Spatial Reasoning: Improvement Of Imagery And Abilities In Sophomore Organic Chemistry. Perspective To Enhance Student Learning

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ABSTRACT

Spatial reasoning has become a demanded skill for students pursuing a science emphasis to compete with the dynamic growth of our professional society. The ability to reason spatially includes explorations in memory recollection and problem solving capabilities as well as critical thinking and reasoning skills. With these advancements, educational requirements seek reassurance in that efficient learning skills can be embedded in science curricula. Organic chemistry is a source in which abilities such as spatial reasoning can benefit students intending to thrive in scientific communities. This study of instructional development in organic chemistry seeks to determine if spatial reasoning can be improved by exposing stereo-chemical techniques from the Purdue Visualization Rotation Test (ROT) to students who have not taken organic chemistry and have science oriented educational goals. We sought to determine two purposes: to gauge how much spatial reasoning a student possessed prior to the course, and to test if spatial ability can be improved in students who present low ability over the span of the three month course. Results show significance in that spatial reasoning can be improved through statistical analysis in students who showed below average qualities.

Keywords: Organic Chemistry; Spatial Reasoning; Visualization

INTRODUCTION

Spatial ability is a capacity for mentally generating, rotating and transforming visual images, and is a specific cognitive representation most important for developing expertise in learning and career settings (Benbow, Lubinski, & Park, 2010). Instructional development is essential for students taking organic chemistry to recognize specific representations (Jose & Williamson, 2008) such as mental rotations, electron repulsion, and spatial perception–the understanding of space and arrangement of organic compounds. While spatial visualization is very important in understanding stereo-chemical transformations, spatial orientation combined with visualization promotes intellectual acceleration students need in order to thrive successfully in scientific communities (Sorby, 2007).

Spatial visualizations in organic chemistry are specific transformations which occur from *two* dimensional structures manipulated into consistent *three* dimensional images, and spatial orientation is successfully transitioning from *two* dimensions to *three* dimensions without experiencing confusion (Bodner & Pribyl, 1985). If a student who has not been exposed to organic chemistry can mentally rotate a *2-D* structure such as an enantiomer, and notice that alternate rotations can occur in different directions while able to still maintain visualization, this student has expressed spatial orientation, and therefore executed spatial reasoning. Spatial reasoning can be difficult to measure as abilities vary from student to student; however, the Purdue Visualization Rotation Test (ROT) developed by Bodner and Guay in 1997 is known to have high effectiveness in the area of spatial reasoning, and therefore chosen to evaluate spatial aptitude in students who have yet to take an organic chemistry course (Branoff, 2000). Those pursuing science should be familiar with spatial reasoning because aptitude in reasoning is tested to evaluate future success rates in certain specialty programs such as dental or medical programs (Hegarty et al., 2009) and engineering programs (Sorby, 2007).

Because spatial reasoning can improve memory recollection and content retention it may be mostly recognized as a skill when students are allowed subsequent testing opportunities (Sorby, 2007). The caveat regarding instructional development in organic chemistry and our hypothesis is if spatial reasoning can be improved in students with scores that are classified as having below average spatial ability skills. If so, we would expect to see significant changes between test assessments over a period of three months in students who presented below average skills.

METHODS

Fifty-eight students enrolled for the first time in an organic chemistry course were given a spatial aptitude assessment. The assessment was given twice: a preliminary test and a post-test which separated by a span of three months. The assessment used was the Purdue Visualization Rotation Test (ROT). During the semester, students were also assessed in the areas that require spatial reasoning: stereochemical classification in naming, enantiomers and diastereomers, and enantiospecific and diastereospecific reactions (See Figure 1). Performance on ROT tests was measured on a scale from 0-1 and the student's success and grade in the course was measured from a scale of 1-5; 1 representing a D and 5 representing an A.

