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Using the Augmented Reality Sandbox to Improve Topographic Map Skill

Nicole D. LaDue[1], Justin W. Moore[1] & Thomas F. Shipley[2]

[1]Department of Geology & Environmental Geosciences, Northern Illinois University, DeKalb, Il

[2]Department of Psychology, Temple University, Philadelphia, PA

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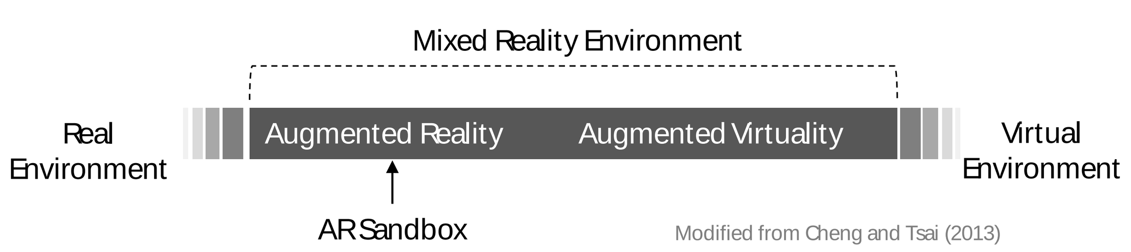
Abstract

Topographic maps represent a three-dimensional (3D) surface using a system of symbols in two-dimensions (2D). To facilitate students' understanding of topographic maps, the Augmented Reality (AR) Sandbox reads the elevation of actual sand and projects the topographic map lines onto the surface of the sand. Although over 600 institutions have built AR Sandboxes to help people interpret topographic maps, classroom studies using the AR Sandbox have not found significant gains on topographic map assessments. The present study is a 2×2 design testing the affordances of the AR Sandbox in a laboratory setting. In the first level of the study, participants interacted with the AR Sandbox (3D) or a regular computer monitor (2D) to give them feedback on five landforms they constructed in the sand. Participants initially constructed the landforms in the sand with the feedback off (i.e., sand without the overlaid projection or monitor). The feedback was then turned on, and participants compared and contrasted their landform to the target topographic map. Participants were then asked to modify their landform with the feedback on (continuous), or the feedback was turned off (discrete) during modification. A mixed-ANOVA revealed significant gains on a modified version of the Topographic Map Assessment (TMA-B) from pre- to post-intervention ($F(1, 74) = 80.34$, $p < .001$). A significant interaction revealed that participants in the 2D condition had greater gains ($M = 2.91$, $SD = 2.48$) than those in the 3D ($M = 1.64$, $SD = 2.07$) condition ($F(1, 74) = 6.38$, $p = .014$), although both conditions had significant pre- to post-intervention improvement (2D: $t(37) = 7.24$, $p < .001$, $d = 1.02$; 3D: $t(39) = 5.01$, $p < .001$, $d = 0.64$). On average, the discrete feedback groups spent significantly less intervention time ($M = 48.3$, $SD = 16.9$) compared to the continuous groups ($M = 58.2$, $SD = 18.1$) ($F(1, 76) = 6.20$, $p = .015$). The findings suggest that the AR Sandbox does improve topographic map skill for individual students using our approach, and that the most efficient technique engages students in discrete episodes of feedback using the 2D computer monitor.

Introduction

The AR Sandbox (ARSB) projects the topographic relief of real sand and can be modified in real time as one moves the sand. It is classified as augmented reality according to Cheng & Tsai (2013).



