ASPECT: Sinking and Floating Haptics for Elementary School Students

Shengyen Tony Chen[1], **David Borland**[2], **Marc Russo**[1], **Ryan Grady**[1], **James Minogue**[1]
[1]North Carolina State University
[2]RENCI, University of North Carolina at Chapel Hill
{stchen | marc_russo | regrady | james_minogue }@ncsu.edu, borland@renci.org

ABSTRACT
Traditional classroom methods of teaching concepts relating to buoyancy (sinking and floating) to elementary students are often ineffective. Incorporating haptic force-feedback controllers may help to improve traditional teaching methods. *ASPECT: Sinking and Floating*, targets student misconceptions via an interactive playable simulation. In addition to targeting misconceptions, *ASPECT: Sinking and Floating* also uses a Novint Falcon (http://www.novint.com/index.php/novintfalcon) haptic force-feedback controller to enable direct feeling of forces. This paper presents our design process and initial findings.

Author Keywords
Games; Simulation; Haptic; Elementary School Education; Conceptual Physics; Intelligent Tutoring System; HCI

ACM Classification Keywords
H.5.2 Information Interfaces and Presentation: Haptic I/O; K.3.1 Computers and Education: Computer-Assisted Instruction; K.8.0 General: Games

INTRODUCTION
Haptics can be defined as the study of touch and/or human interaction using touch [8]. The use of haptics in K-12 is relatively new. Williams[12] stated that prior to the publication "literature regarding the use of haptics in K-12 education seems to be nonexistent." Even though there have been advances in using haptic controllers in education since , only a few have discussed teaching concepts of physics [2, 7, 11]. Our design focuses on creating an simulation that teaches buoyancy-related concepts to elementary students.

The true efficacy of haptics in learning about "invisibile" science ideas remains unknown due to the lack of studies that have directly examined haptic interfaces for teaching and learning science concepts [2, 7, 11]. These studies set a precedent for using haptic interfaces to study cognitive processes. However, taken together their mixed findings and theoretically-based explanations of observed results speak to the complexity of the issue at hand and underscore the need for more work in this area. The ASPECT project is attempting to unravel the complex issues of the nature, persistence, and utility of visual-haptic information in memory.

We challenge the assumption that elementary school students cannot learn about abstract, often invisible, content. Traditional methods of teaching buoyancy involve students using a ball of clay to create a non-sinking object. This concept of making a hypothesis and experimenting is well documented in Klahr et al's theory of scientific discovery as dual search (SDDS) [6]. De Jong et al. [3] discuss how to create computer simulations to encourage scientific discovery learning. The design of the experiments are crucial. ASPECT adopts an informant design approach [4, 9]. Our key informants are children, expert STEM teachers, and content experts that form an Advisory Committee. We then use what we learn via testing with students to iteratively revise our simulation.

METHODOLOGY
Designing the simulation was a four step process. First we conducted a focus group study to determine if the traditional method of teaching buoyancy was effective. Using the results from the focus group study we then designed parts of the simulation to correct misconceptions. Then usability testing was conducted to improve our simulations. Lastly, we refined the simulation and turned it into a playable experience.

For our focus group, we employed a pre-test asking ten fifth-grade students to tell us why things sink or float. After the answers were recorded, we used the traditional method of teaching buoyancy. Each student was instructed to create an object out of clay that will float. Many students were able to design an object that will float. We then asked each student again why things sink or float. During the pretest all students stated that heavy things sink and light things float with only two students suggesting either material or size. The post test result showed that six out of ten students (60%) still believed that weight was the only factor with the remaining four (40%) discussing shape, mass, material, and water content as determining factors. Prior research [5] "suggests that novices often focus on only one dimension of sinking and floating." During our design phase we wanted to target three dimensions of sinking and floating. These dimensions are shape, size, and material. We designed a series of experiments that showed how these three dimensions can affect why things sink or

CHI PLAY '14, Oct 19-22 2014, Toronto, ON, Canada
ACM 978-1-4503-3014-5/14/10.
http://dx.doi.org/10.1145/2658537.2661319

float. Using four experimental scenarios (same size different weight, same weight different size, same material different size, and different shapes), students are able to experiment with different objects while using a Novint Falcon.