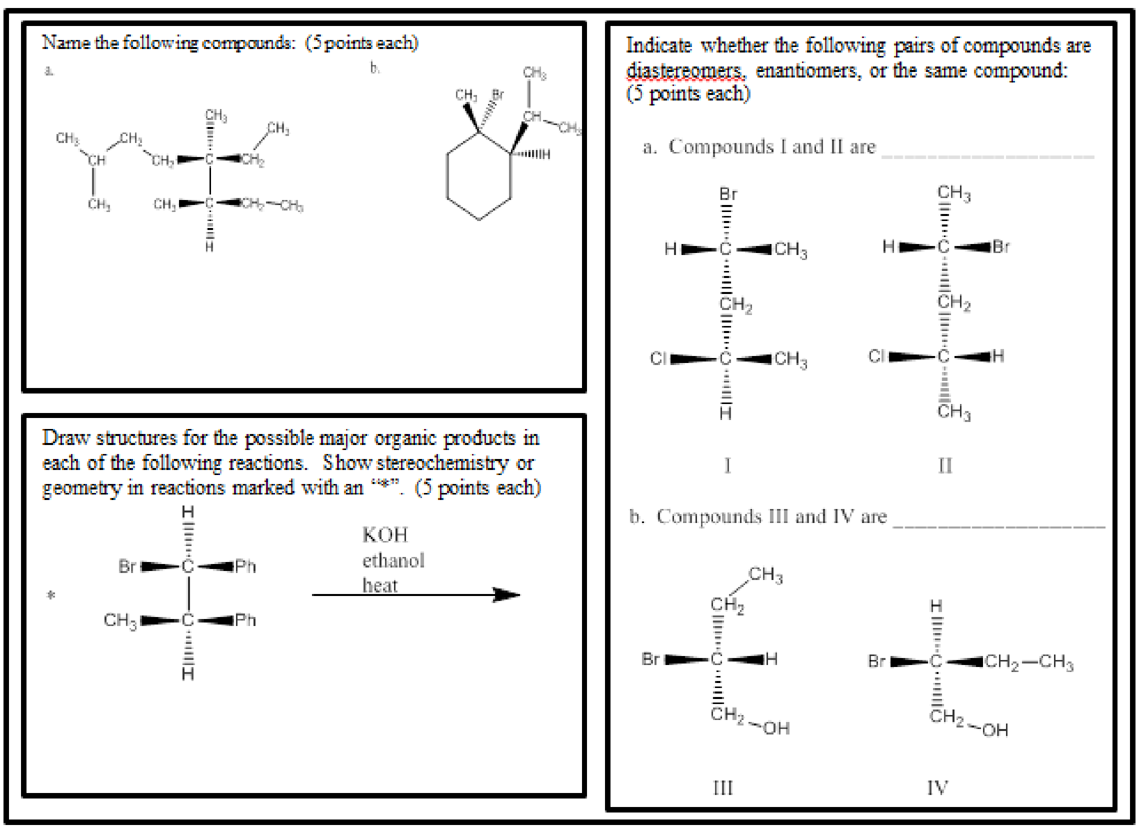

Figure 1: Sample Questions from Classroom Assessments during the Semester

RESULTS

The initial assessment, (ROT1), serves as a preliminary measurement representing the spatial reasoning of the student prior to instruction in the course. This score was used to group the students into two categories, "above average" and "below average" as seen in Tables 1 and 2. The average data for all 58 students is reported in Table 3. The final assessment, (ROT2), serves as a measurement for spatial reasoning improvement during the three month period the students were enrolled in an Organic Chemistry course.

Table 1: Statistical Data for Above Average Students; N = 29

	Mean	Standard deviation
ROT 1	0.6776	0.1014
ROT 2	0.7345	0.1727
Change in ROT	0.0569	0.1215
Final Class Grade	4.2759	1.1306

Table 2: Statistical Data for Below Average Students; N = 29

	Mean	Standard deviation
ROT 1	0.3776	0.1333
ROT 2	0.4534	0.1922
Change in ROT	0.0759	0.1492
Final Class Grade	3.9655	1.1175

Table 3: Statistical Data for All Students; N = 58

	Mean	Standard deviation
ROT 1	0.5276	0.1915
ROT 2	0.5940	0.2300
Change in ROT	0.0664	0.1369
Final Class Grade	4.4165	1.1251

Figure 2 illustrates grade comparisons from a scale of 1-5 and ROT comparisons in below average students over a three month period. Figures 2 and 3 illustrate that 28 out of 29 students showed improvement in spatial reasoning, roughly 96 percent showed improvement. The combined results between above and below average students were statistically analyzed and determined by performing a t-test to evaluate significance. The p-value of 0.0002* showed significance in the population of 58 students, and therefore rejected H_0. Below average students were also analyzed in a 29 student sample population by also using a t-test which also yielded significance, p-value of 0.0053*. This study shows a statistical significance between the mean in a population of 58 students and the mean of 29 students categorized as below average.