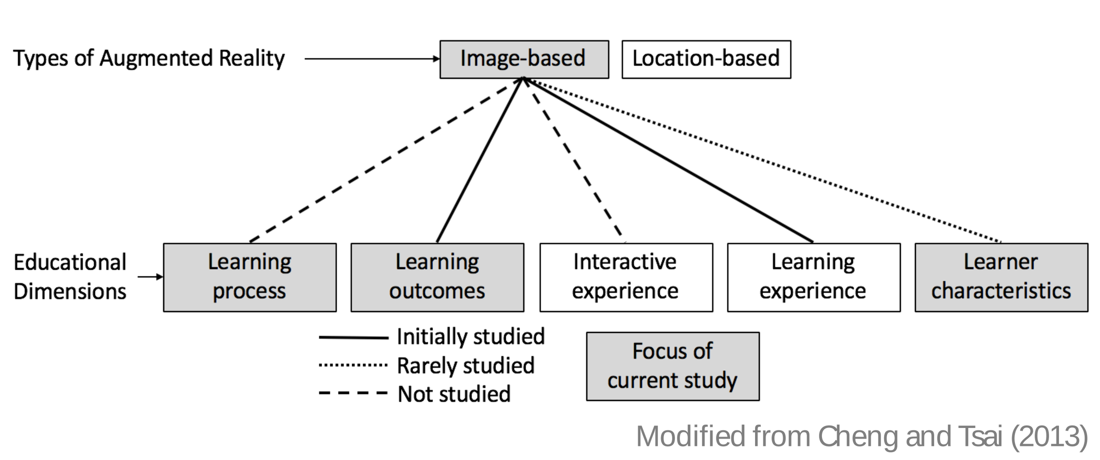
Previous studies involving groups of students (Giorgis, 2017) in free play (Ryker et al. 2017) and instructor-led activities (Woods et al., 2016) with the ARSB in classroom settings show no significant improvement in topographic map skill.

The present study implements a tested strategy for improving students' mental models (Chi, 2008; Gagnier et al., 2017): engaging students in spatial feedback one-on-one in a laboratory study of the ARSB.

