3D Visualization of Geologic Structures

Mallory Gross[1], Robert Lodge[1], Merilie Reynolds[1,2]

[1]Geology Department, University of Wisconsin-Eau Claire

[2]Northwest Territories Geological Survey

University of Wisconsin Eau Claire

Abstract

An important skill in geology is the ability to visualize spatial relationships of geologic units beneath the Earth. Virtual and physical models allow students to observe and measure geologic structures and visualize their relationships to surface map patterns. Although such models have been utilized in geoscience education in the past, their impact on student learning has not been tested. We have created several new virtual and 3D-printed physical models to complement existing assignments in two upper-level undergraduate geology courses at UWEC including a classroom and field course. To assess the impact of the models on learning, students will be asked to complete a short survey before and after each course to test their 3D visualization skills and to reflect on which learning experiences helped them with 3D thinking. This research project will help us better understand how helpful physical and virtual models are to students and if the type of learning environment they are deployed in affects their impact. We hope this study will lead to the adoption of more effective teaching methods in geology courses at UWEC and at other institutions.

Introduction

An important part of Earth science education provides students with the skills needed to visualize in 3D (e.g., Ormand et al., 2017). A key learning objective of structural geology is that students will view a geologic map (i.e., a 2D representation of the Earth's surface) and visualize the shapes and relationships of geologic structures in the subsurface. Physical and virtual models allow students to observe and measure geologic structures and visualize their relationships to surface map patterns.

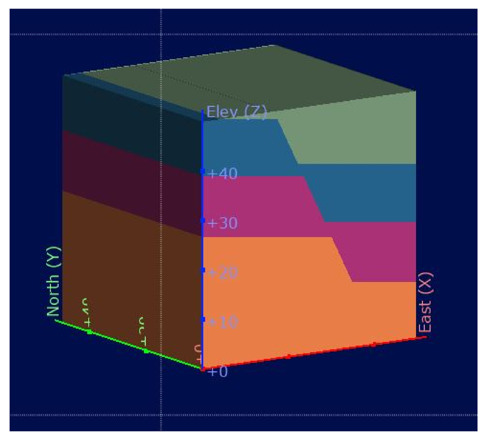


Fig.1: Normal Fault block model created in Leapfrog Geo software.

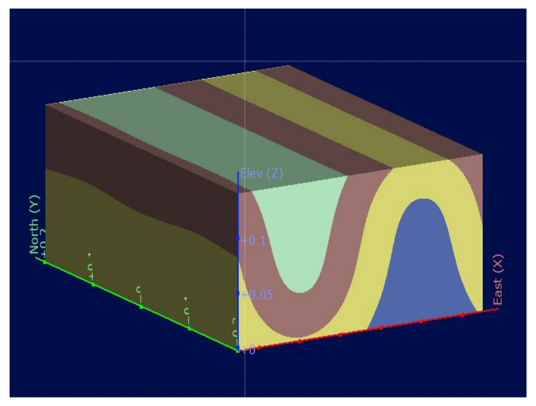


Fig.2: Folded structures block model created in Leapfrog Works software.

Recent advances in 3D-modeling and 3D-printing technology present new opportunities for educators to create customized geologic models to support learning. In this study, we created several new virtual and physical models to be used in upper-level geology courses at UWEC as shown in Fig.1 and 2. We then used spatial visualization tests developed by previous workers (Guay, 1976; Titus and Horsman, 2009; Ormand et al., 2014) to assess how the use of the new models impacts student learning.

Materials and Methods

Models

We used the Leapfrog 3D modeling software to create virtual geological models (Fig. 3A). The models are designed to clearly communicate complex geological data to provide a higher level of understanding and aid in 3D visualization skills. Some of the simpler models were 3D-printed using an Ultimaker S5 printer in the Materials Science & Engineering Center (Fig. 3B-D).

