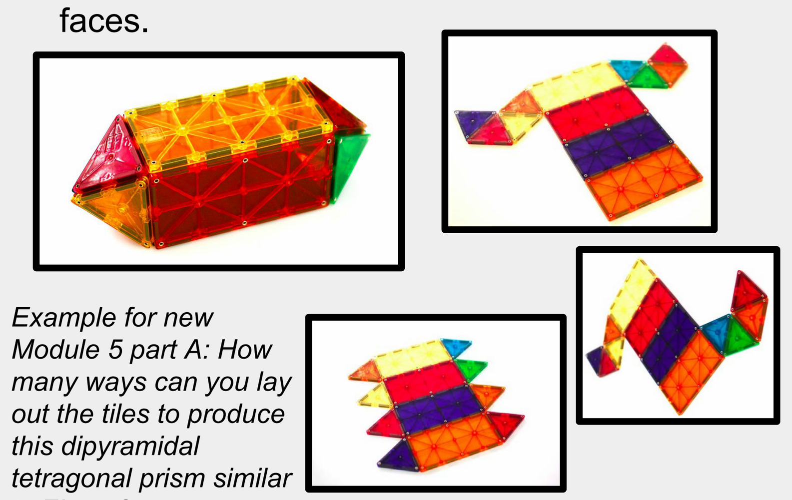
-All but one respondant to our surveys said that more direct instruction on drawing in 3D is needed.

Future and Ongoing Work:

New Modules

In response to student comments and our perception of their needs, we have decided to pursue several developments.

1) Split-up & expand topics in module #5: 1) Identification of the symmetry elements of crystal forms and 2) Determining Miller indices of crystal faces.



Example for new Module 5 part A: How many ways can you lay out the tiles to produce this dipyramidal tetragonal prism similar to Zircon?

2) Visualizing and drawing polyhedra within mineral structures.

Example: visualization of trioctahedral and dioctahedral layers present in many silicate mineral structures.

Secondary School Lesson Plan

Example: 7th grade California Mathematics Common Core Standards for Geometry

Draw, construct, and describe geometrical figures and describe the relationships between them.

1. Solve problems involving scale drawings of geometric figures, including computing actual lengths and areas from a scale drawing and reproducing a scale drawing at a different scale.
2. Draw (freehand, with ruler and protractor, and with technology) geometric shapes with given conditions. Focus on constructing triangles from three measures of angles or sides, noticing when the conditions determine a unique triangle, more than one triangle, or no triangle.
3. Describe the two-dimensional figures that result from slicing three-dimensional figures, as in plane sections of right rectangular prisms and right rectangular pyramids. (Visually penetrative problem-solving)

Incorporation of modules into lesson plan:

The patterns and shapes that can be made with the Magna-Tiles® correlates to the angles present in the shape. The Magna-Tiles® can provide the students with a visual that can assist in the fundamental understanding of angles, lengths, and area.

References:

Our Mission. (2013, January). Retrieved August, 2016, from http://www.cde.ca.gov/be/st/ss/documents/ccssmathstandardaug2013.PDF

*Titus and Horsman (2009) Characterizing and improving spatial visualization skills, J. Geo. Edu.

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