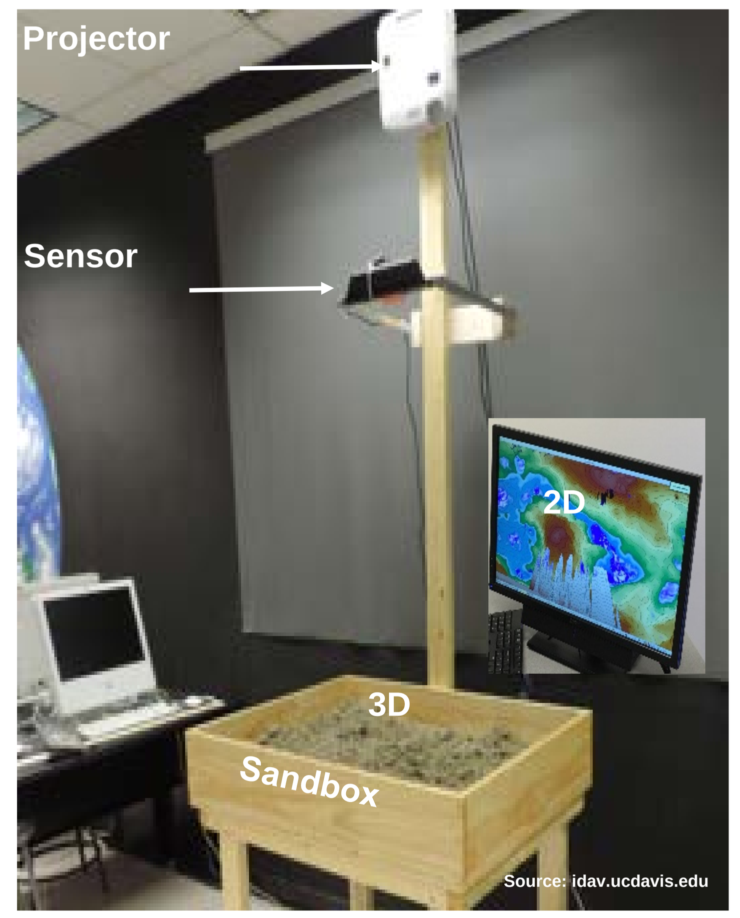
Research Questions

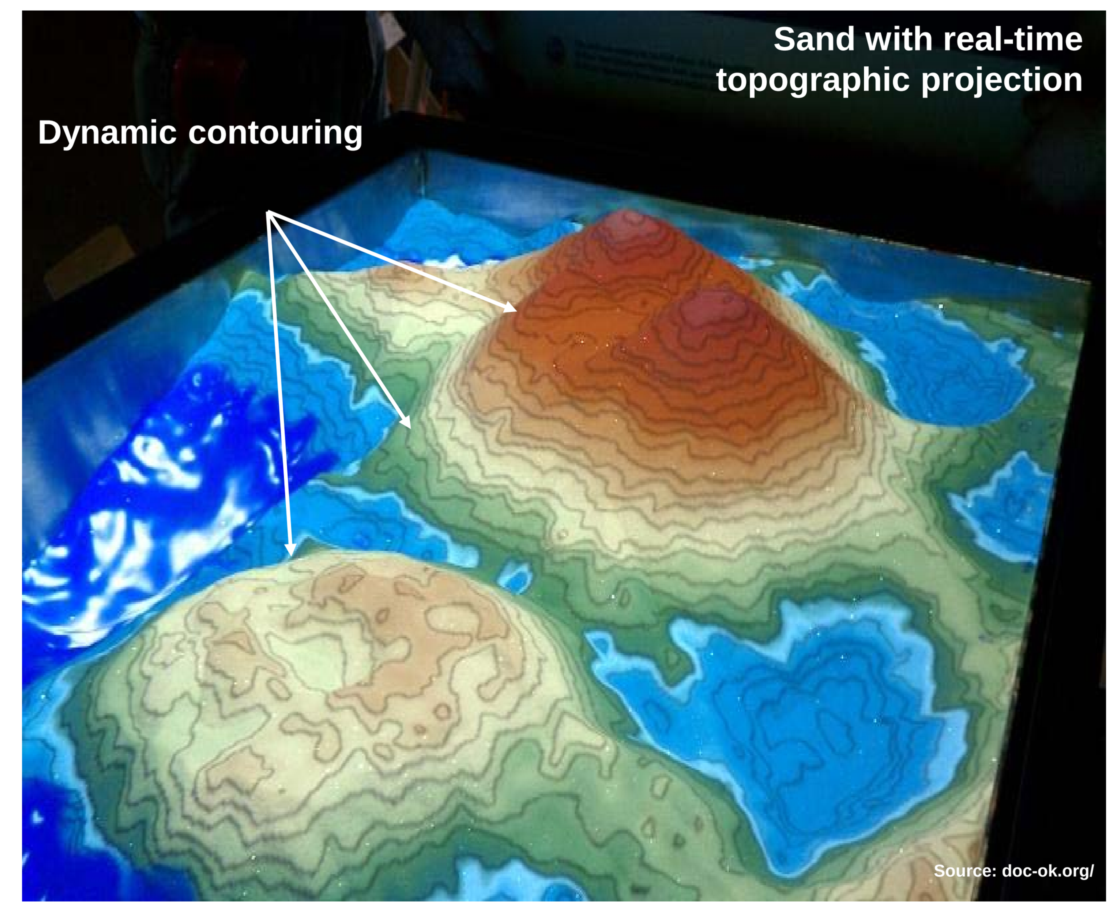
1. **Does spatial feedback using the ARSB improve students' topographic map skill?**
2. **Does 2D or 3D feedback lead to greater learning gains?**

This study fills a gap in the existing literature on the learning process and outcomes for engaging students with augmented reality and has implications for classroom practice using the ARSB.



Augmented Reality Sandbox





Study Design

Participant Task & Prompts

Build landforms in the ARSB, analyze similarities and differences, and repeat

Textual descriptions: geomorphology and contour line pattern

Hill: A hill is an area of high ground. From a hilltop, the ground slopes down in all directions. On a topographic map, the contour lines are arranged in concentric circles. The inside of the smallest closed circle is the hilltop.