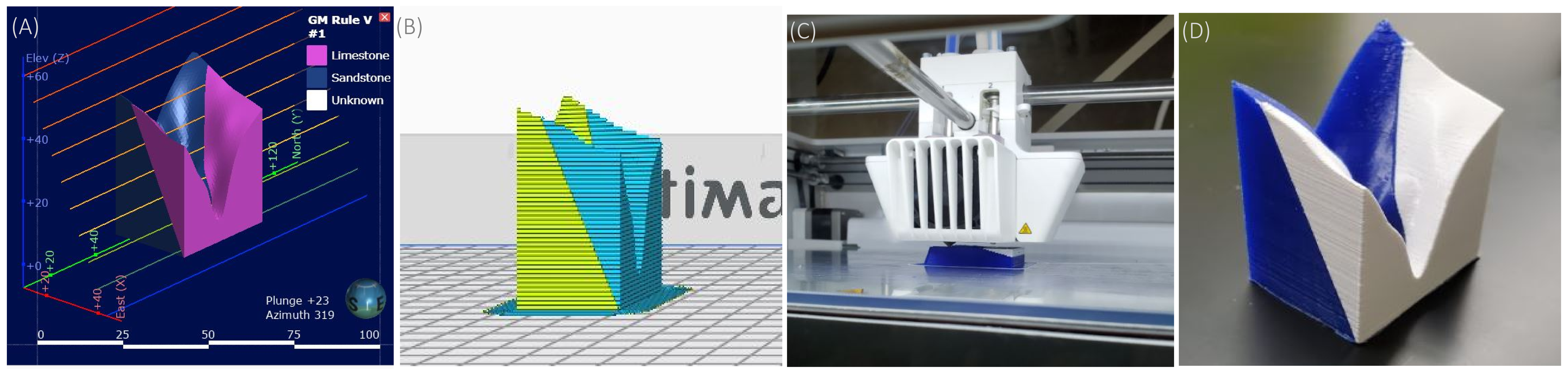
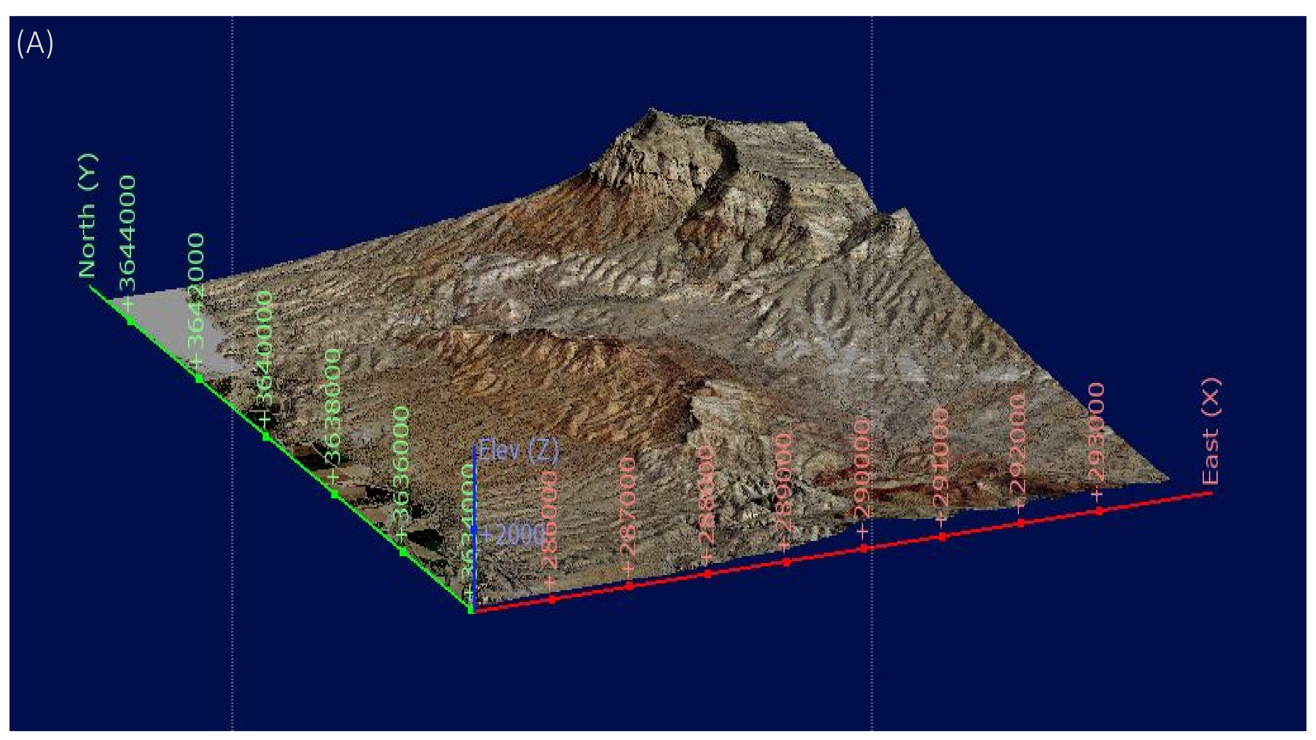


