Developing spatial and penetrative thinking skills through technology

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Spatial visualization, the ability to 'see' in 3D, is essential for understanding geologic features at all scales, ranging from nano-scale materials and complex geochemical interactions through kilometre-scale features of planetary structures. Undergraduate (ug) geoscience students enter major's courses with a wide range of spatial skill levels. Recent research from cognitive sciences suggests that students improve with practice and benefit from intentional training. To facilitate spatial learning, one teaching strategy is to specifically employ technology. For example, in an ug mineralogy course, technology-based self-directed laboratory exercises utilize the computer program CrystalMaker$^{(RT)}$. Specifically developed questions require students to 'see' hidden features, identify (dis)similarities by rotating and manipulating structures, slice a 3-D structure/object to observe its 2-D representation, and relate microscopic to macroscopic features. Students are comfortable with enhanced technology, thus providing a positive affective domain. In addition, they can test their hypothesis and quickly self-assess by manipulating 3-D images on the screen. Pre- and post-tests assess skills development. In our studies over a four-year period, students demonstrated improvements in their spatial and penetrative thinking with the addition of deliberate teaching and learning opportunities. Such a strategy can be applied to other geoscience disciplines using a variety of new technologies. Teaching with technology enhances spatial and critical thinking and has the potential to transform education and remove a significant barrier to success in the geosciences.