ASPECT Sinking and Floating: An Interactive Playable Simulation for Teaching Buoyancy Concepts

Shengyen Tony Chen
North Carolina State University
890 Oval Drive
Raleigh, NC 27695 USA
stchen@ncsu.edu

Ryan Grady
North Carolina State University
College of Design
Raleigh, NC 27695 USA
regrady@ncsu.edu

David Borland
University of North Carolina at Chapel Hill
RENCI
100 Europa Drive Suite 540
Chapel Hill, NC 27517 USA
borland@renci.org

James Minogue
North Carolina State University
Department of Elementary Education
Campus Box 7801
Raleigh, NC 27695 USA
james_minogue@ncsu.edu

Marc Russo
North Carolina State University
College of Design
Campus Box 7701
Raleigh, NC 27695 USA
marc_russo@ncsu.edu

CHI PLAY '14, Oct 19-22 2014, Toronto, ON, Canada
ACM 978-1-4503-3014-5/14/10.
http://dx.doi.org/10.1145/2658537.2662978

Abstract
Traditional methods of teaching concepts relating to buoyancy (sinking and floating) to elementary students are often ineffective. With the development of new const-effective haptic controllers, we may be able to improve upon traditional teaching methods. Data was gathered during focus groups with both teachers and students to develop a list of misconceptions to target. In addition to targeting misconceptions, we use a Novint Falcon [1] haptic force feedback controller to enable direct feeling of forces. To effectively merge the haptic controller into the system usability testing was performed. This paper presents the initial findings of our interactive playable simulation.

Author Keywords
Games; Simulation; Haptics; Elementary School Education; Buoyancy; Conceptual Physics; Intelligent Tutoring Systems; HCI

ACM Classification Keywords
H.5.2 [Information interfaces and presentation]: Haptic I/O; K.3.1 [Computers and Education]: Computer-assisted instruction (CAI); K.8.0 [General]: Games

Introduction

Haptics can be defined as the study of touch and/or human interaction using touch [6]. The use of haptics in K-12 is relatively new. Williams[9] 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 haptic controllers in education since, only a few have discussed teaching concepts of physics [8]. Our design focuses on creating an interactive playable simulation that will teach buoyancy-related concepts to elementary school students. Some inspirations come from Loverude's experimental design [5].

With little research regarding haptics in K-12 education, we wanted to know if haptics will have a positive impact on learning. First we looked at traditional methods of teaching buoyancy in elementary school. In traditional methods students are given a ball of clay and a tub of water. The students are then asked to create an object using the ball of clay that will not sink. This concept of making a hypothesis and experimenting is well documented in Klahr et al's theory of scientific discovery as dual search (SDDS) [4]. Using the idea of SDDS, De Jong et al. [3] discuss how to create computer simulations to encourage scientific discovery learning.

Following the concepts of De Jong et al., designing the experiments is crucial. We hypothesized that being able to interact with objects in controlled simulations targeting common misconceptions using haptics, students will be able to develop a better understanding of buoyancy.

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 common misconceptions. Then usability testing was conducted to improve simulations. Lastly, we refined parts of the simulation and turned it into a fluid interactive playable experience.

Figure 1: Student performing experiment in focus group.

For our focus group, gave a pretest to ten fifth-grade students asking them why things sink or float. After the answers were recorded, we used the traditional method of teaching buoyancy. Students were given a clay ball and a tub of water to experiment with. Each student was instructed to create an object that will float. After the session was completed, 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

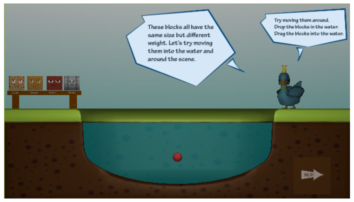

Figure 2: Four objects same size different material.

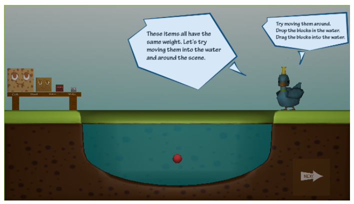

Figure 3: Four objects different size same weight.

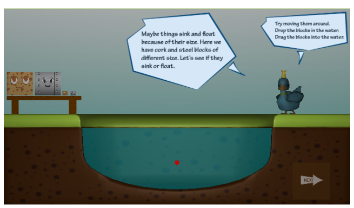

Figure 4: Four objects, two materials with two sizes.

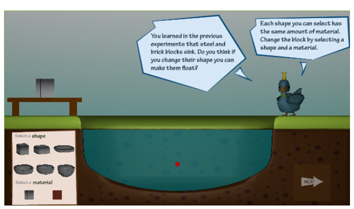

Figure 5: Two materials multiple different shapes.

factor with the remaining four (40%) discussing shape, mass, material, and water content as determining factors.