Fig.3: This sequence demonstrates the process of generating a 3D-geologic model. (A) The rule-of-V's geologic concept model was created to illustrate how V-shaped topographic contour lines influence how the stratigraphy of underlying rock is interpreted. (B) The model was exported to a 3D printing software, Ultimaker Cura, to prepare for printing. (C) This photo demonstrates the 3D-printing in progress. (D) The finished model demonstrating the rule-of-V's.

Using geologic field data as shown in Fig.4, we are creating a model of Apache Gap, New Mexico, a geologic mapping area exercise presented in Field Camp 1. We are hoping that this model will aid in student's 3D understanding of geologic relationships on a smaller scale while completing field work in Southern New Mexico.



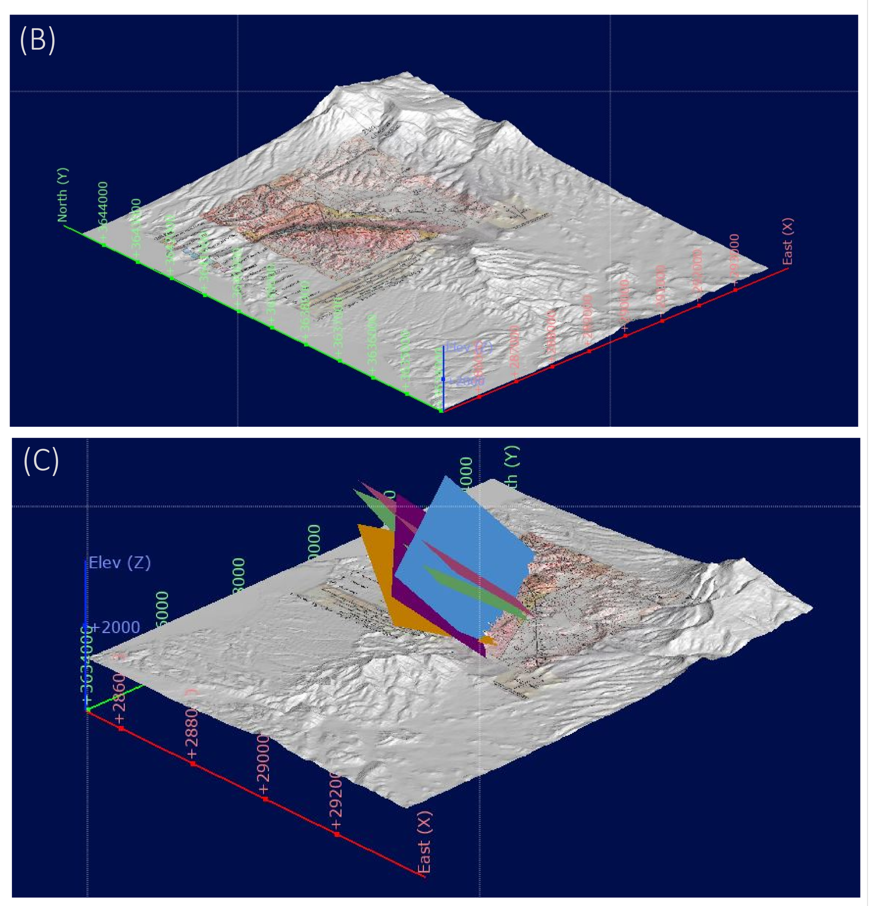


Fig.4: Process of generating Apache Gap geologic model in Leapfrog Geo. (A) DEM of Apache Gap imported into Leapfrog Geo. (B) Scanned field map overlayed on top of topographic surface. (C) Geologic surfaces created from the *Moving Plane* feature in Leapfrog Geo and is the foundation of our geologic model units.