This three degree of freedom force-feedback controller enables the students to feel both the weight of the object and the combined weight and buoyant force when in water if force feedback is turned on. A pool of 48 third and fifth graders were asked to play through the simulation. To allow for a comparison of the relative impact of haptics, roughly half the population (23 out of 48) played through the simulation using the Falcon device without force feedback; the remaining 25 received both visual and haptic feedback. As the students played through the simulation, we collected data regarding time spent on different experiments as well as doing pre and post tests. The pre and post tests were scored based on the following SOLO Taxonomy [1]:

- 1 point for no aspect of buoyancy used in response.
- 2 points for a single aspect of buoyancy used in response (weight/mass, size, shape, material, and or force).
- 3 points for two or more aspects of buoyancy used in response.
- 4 points for two or more aspects of buoyancy used in response as well as some explanation of these aspects.
- 5 points for reflecting applications/extensions beyond the immediate context including abstract concepts such as density, volume, and/or water displacement in response.

PRELIMINARY FINDINGS

Using the SOLO Taxonomy outlined above, we have started the initial data analysis of the pre and post tests. When evaluating pre- and post-test, the consensus estimate of interrater reliability was 73% (as a simple percent-agreement figure) [10]. The resulting discrepancies were discussed in person and final SOLO taxonomy scores were assigned.

Independent t-tests (alpha = .05) that were conducted using the gain scores on the pre and post tests. The results showed that third graders as a whole gained 0.75 points and fifth graders gained 0.95 points on our SOLO taxonomy. These result suggests that our simulation does help students learn about buoyancy. Third grade students with force feedback averaged 2.92 on post-test compared to 2.27 without force feedback (gains of .846 and .636 respectively). The Cohen's d of 0.35 suggests a modest effect of haptics on our third graders. Fifth grade students averaged 2.80 with haptics and 3.00 without (gains of .900 and 1.00 respectively). This results suggests no significant difference due to having haptics.

CONCLUSION AND FUTURE WORK

ASPECT is a three year long project that will look at the impact of haptics in elementary science education. Our preliminary results have open up some new questions that we can try to answer with future simulations. Currently we are looking at two major questions. First question is why haptics seemed to have little or no effects on fifth graders in our sample. The other question is how can we better pinpoint the differential impact of haptics in educational simulations. In addition to the data described above (pre and post test), we have used screen capture and in game prompts. We will develop a typology of user behaviors to help us pinpoint any differences in user actions across the treatment groups (haptics vs. no haptics). We are also looking at evaluating the development of knowledge through the simulation scenes. The hope is that we can trace learning through the scenes and see how knowledge is being gained throughout the simulation. In future years, ASPECT will create simulations based on chemical bonds and magnetism.

ACKNOWLEDGMENTS

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

REFERENCES

1. Biggs, J., and Collis, K. Evaluating the quality of learning. *New York* (1982).
2. Bivall, P., Ainsworth, S., and Tibell, L. A. Do haptic representations help complex molecular learning? *Science Education 95*, 4 (2011), 700–719.
3. De Jong, T., and Van Joolingen, W. R. Scientific discovery learning with computer simulations of conceptual domains. *Review of educational research 68*, 2 (1998), 179–201.
4. Druin, A. Cooperative inquiry: developing new technologies for children with children. In *Proc. SIGCHI*, ACM (1999), 592–599.
5. Hardy, I., Jonen, A., Möller, K., and Stern, E. Effects of instructional support within constructivist learning environments for elementary school students' understanding of" floating and sinking.". *J. of Educational Psychology 98*, 2 (2006), 307.
6. Klahr, D., and Dunbar, K. Dual space search during scientific reasoning. *Cognitive science 12*, 1 (1988), 1–48.
7. Minogue, J., and Jones, M. G. Haptics in education: exploring an untapped sensory modality. *Review of Educational Research 76*, 3 (2006), 317–348.
8. Robles-De-La-Torre, G. Virtual Reality: touch/haptics. *Encyclopedia of* (2009).
9. Scaife, M., and Rogers, Y. Kids as informants: Telling us what we didnt know or confirming what we knew already. *The design of childrens technology* (1999), 27–50.
10. Stemler, S. E. A comparison of consensus, consistency, and measurement approaches to estimating interrater reliability. *Practical Assessment, Research & Evaluation 9*, 4 (2004), 66–78.
11. Wiebe, E. N., Minogue, J., Gail Jones, M., Cowley, J., and Krebs, D. Haptic feedback and students learning about levers: Unraveling the effect of simulated touch. *Computers & Education 53*, 3 (2009), 667–676.
12. Williams, R. L., Chen, M.-Y., and Seaton, J. M. Haptics-augmented simple-machine educational tools. *J. of Science Education and Technology 12*, 1 (2003), 1–12.