This misconception of heavy things sink and light things float was something that traditional methods did not address. During our design phase we wanted to target three dimensions of sinking and floating. These dimensions are material, size, and shape. We designed a series of experiments (Figures 2-4) that showed how these three dimensions can affect why things sink or float[1]. Using these four scenes, students are able to experiment with different objects while using a Novint Falcon device as shown in Figure 6.

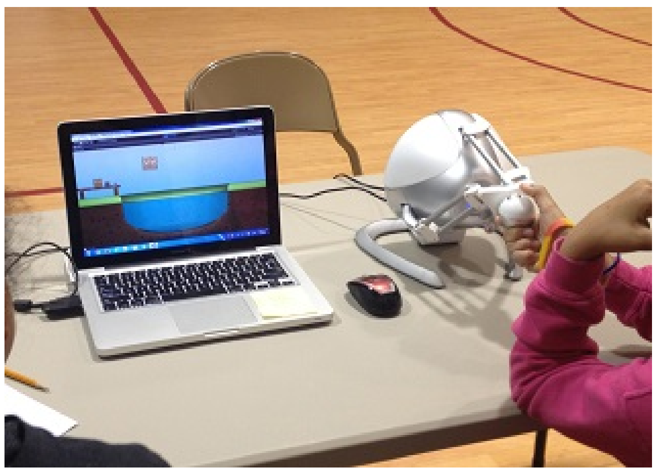

Figure 6: Students using a Falcon device.

We tailored the scenes in this order to target misconceptions one at a time. First we designed a scene in which all objects have the same size but different material. When experimenting in this scene students might realize that material and/or weight are factors. To target the misconception of weight by itself being a contributing factor, the second scene presents objects that have the same weight but different sizes. Next, the student can play with objects that have the same material but different sizes. Lastly, we present different shapes to try to get students to consider that combination of each dimensions affect buoyancy.

The three degree of freedom force-feedback controller enables the students to feel both the weight of the object and the net weight and buoyant force when submerged if force feedback is turned on. We hypothesized that being able to directly feel the forces involved in sinking and floating will help students think about more abstract concepts. A pool of 48 third and fifth graders were asked to play through the simulation. To establish a comparison of the benefits of haptics, roughly half the population (23 out of 24) played through the simulation using the Falcon device without force 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 [2]:

- 1 point for having no aspect of buoyancy used in response.
- 2 points for a single aspect of buoyancy used in response (weight/mass, size, shape, material, and force).
- 3 points for having two or more aspect of buoyancy used in response.
- 4 points for having two or more aspect of buoyancy used in response as well as some explanation of aspects.

[1]Download game play video: http://tinyurl.com/m29ejgw

- 5 points for reflecting applications/extensions beyond the immediate context including abstract concepts such as density, volume, and/or water displacement in response.

Results

Our results from the experiment has shown that our simulation increases student understanding, haptics are more effective in third graders than fifth graders (for this simulation), and haptics increase time spent during the simulation.

When evaluating pre and post test, the consensus estimate of interrater reliability was 73% (as a simple percent-agreement figure) [7]. The resulting discrepancies were discussed in person and final SOLO taxonomy scores were assigned. The results showed mostly positive benefits of haptics. On average third graders gained 0.75 point and fifth graders gained 1 point from pre test to post test. Third grade students with force feedback showed and average of 2.64 on the post test compared to 2.08 from students without force feedback. The resulting average for fifth graders was 3 with or without force feedback. And finally, we see that on average students who had force feedback spend longer in the simulation than students who did not have force feedback.

Future Work

ASPECT is a three year long project that will look at the effects of haptics in elementary education. With our preliminary results there are many questions left to answer. One major question is why haptics seemed to have little or no effects on fifth graders. Another question is how can we pinpoint and increase the effects of haptics in educational simulations.

Acknowledgements

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

References

[1] Novint Falcon. http://www.novint.com/index.php/novintfalcon.

[2] Biggs, J., and Collis, K. Evaluating the quality of learning. *New York* (1982).

[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] Klahr, D., and Dunbar, K. Dual space search during scientific reasoning. *Cognitive science 12*, 1 (Jan. 1988), 1–48.

[5] Loverude, M. E., Kautz, C. H., and Heron, P. R. L. Helping students develop an understanding of Archimedes principle. I. Research on student understanding. *AJP 71*, 11 (2003), 1178.

[6] Robles-De-La-Torre, G. Virtual Reality: touch/haptics. *Encyclopedia of* (2009).

[7] Stemler, S. E. A comparison of consensus, consistency, and measurement approaches to estimating interrater reliability. *Practical Assessment, Research & Evaluation 9*, 4 (2004), 66–78.

[8] 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.

[9] Williams Ii, R. L., Chen, M.-Y., and Seaton, J. M. Haptics-augmented simple-machine educational tools. *Journal of Science Education and Technology 12*, 1 (2003), 1–12.