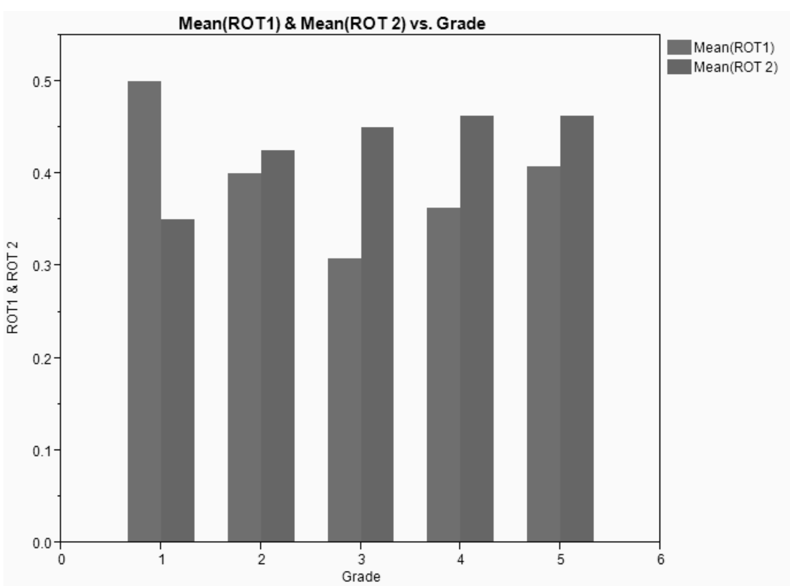

Figure 2: ROT1 & 2 Grade Comparison in Below Average Students

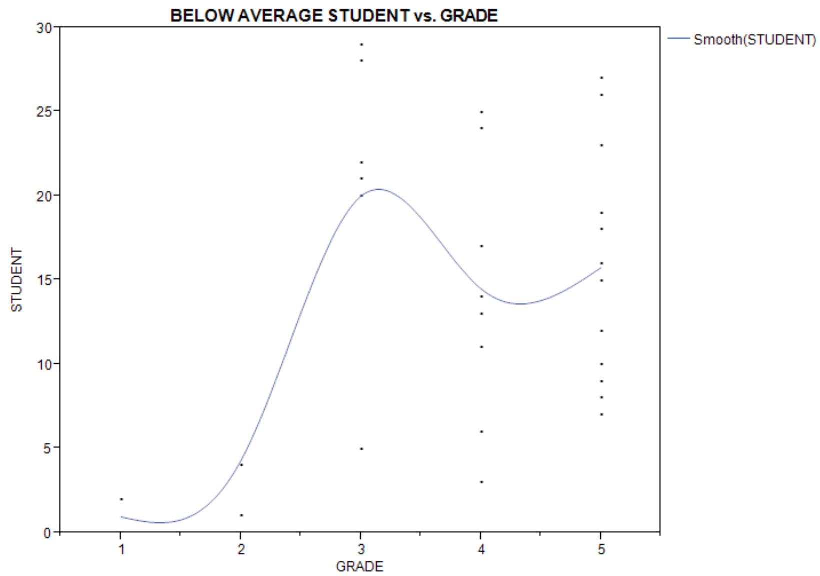

Figure 3: Overall Grade in the Course 1-F; 5-A

DISCUSSION

Differences between ROT1 and ROT2 in below average students showed that spatial reasoning improvement is not to have likely occurred by chance alone. Because statistics support this, it is likely that organic chemistry can improve spatial reasoning skills which in turn may improve performance in settings that demand this as a skill. Above average students in this study presented spatial reasoning ability in the preliminary test, and therefore show that improvement is not necessary because this group already possessed the skill however, below average students show interesting characteristics in spatial reasoning improvements. As overall spatial ability improvement is important to organic chemistry as well as students seeking success in the field of science, further analysis using computer simulations may better enhance this study for extended confident results. Specifically, the Cambridge Structural Database which would allow students to view 3-D images while in motion may be a good simulation to further enhance spatial ability.

AUHTOR INFORMATION

Susan F. Hornbuckle received her B.S. degree Magna Cum Laude in chemistry in 1985 from Columbus State University. She earned her M.S. in organic chemistry from Auburn University in 1987 where she carried out research under the direction of Peter D. Livant. She earned her Ph.D. in organic chemistry at Emory University in 1992 where she carried out research under the direction of Albert Padwa. She has been a chemistry professor at Clayton State University from 1992 until the present where she focuses on research in the areas of chemical education and organic synthesis. Susan F. Hornbuckle, Clayton State University, 2000 Clayton State Boulevard, Morrow, GA 30260. E-mail: susanhornbuckle@clayton.edu (Corresponding author)

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