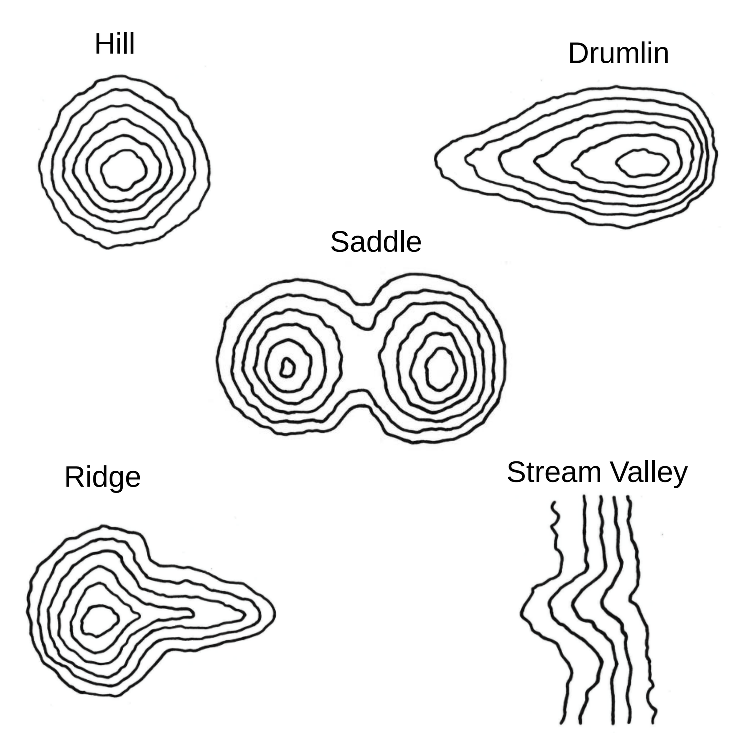
Drumlin: A drumlin is an elongated hill that looks like a half-buried egg. One end of the drumlin will have a steep slope and the other will have a gentle slope. On a topographic map the contour lines are arranged in concentric circles, with lines closer together on the steeper side and further apart on the gentle side.

Saddle: A saddle is a dip or low point between two hilltops. On a topographic map, the contour lines are arranged in concentric circles for the hills, with an hourglass shape surrounding the hills.

Ridge: A ridge is an area of high ground that extends in one direction off of a hilltop. On a topographic map, the contour lines are arranged in concentric circles for the hill, with curved lines pointing downhill in the direction the ridge extends.

Stream Valley: A stream valley is an area of low ground that is cut into a sloping surface. On a topographic map, the contour lines are V-shaped and point uphill, or in the opposite direction that a stream would flow.

