Technology Enhanced Mathematics Learning Environments

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Abstract: Physically representing and acting out mathematics problems has the potential to support student learning. In my research, I am using motion-controlled technology to develop learning environments that teach geometry concepts to elementary and middle school students. I am examining students' perspective taking as they learn. Also, using log data tracking students' actions within these environments, I am classifying successful and unsuccessful sequences of actions students make.

Introduction

Success in mathematics is critical in order to be competitive in an increasingly information-based, global market, yet less than half of all US high school graduates meet college readiness requirements in mathematics (McCormick & Lucas, 2011). The call for reform in mathematics education is not new, but the need is becoming more critical. Incorporating technology and recognizing the body as a resource for mathematical reasoning are possible ways to significantly change how students learn and teachers teach. Using a theoretical framework of embodied cognition, I have been studying the affordances of full body interaction both within and outside of technology-enhanced learning environments. I am examining whether or not physical learning experiences can make a difference in achievement. Body-based learning activities have the potential to support a greater number of students in engaging in and developing a strong understanding of mathematics. The long-term goal of my research is to determine key instructional strategies that promote success of children learning mathematics through relevant, interactive experiences that increase interest, engagement, understanding, and achievement.

Background

Contrary to classical theories of cognition, which emphasize a split between the functions of the mind and the body, the theory of embodied cognition recognizes that the mind and the body work closely together with the environment to help us make sense of the world (Glenberg, 2010; Barsalou, 1999). Physical experiences related to mathematics content have been shown to be effective at improving mathematical reasoning. Howison, Trinic, Reinholz, and Abrahamson (2011) found when students moved their hands to simulate proportional relationships while interacting with a Wii game, they developed more advanced understandings of proportional equivalence. Walkington et al. (2012) found that directing students' movements when problem solving led to a more meaningful understanding of geometric proof. Similarly, in a case study, Wright (2001) showed how physically acting out motion problems helped a student better understand rate of change. The potential for physical activities to positively impact learning is encouraging, but there is a need for a better understanding of how students assign mathematical meaning to their actions.

Methods

I am working primarily with middle and secondary students, and I am developing and studying a series of motion-controlled learning environments using Kinect for Windows that teach different geometry concepts. The learning environments log spatial data of students' bodily movements as they progress through the environment. I use pre- and post-assessments to track learning gains, and I collect data on students' cognitive-affective states while they are playing using the Baker-Rodrigo Observation Method Protocol (BROMP 1.0) (Ocumpaugh, Baker, Rodrigo, 2012). The BROMP data is time-stamped and can be synced with the log files from the Kinect game. I use a combination of one-on-one design experiments with a teacher-researcher (Cobb et al., 2003) and experimental classroom studies to examine how students learn.

Previous Work

In my early work applying embodied cognition theory to instruction, I studied a kindergarten mathematics class learning about patterns. I found differences in the ways students talked about patterns depending upon whether or not the activity was embodied (Petrick, 2011). When the class physically enacted patterns, students used more first person language and noticed different kinds of mathematical relationships than when they made patterns with manipulatives. In my work in computer science, I found that students naturally use their bodies to act out and solve problems while learning to write code in mobile, social environments (Smith, Berland, & Martin, 2012; Petrick, Berland, & Martin, 2011).

These studies led me to hypothesize that physically acting out problems could support conceptual development better than traditional instruction. To test this conjecture, I worked with 162 high school students who participated in a two-week unit on similarity under one of two conditions. One group physically represented and acted out mathematics concepts, while the other watched abstract simulations or drew pictures. Results showed that both conditions learned over the course of the study; however the group that physically acted out concepts had significantly greater gains, particularly in the area of conceptual understanding (Petrick & Martin, 2012; Smith & Martin, 2013). These findings offer exciting potential for embodied learning experiences. The next step in my research combines embodied cognition, learning, and motion-controlled environments.

Current & Future Work

I have begun using motion-controlled learning environments as both instructional and data collection tools. This will allow the categorization and analysis of specific sequences of students' physical movements that do and do not support learning. Motion-controlled technologies can record spatial data of students' physical movements. This enables me to overcome a challenge I faced in some of my prior studies, as I was unable to capture and track how students' actions changed over time. The log data will allow me to engage in a fine grain analysis of the relationship between students' actions and learning that was not previously possible.

In addition to looking for successful patterns of actions, I am researching the role of perspective taking in embodied learning. When students become actors in mathematics problems, their perspective on the problem changes. Instead of viewing the problem from an external perspective, they are now "in the action" so to speak. I hypothesize that one of the reasons embodied activities support learning is that students are prompted to take multiple perspectives. I am examining whether specific design features of motion-controlled environments encourage taking multiple perspectives, and I am looking at how this impacts students' movements and learning.

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