Testing the Efficacy of 3D-Printed Geologic Block Models as Tools for Fostering Spatial Visualization Abilities

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Abstract

Spatial visualization is crucial to success in the geosciences, especially in courses such as sedimentology and stratigraphy, structural geology, and field techniques. Students with the spatial visualization abilities necessary to succeed in these courses are more likely to continue in the geosciences. Unfortunately, an overwhelming proportion of students are unprepared for spatially intensive coursework due to a lack of spatial training in K-12 and undergraduate education. Previous studies have demonstrated that spatial visualization abilities are malleable skills that can be trained efficiently and inexpensively, yet widespread spatial training is uncommon. With this in mind, we propose the use of 3D-printed geologic block models (Figure 1) as tools for fostering spatial visualization abilities in conjunction with an introductory-level structural geology course/lab.

Research Questions and Methodology

The study will be comprised of at least 700 students enrolled in introductory sections of Geology 101 that include a geologic structures lab (Figure 3) as part of their coursework. A pre-lab and post-lab spatial visualization survey (henceforth referred to as “viz quizzes,” Figure 4) is being used to assess students’ spatial visualization abilities before and after the geologic structures lab either with (Experimental) or without (Comparison) the assistance of 3D-printed geologic block models. A demographic background questionnaire is also being administered after each lab to collect data on student demographics such as gender, ethnicity, age, and academic background.

Current Instructional Methods and Materials

In introductory-level geology courses, instructors are expected to train spatial visualization skills from painted wooden blocks to interactive virtual models (Figure 2).

Project Rationale

Previously employed instructional methods tend to require more time and funding than are feasible for many geoscience educators. Digital materials help to remedy this issue, but they unfortunately lack tangible, interactive cues that allow students to complete spatially intensive exercises in a truly three-dimensional environment. Recent advances in 3D-printing technologies make it possible to address the need for use of 3D printed instructional aids. In particular, we are interested in 3D-printed geologic block models as an alternative to previously employed materials for the following reasons:

1. Modern advances in 3D printing make 3D-printed models a cheaper alternative to professionally produced models (Horstclke and Schultze, 2014).

2. 3D-printed models can be produced more easily and efficiently than traditional materials, and are more accessible to students than virtual models.

3. Once models have been designed, the files used to print each model can be easily and quickly shared with anyone who wishes to print their own.

References


Preliminary Findings and Discussion

381 students have participated in the study thus far (of an anticipated 750 by study completion). 298 of the students who completed the geologic structures lab did not have access to 3D printed block models, or any other form of three-dimensional aid. 83 students - who were taught by the same instructor - have completed the lab with access to sets of 3D printed block models.

The current dataset indicates that 3D printed block models have a statistically significant impact on student acquisition of spatial rotation and visual penetrative abilities. Given the small sample sizes, we have only seen a trend in the domain of spatial visualization in which we see statistically significant differences only in one score variable (Table 1). We have plotted the current data and currently show an increase in spatial visualization development that we see follow through the duration of this study (Figure 5).

Plotting the effects of block presence on the development of spatial abilities revealed some interesting trends. First, we see that students who had access to blocks seemingly improve more in spatial manipulation ability when compared to students without blocks. Furthermore, the opposite seems to be true for spatial rotation and visual penetrative ability. These trends may relate the spatial ability followed by the blocks, and how students are using them to solve problems in the lab.

Students cannot physically digest the block models to perform manipulative operations. As such, they are required to work through such operations in their head in order to solve problems, practicing skills that they may not have practiced previously. As a result, the blocks are acting scaffolding for the students. Conversely, students are able to rotate the blocks in their hand to visually penetrate the blocks with the assistance of the block’s recognizable cues. Because students can easily perform these operations without much thought, it is entirely possible that students are not practicing rotational or penetrative operations, resulting in lesser spatial visualization gains when compared to students who had no access to blocks.

The current dataset indicates that 3D printed block models do not have statistically significant impacts on the development of their spatial visualization abilities, regardless of whether or not they have access to block models. While we had initially believed that students from different backgrounds would benefit differently from our blocks, it seems that we see development trends that are broadly accessible.

Going forward, we will be producing interaction diagrams to document trends that match with our findings. We hope to collect approximately 380 student worth of experimental data during the remainder of the academic year, enabling us to further explore the impact of spatial visualization gains when compared to students who had no access to blocks.

Figure 5: Effect of Block Presence on Spatial Visualization Score Differences.

Table 1: Impact of Access to Blocks on Spatial Visualization Score Differences.