Topographic maps



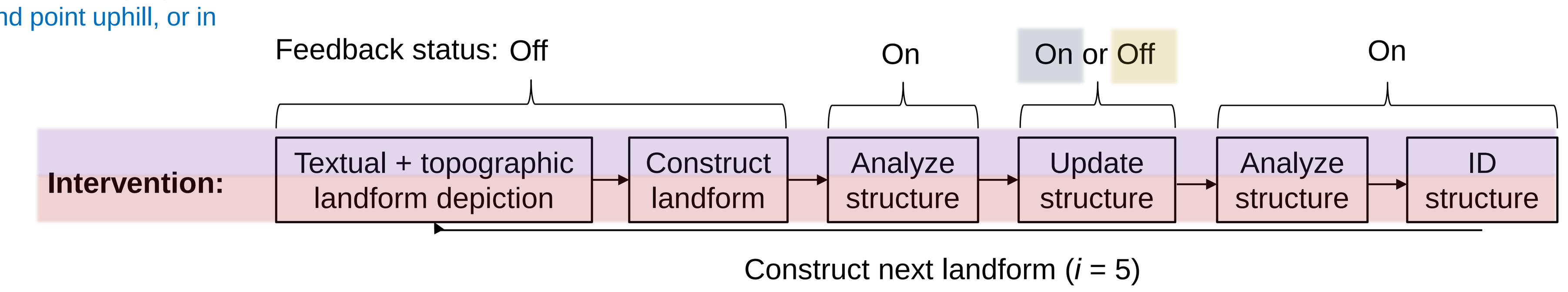
Spatial Feedback Conditions

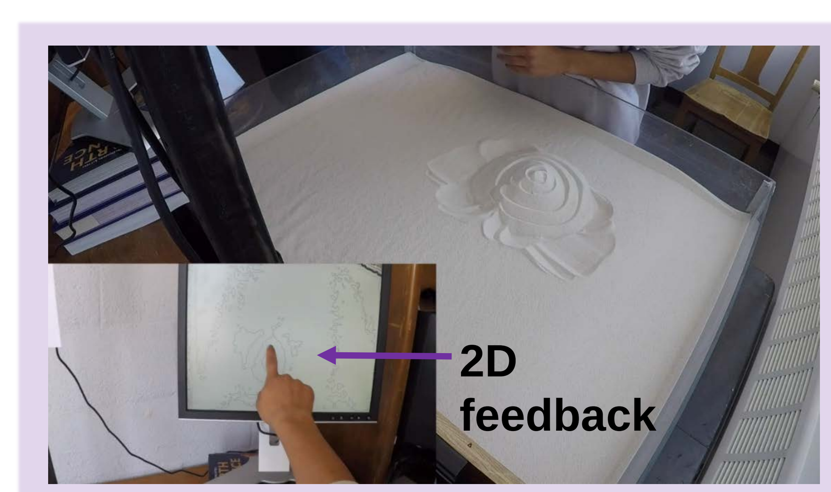
Participants were selected using an online survey and retained if they rated their experience with a sample topographic map as low. Those retained were paid $20 for participation in a 90 minute study session and randomly assigned to one of 4 feedback conditions in a 2x2 study design. The outcome variable was the Topographic Map Assessment – Version B, modified from Newcombe et al., 2015.

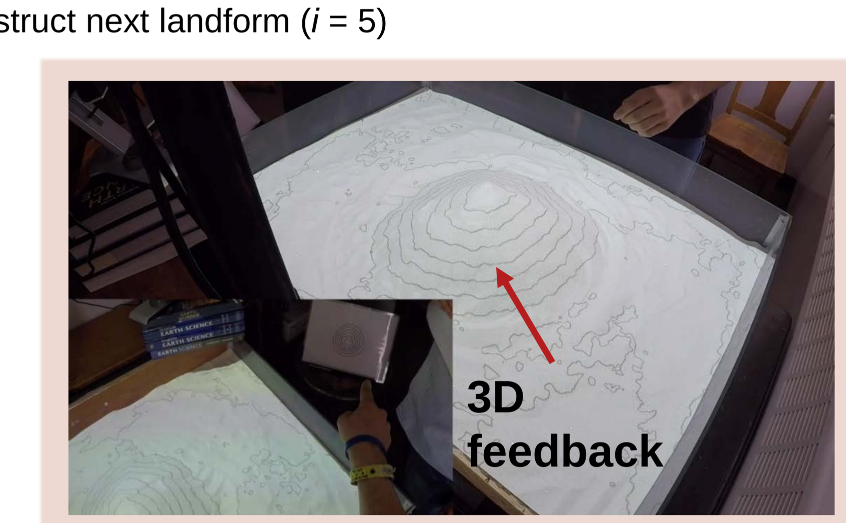
Demographics	
Age, mean (*SD*)	20.2 ± 1.6
Male	30 (38%)
Female	46 (59%)
Not Available	2 (3%)

Feedback status during update

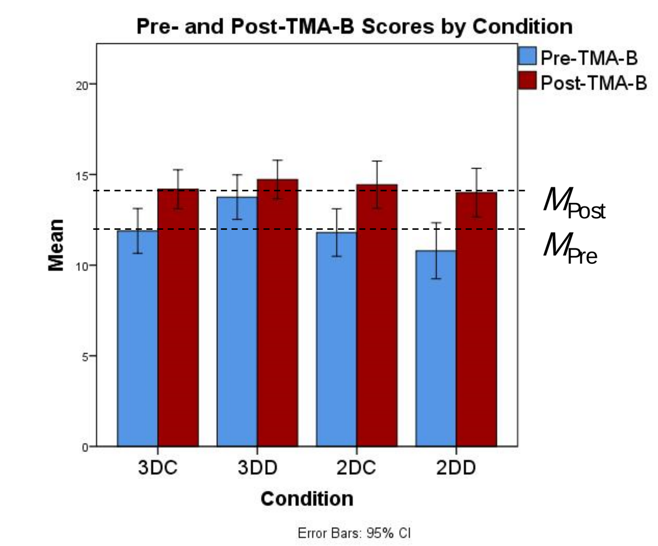
	On	Off
Monitor	2D Continuous n=20	2D Discrete n=20
Projector	3D Continuous n=20	3D Discrete n=18