Impact Assessment of Models

To assess the impact of the models on learning, students will be asked to complete a 20-minute survey 3 times during the spring semester and summer session. The survey contains 3 spatial visualization tests including two mental slicing tests (Fig. 5A and 5B) and one mental rotation test (Fig. 5C). The survey was introduced to students in-person in class to encourage student participation and then distributed by email. Students completed the survey online at a time and place that was convenient for them for them. Survey data was collected in Qualtrics, a password-protected online platform with an encrypted server. The implementation of this survey was approved by the UWEC Institutional Review Board.

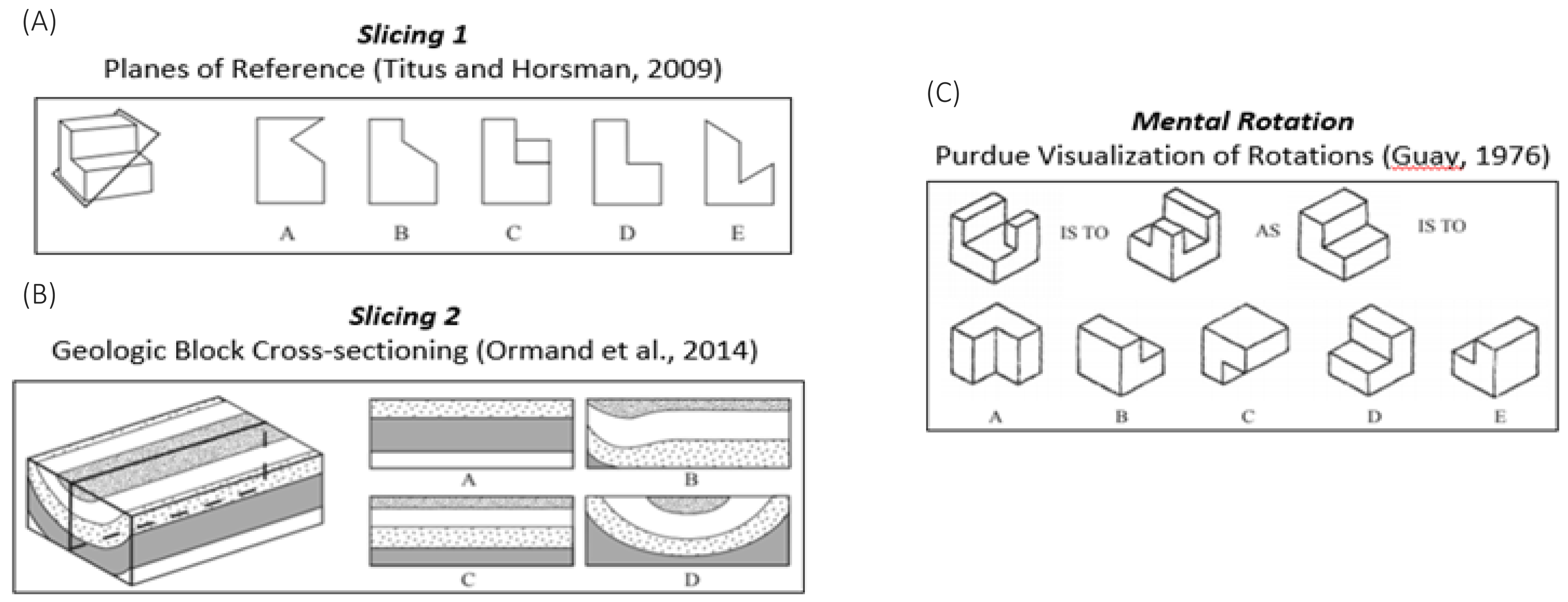


Fig. 5: (A) The first slicing test where each problem consists of an irregularly shaped 3D block set inside a rectangular outline. (B) The second slicing test asks students to study 3D block diagrams and choose the answer that best illustration that represents the structure along the plane. (C) The rotation test asks students to study rotated objects and choose the second object that was rotated in the same manner as the first.

