PreK Teachers & Students Using Multi-touch Virtual Manipulatives: An Analysis of Usability and Learner-centered Design

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Abstract: For the reported work we focus on several iterations to refine a tangram application for a multi-touch, multi-user interactive surface, the SMART Table™ by SmartTech. We recruited one PreK teacher and six students (ages 4 to 5) from the university's child development center to capture usability data and reactions to design choices. Preliminary findings have guided development to support research into the socio-cognitive parameters of collaboration while exploring the limitations of the commercial technology to support CSCL.

Overview

Our agenda is motivated by the construct of group cognition (Stahl, 2006) as a means to develop applications under the rubric of computer supported collaborative learning (CSCL). Contributions to CSCL are highlighted by interests in advances in early childhood mathematics education, and the design of virtual manipulatives for multi-touch tabletop computers. We report on recent iterations of a tangram application for the SMART Table™ that supports collaborative, co-construction of mathematical thinking in PreK students (ages 4-5).

Initial Investigation with Physical & Virtual Manipulatives

Participants. For the purposes of this design experiment, participants were one teacher, three girls and three boys from a PreK child development and learning research center at a large, mid-Atlantic university in the United States. However, during the virtual phase of the study, only two of the three girls were present due to fluctuations in summer attendance at the center. Thus, for the girls' virtual stages of this study, the child C position was eliminated. *Setup.* Video equipment, consisting of two cameras, was set up to capture both the students' faces and the students' hands (Figure 1a). Next, a SMART Table, a multi-touch, multi-user surface, was placed in the center of the room, students being arranged around it (Figure 1b).
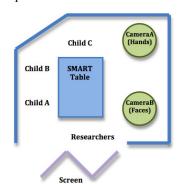

Figure 1. a. Set-up of Research Facility; b. Completing "Bear" Puzzle; c. Fisherman Puzzle, Divided Ownership.

The tangram puzzles selected were developed using Clements's et al. (2004) learning trajectory. For the first set of puzzles (those completed during the physical phase of the study), some regions consisted of only one tangram piece while others regions consisted of several. Furthermore, as students became familiar with transformational geometry tasks, they appeared to exhibit higher levels of thinking along the learning trajectory (Clements, et al., 2004). *Procedure.* Data collection for this study took place in five stages for the physical phase and four or five stages for the virtual phase, for the girls' group and the boys' group, respectively. Prior to the beginning of each stage, the rules for tangrams were explained or reviewed and pictorial representations of these rules were posted. Social constraints (*free ownership, divided ownership,* and *single ownership*) were implemented verbally and participants each received a cue card with her "role" on it. The card reading "touch"

meant that the participants were allowed to touch any and all of the tangram pieces, the card reading "helper" signified that the participants could guide tangram placement but not actually touch the pieces, and the red, green, and blue cards indicated which color tangrams were touchable.

Virtual Manipulatives as a Basis for Usability

The initial implementation offered little more than the translation and rotation of tangram pieces and the outline of the puzzle to complete. The application produced unexpected side effects such as the *tornado effect* where low virtual friction of each piece caused effortless rotation and flicking. As a result, students diverted their attention from the completion of the puzzle, prohibiting useful data. Increasing the friction of the pieces prevented flicking and in turn stopped the tornado effect. The absence of a locking mechanism made it difficult for students to complete puzzles as pieces could be accidentally moved or intentionally stolen by other students. Rather than use the automatic locking mechanism aforementioned, we designed a behavior based locking system that required students to commit to a placement before locking a piece into position. This led to a question of what gesture best described the locking effect. We first implemented a locking behavior in which a single finger holding on top of a piece with no movement for a short period of time initiated the lock. Field tests resulted in frustration as users might activate the lock with little movement. The second implementation of a locking feature employed a more natural locking behavior based on an unsticky sticker concept: applying extra pressure to a piece activates the locking mechanism. In the implementation of the locking features in general, locking large tangram pieces on top of smaller pieces caused pieces to be misplaced due to occlusion. To make the pieces always visible, we modified the outlines and opacities. In several trials we found that students became impatient when unable to complete the puzzle after several minutes and simply gave up. To virtualize the idea of giving students hints, we designed and implemented a hinting system based on unanimous vote. The voting system was employed to allow a single user, who did not want a hint, to cancel the vote. In previous designs, social constraints for the puzzle were implemented using cards given to the children. One card contained a single rule and another card denoted the color that the rule applied to. We designed and implemented a new rule system that removed the physical cards by virtualizing and combining both rules and colors. With a simple press of a rule, it displays a label reminding the learner of their personal constraints.

Drawing on Informal Geometry Pedagogy to Drive Evidence-based Design

In solving puzzles through play, learners are able to manipulate pieces and think about the shapes, their attributes, and their position relative to the final puzzle. Through social interaction children are able to talk about the pieces that allow them to further develop their geometric language. To promote social interaction, the latest build supports three different scenarios or constraints for each puzzle given: free, single and divided. Each of these scenarios provides the learner with a unique experience that promotes cooperation allowing learners to take the opportunity build necessary social skills through collaborative reasoning. In the free ownership mode, we allow learners to move any of the pieces they see fit in order to complete the puzzle. In divided ownership mode, we separate the pieces into three different colors, one for each learner. In each of the modes, we encourage learners to talk with each other to complete the puzzle. In the single ownership mode, we allow a single learner to move any of the pieces while the other two learners assist in moving the piece using gestures and dialog. Each mode, particularly single ownership, relies on speech and gesture to complete the puzzles.

Conclusion

As Bjuland et al., (2009) state: "Collaborative mathematical reasoning cannot be fully captured by only paying attention to what they write and what they say…pupils use the modalities of speech, gesture, and writing to solve the mathematical tasks" (p. 290). From recent findings examining talk, gesture, and gaze, we are developing future applications for the SMART Table that support group cognition via collaboration and co-construction. A design experiment approach ground the research in the local context and contingencies.

References

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