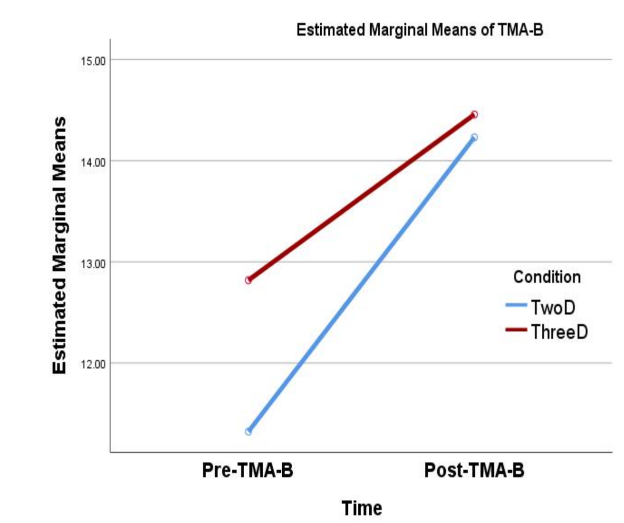






Results





A mixed-ANOVA yielded significant overall learning gains on the topographic map assessment from pre- to post-assessment, $F(1, 74) = 80.34$, $p < .001$.

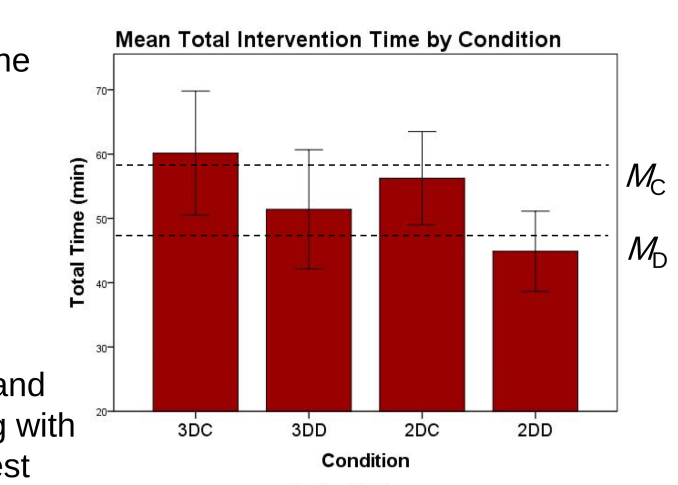
There was a significant Interaction effect between the 2D and 3D condition, $F(1, 74) = 6.38$, $p = .014$. Although both groups had significant gains, the effect size for the 2D group was nearly twice that of the 3D group:

$t_{2D}(37) = 7.24$, $p < .001$, **$d = 1.02$** $t_{3D}(39) = 5.01$, $p < .001$, **$d = 0.64$**

Conclusion & Teaching Implications

Limitations

- A ceiling effect on the TMA-B limits the interpretations of the gains
- Discrete condition participants spent significantly less time
- No test-retest group to look at gains without the intervention



Teaching Implications

The 2DD group had the greatest gains and spent the least amount of time engaging with the ARSB. This condition has the greatest potential for classroom application.

Conclusions

The ARSB can help student if implemented using iterative spatial feedback that facilitates 2D to 3D conceptual mapping. Implement the ARSB with individual students requiring additional support understanding topographic maps.

Acknowledgements

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For more information contact: Nicole LaDue (nladue@niu.edu)