Preliminary Results

The results from our first survey this semester are displayed below. Nine out of 21 students responded. Based on the number of questions answered and time spent on each test, all participants seemed to been engaged while completing the survey. The plots below show the score (Fig. 6) and score efficiency (Fig. 7) for each test. The score is presented as the percent of questions answered correctly and the score efficiency is calculated by dividing total points earned by the total time each student took to complete the test.

On average, students scored the highest on the Slicing 2 test (58% correct) and the lowest on the Rotation test (42%). In contrast, students had the highest score efficiency on the Slicing 1 test (0.045 points / second) and the lowest score efficiency on the Rotation test (0.024 points / second).

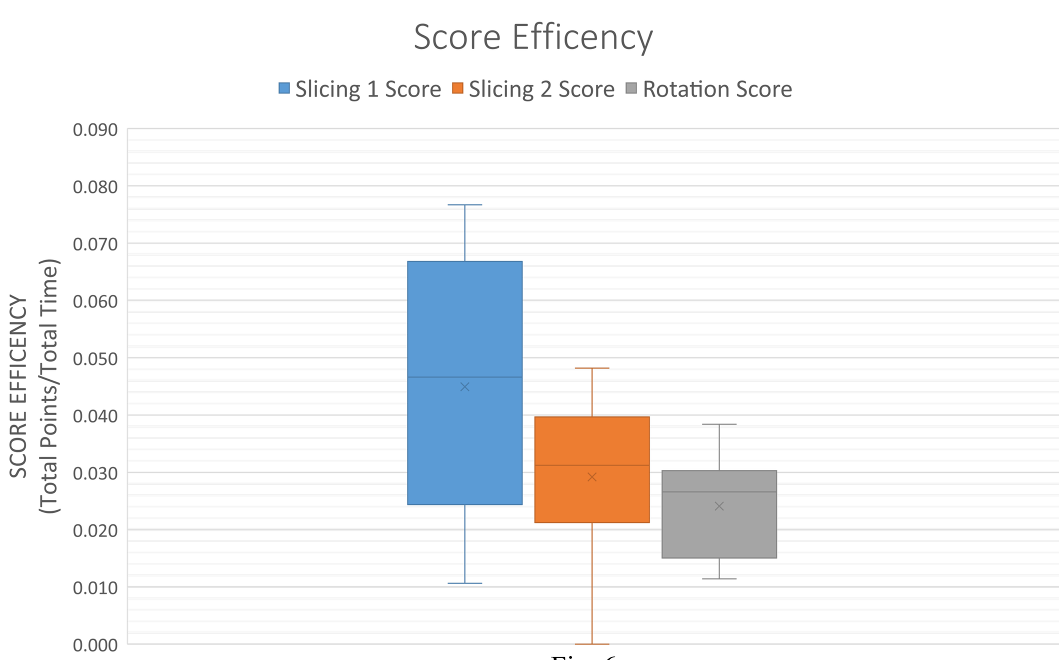


Fig. 6

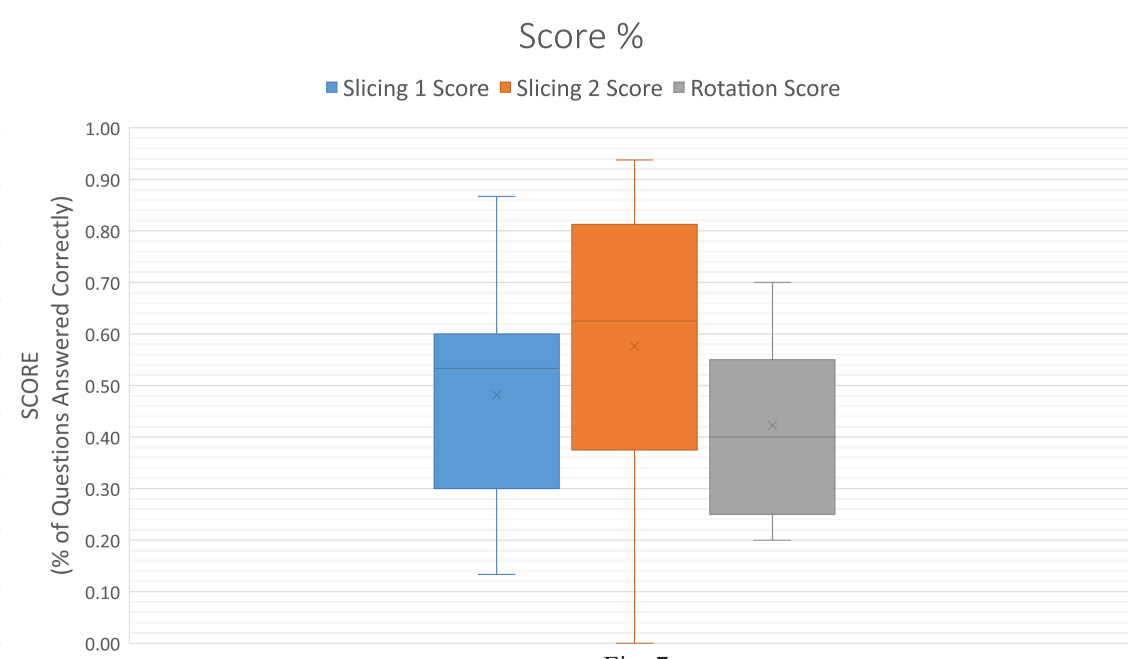


Fig. 7

Discussion

The score in this survey relates to the students' ability to answer the questions correctly, whereas the score efficiency is related to how quickly students were able to answer the questions correctly. By looking at how the students answered the questions and the timing of inputting an answer, it overall demonstrates their proficiency in spatial visualization. Because the tests are mentally challenging, we were not surprised to see a range of score results. We were also not surprised that students scored the worst on the Rotation test, as we found this test to be the most difficult.

One unexpected result was that although students scored the best on the Slicing 2 test, their score efficiency was lower than on the Slicing 1 test. This could be because the Slicing 1 test contains generic shapes whereas the Slicing 2 test contains geologic block models with more information. This information might take longer to take in but also help in solving the visualization problem correctly.

