A 3-year DR K-12 ***Exploratory Project*** targeting the *Learning Strand*

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Project Goals

- Successfully integrate Unity and haptics as an innovative teaching tool.
- Design and build a series of prototype science simulations targeting the core science content of forces and matter and its interactions.
- Conduct small-scale pilot tests to provide proof-of-concept and preliminary estimates of impact of haptically-enhanced simulations for learning upper elementary (grade 3-5) science content.
- Clarify the construct of haptically-grounded cognition in an attempt to isolate and describe the differential impact of the haptic augmentation of science simulations.

Our Approach

- ASPECT uses an *informant design approach* where key informants are children, expert STEM teachers, and content experts on the Advisory Committee.
- Users (children and teachers) are not in a reacting role but rather they are an integral part of the design process.
- ASPECT's development cycle includes ***focus groups*** (both children and expert STEM teacher informants provide feedback on low-tech versions of our simulations and assessments), ***usability testing*** (generates data regarding task performance, user behavior, and user preference), and ***small scale classroom pilot testing*** with grade 3 and 5 students (N= 48 in YR 1).

YR1 Accomplishments & Early findings

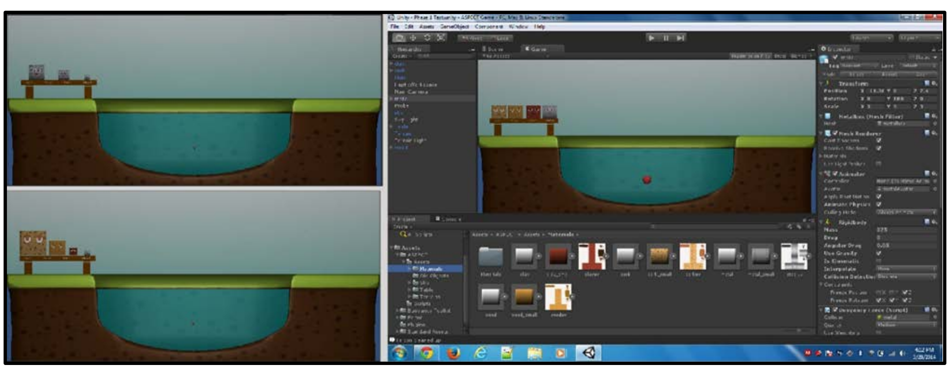
- We have successfully integrated Unity and haptics & created a stable simulation for learning
- We designed, built, & tested a sinking & floating (buoyancy) simulation (one in a series of three).
- Student Focus Group results showed that students had a lot of difficulty working with the physical materials (e.g. shaping clay), underscoring the value of virtualizing these experiences. Students also seemed stuck (conceptually) at the "heavy things sink and light things float" level. Only a few students considered dimensions other than weight.
- Pilot-testing results showed that, regardless of their treatment group, third graders gained 0.75 points and fifth graders gained 0.95 points on our SOLO taxonomy, suggesting that our simulation did help students learn about sinking and floating.
- Third grade students having force feedback showed an average of 2.92 on the posttest compared to 2.27 for the visual only group (gains of .846 and .636 respectively). The Cohen's d of 0.35 here points to a modest effect size of haptics for the 3rd graders in our sample. No significant differences were observed in the 5th graders from our study. Fifth grade students that received force feedback showed a mean of 2.80 on the posttest compared to 3.00 for the visual only group (gains of .900 and 1.00 respectively).
- Descriptive results of two-tiered assessment indicate that on the free-body diagramming task (regardless of treatment group) 5 students (10%) didn't draw any arrows, 39 (81%) drew one arrow on each object (downward for the sunken block and upward under the floating block), and 4 students (8%) drew multiple arrows surrounding each of the blocks.
- On the near transfer task, 17 students (35%) answered correctly (that the combined block would float). Of these 17 users, 7 (41%) received haptic feedback and 10 (59%) had only visual feedback.

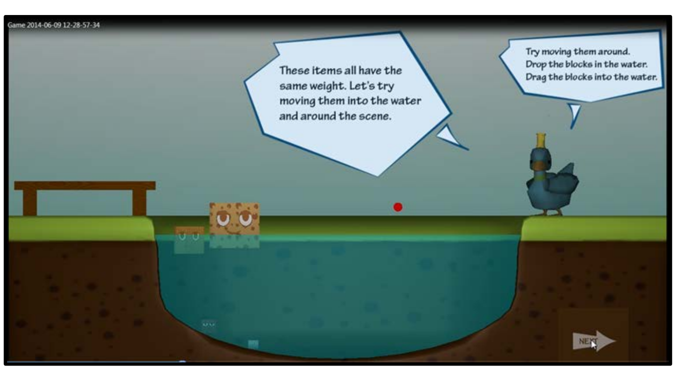
Current Efforts

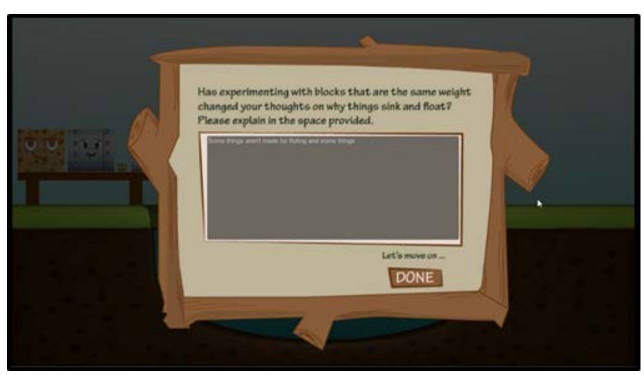
- We are currently developing a typology, based on Driver et al., reasoning framework (1996), of user behaviors captured by the screen recording software to help us better pinpoint any differences in user actions across the treatment groups (haptics vs. no haptics).
- We are also beginning to look at the students' responses to the in-simulation prompts. These prompts deal largely with metacognitive aspects (e.g. Has experimenting with blocks that are the same size but different weights changed your thoughts on why things sink and float? and Has experimenting with blocks that are the same weight changed your thoughts on why things and float?). We will qualitatively explore differences across treatment groups, gender, and grade level in regard to how answers change/progress. We will also analyze their use of haptically-grounded terms (e.g. push, pull, force) and for signals of their attempts to reason about sinking & floating (e.g. considering multiple dimensions of the phenomena & hypothesis testing)

Early Impacts

- We have evidence that many users moved beyond the incomplete notion that things sink or float because of the weight alone to consider additional factors like the material itself and the shape of the object; evidence of a move from phenomenon-based reasoning to relation-based reasoning (Driver et al., 1996).
- Interestingly, not a single student in the study drew opposing forces in our free-body assessment. Images were virtually identical across the population depicting a downward arrow on the sunken block and an upward arrow on the floating block. Rarely were multiple forces shown acting on an object and we have no evidence of students using opposing forces in their explanations. This finding is in line with earlier work describing conceptual difficulties here (e.g. Driver, Rushworth, & Wood-Robinson, 1994; Heywood & Parker, 2001).
- From a HCI perspective, users may not be fully capitalizing on the force feedback the haptic device affords them. We found that users in the haptic feedback treatment did not hold the objects in/under the water as we expected them to do intuitively. This inaction may have lessened the cognitive impact of being able to "feel the buoyant force" and lends credence to Klatzky, Lederman, and Matula's (1993) visual dominance model of haptic cognition where visual analysis is exhausted before any haptic exploration is initiated.







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