Tracing the Development of a Haptically-enhanced Science Simulation for Teaching Phase Change

James Minogue, PhD, Associate Professor, Elementary Education, NCSU (PI)
David Borland, PhD, Senior Visualization Researcher, RENCI, UNCCH (Co-PI)
Marc Russo, M.A.D., Assistant Professor of Art & Design, NCSU (Co-PI)
Shengyen Tony Chen., PhD student, Computer Science, NCSU

The ACM SIGCHI Annual Symposium on Computer-Human Interaction in Play (CHI PLAY)
October 16-19, 2016 Austin, TX

Abstract: This poster traces the research-design-develop-test cycle of a haptically-enhanced science simulation designed to teach upper-elementary/primary students core ideas about matter, phase change, and the role of intermolecular forces.

Project Goals

- Integrate Unity® & the Novint Falcon® force-feedback device
- Reach beyond typical teaching methods to provide opportunities to learn about underlying invisible (micro) scale mechanisms.
- Pinpoint the cognitive influence of haptic force-feedback w/a framework that assesses learners' agility moving between macroscale & microscale representations, along with their mechanistic thinking.

Our Approach

- *Informant design approach* (children, expert STEM teachers, & content experts).
- Development cycle includes ***focus groups*** (children & teacher feedback on low-tech versions of simulations & assessments, ***usability testing*** (task performance, user behaviors, & user preference), & ***small scale classroom pilot testing*** with 8-11 year old students.
- We designed, built, & tested a **Phase Change** & **Intermolecular Forces** haptically-enhanced simulation

Fall Student Focus Group

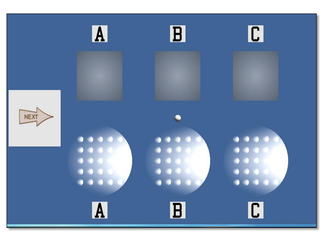
- Interviewed 12 (9-10 year olds); modified ***Children's Beliefs about Matter Interview*** protocol (Nakhleh & Samarapungavan, 1999)…see hand-out.
- None of the students exhibited a ***macrocontinuous*** view (i.e. materials cannot be broken down).
- 75% had ***macroparticulate*** views (i.e. made of little pieces/parts); 25% ***microparticulate*** (molecular view of matter)
- The bulk offered ***macroprocess*** explanations of ***why ice melts***…recognized that temperature was part (the entity) but not the mechanism (activity)…"***if water gets cold it freezes***"; "***if ice gets warm it melts***".
- Only 2 two gave any signals of ***microprocess*** thinking (i.e. a molecular view of the process).
- Recognition of any sort of ***molecular forces at work*** was non-existent (Erickson & Tiberghien, 1985; Osborne& Cosgrove, 1983; Smith et al., 2006; Wiser & Carey, 1983).

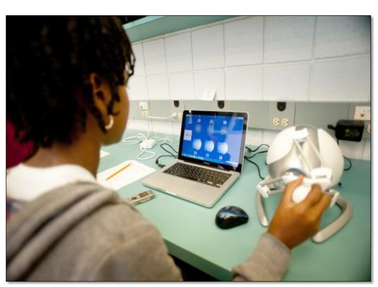
Spring Focus Group

- Involved 9 (9-10 year olds); tested our **core haptic interactions** with objects that modeled ***macroscopic physical properties*** (viscosity & hardness/compliance) & ***microscopic forces*** (intermolecular and vibratory).
- **Hardness** was easier to discern; 67% correctly matched the steel, 89% correctly identified the dough & rubber; 75% correctly matched all 3 solid models with their real-world substance.
- **Viscosity** was not as accurate; 33% correctly matched the peanut butter, 44% matched the honey, & 67% recognized the oil; only 33% correctly matched all 3 liquid models with their real-world targets.
- **Phase recognition at the microscal**e…56% correctly matched all three models with its phase; 44% got only the solid correct, confusing liquid & gas.

Usability Testing

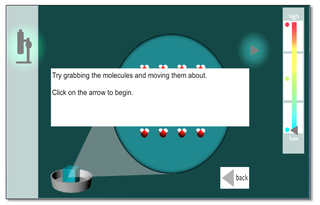
- 8 (9-10 year olds) tried out a set of more refined core haptic interactions; modeled hardness & viscosity at the ***macroscale*** & ***microscale***.
- We were interested in users' agility moving between the two scales…feel the models & match the two different levels of representation.
- 62.5% correctly matched all three solid models; 50% matched all three viscosity models.
- In all but one case, if they got all of the solid blocks correct they also got all of the liquid spheres correct.
- Technical issues (unwanted device vibration & excessive solid surface deformation) emerged.

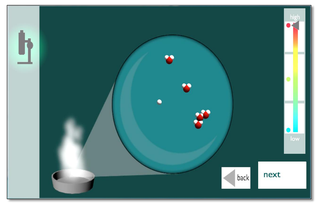




Pilot Testing the Simulation

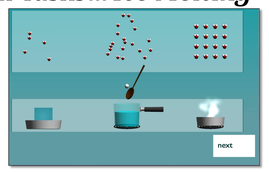
- Convenience sample (32,10-11 year olds; 18, 8-9 year olds)
- Pretest-posttest control group design (haptic vs. no haptic)

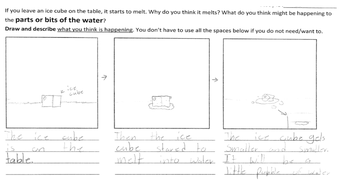


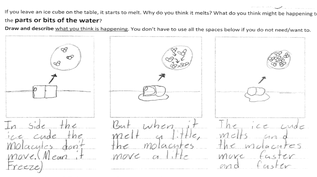


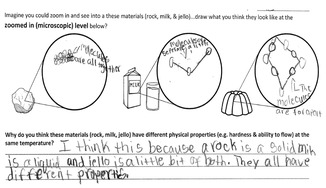
Assessments

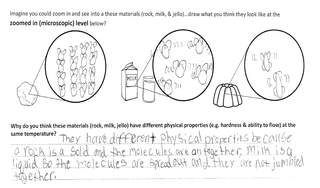
- Open-ended Drawing & Explanation Tasks… ***Ice Melting*** & ***Physical Properties***
- Interactive Assessment
- Fraps- User Interactions
- See handout with Scoring Schemes











Technical Work (see handout)

- Developed a Unity® plugin for the Novint Falcon® device that provides a high-level wrapper interface to Novint's ® Haptic Device Abstraction Layer (HDAL) library.
- Enabled our simulation with various features including: ***microscopic forces***, ***solid & deformable surfaces***, ***viscosity***, & a ***non-haptic mode***.

This material is based upon work supported by the National Science Foundation under Grant No. 1316473

ASPECT
ADVANCED SCIENCE PERFORMANCE WITH EMERGING COMPUTER TECHNOLOGIES

Project Website: **http://aspectproject.weebly.com/**