Future Work

The survey will be implemented 2 more times, once at the end of this semester and once after students attend the Field 1 course, where they will interact with new physical and virtual models. An additional question about which learning experiences helped them with 3D thinking will be included. Results from the 3 survey implementations will be compared to see how students' 3D visualization skills improved over time.

Acknowledgements

We would like to thank the Office of Research and Sponsored Programs for supporting this project and the Student-Faculty Research Collaboration program for funding this project. Our special thanks are extended to Dr. Doug Dunham from Materials Science & Engineering Center for providing the tools and knowledge needed to print the geologic models. Lastly, we would like to thank Sequent for providing a free educational license to their Leapfrog software.

References

Guay R (1976) Purdue spatial visualization test. Purdue Research Foundation, West Lafayette, Indiana

Horowitz SS, Schultz PH (2014) Printing Space: Using 3D Printing of Digital Terrain Models in Geosciences Education and Research. J Geosci Educ 62:138–145. https://doi.org/10/gc8s9x

Ormand CJ, Manduca C, Shipley TF, et al (2014) Evaluating Geoscience Students' Spatial Thinking Skills in a Multi-Institutional Classroom Study. J Geosci Educ 62:146–154. https://doi.org/10.5408/13-027.1

Ormand CJ, Shipley TF, Tikoff B, et al (2017) The Spatial Thinking Workbook: A Research-Validated Spatial Skills Curriculum for Geology Majors. J Geosci Educ 65:423–434. https://doi.org/10.5408/16-210.1

Titus S, Horsman E (2009) Characterizing and Improving Spatial Visualization Skills. J Geosci Educ 57:242–254. https://doi.org/10.5408/1.3559671

We thank the Office of Research and Sponsored Programs for supporting this research, and Learning & Technology Services for printing this poster.