Cueing Gestures in a Seasons Simulation: Outcomes of an Embodied Learning Approach to Supporting Explanations

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Abstract: This study involved middle school students using a gesture-augmented computer simulation to construct causal explanations. In individual interviews, students were prompted to explain what causes seasons before, during, and after using the simulation. We found strong evidence that students improved their explanations, and although students frequently used gestures in their post-simulation explanations, they infrequently used the specific gestures prompted by the interface.

Keywords: embodied learning, explanation, gesture-augmented simulations, science education

Introduction

Research on gesturing has suggested that there are deep connections between the ways we move our bodies and cognitive processes including how we reason and learn (Clark, 2013; McNeill, 2008; Roth, 2001). Emerging digital technologies are making it possible to integrate student gesturing with computer simulations that model critical science processes and phenomena. Devices can transform natural body movement such as gestures, performed in real time, into input that simulations can interpret as expressions of students' understanding.

The design of the gesture-augmented simulation environment used in this study draws from theories of embodied cognition (Shapiro, 2010; Wilson, 2002) and corresponding principles for creating effective embodied learning designs (Abrahamson & Lindgren, 2014). In particular, these simulations attempt to "cue" the performance of gestures shown to be productive for developing new understandings.

The focus of the current study is a gesture-augmented simulation of seasons and how the cued gestures interact with students' explanations. Crowder and Newman (1993) have shown that gestures play a pivotal role not only in the communication of scientific insights, but also in their construction. The construction of explanations in this work is viewed as involving the development of imagistic mental models that visualize unobservable causes for observable effects (Clement, 1989). The particular ways of configuring cued gestures with visualizations, and their interplay with explanations, is ripe for exploration. In this study, we investigated the following questions: (1) To what extent do students' explanations of seasons change after using a gesture-augmented simulation? (2) Does using a gesture-augmented simulation elicit gesturing in post-simulation explanations of seasons? (3) To what extent do students use cued gestures in their explanations of seasons after using the simulation?

Methods

The initial design conjecture (Sandoval, 2014) guiding this cycle of research from a broader project was that cueing gestures that are congruent with key explanatory elements of the system would support learners in constructing more sophisticated explanations of the seasons. We posited that students would subsequently draw upon the cued gestures as resources for explanation even after they were done using the simulation.

A total of 26 students from multiple middle schools located in a small urban community participated in this study. There were 20 males and 6 females, and participants' ages ranged from 12-15 years old (average 12.8 years old). Students were recruited to participate in the study during study hall periods and after school programs, and they were compensated ten dollars for their participation.

The seasons simulation in this project afforded embodied interaction using three gestures cued by the system and embodying different aspects of the phenomena: (1) angle of light rays, (2) concentration of light rays, and (3) angle of earth relative to the sun. Students used the simulation on a laptop computer with a *Leap Motion* device plugged in via USB that can track hand movement with infrared cameras.

Interviews on the topic of seasons were conducted individually and lasted approximately thirty minutes. During interviews, students were asked for their ideas about what causes the seasons before using the gesture-augmented simulation. While using the simulation students were presented with several explanatory challenges, which involved making something happen in the simulation and explaining how that action affected the seasons. After using the simulation, students were asked again about their explanation of the causes of seasons, and then they were asked to explain a second time with an explicit request that they use their hands.

This study uses mixed methods, with quantitative analyses to compare the quality of pre-simulation explanations and post-simulation explanations and to identify instances of the cued gestures, and qualitative analyses to examine how students used cued gestures in their explanations. To address RQ1, explanations were coded for the presence of two normative explanatory elements (tilt and intensity of light rays) and one non-normative explanatory element (distance). These data were transformed to ordinal data for analysis. An iterative approach was used to address RQ2-3, in which the researchers began with closed coding, using an initial set of top-down codes, and then used open coding to expand and refine these codes (Saldaña, 2012).

Findings

Research Question 1: A Wilcoxon signed ranks test was calculated, and it indicated that students' post-simulation explanation scores were statistically significantly higher than pre-simulation explanation scores, $Z = 153.000$, $p < .001$. Kendall's W was calculated as a measure of effect size, and $W = 0.654$, indicating a large effect.

Research Questions 2 and 3: Twenty students used representational gestures post-simulation when they were initially asked for their explanations and were not prompted to gesture, and 24 students used representational gestures when they were asked to use their hands to help show their explanations. However, very few students (1 student unprompted and 3 students when prompted) used the gestures cued by the simulation.

Discussion and Conclusions

The results showed that after using a simulation that cued their gestures, students improved their explanations of causes of the seasons (RQ1) and often used gestures in their final explanations (RQ2). This indicates that gesture-augmented simulations can be effective for creating a space where students can more adeptly integrate physical representations into their explanations. However, students rarely used the specifically cued gestures in their final explanations (RQ3). It is possible that while these simulation-cued gestures encouraged embodied interaction generally, they did not afford specific explanatory power for students on this topic.

A simulation that cued gestures led to subsequent student explanations that were rich with gestures and were assessed to be more sophisticated compared to the explanations given prior to using the simulation. These findings suggest a genuine affordance of these designs for integrating verbal and spatial representations. Additional research on the effects of embodied cueing, and how these cues intersect with specific learning content, is needed to fully understand the applications of gesture-augmented simulations.

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