Investigating the Influence of Haptic Technology on Upper Elementary Students' Reasoning about Sinking & Floating

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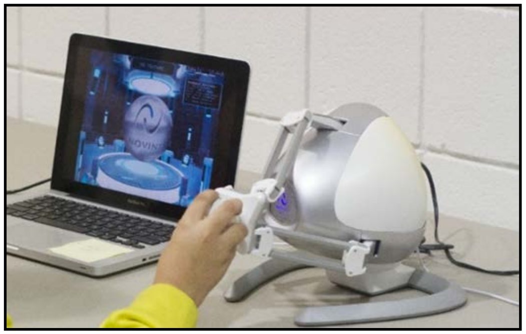
Project Overview

Advancing **S**cience **P**erformance with **E**merging **C**omputer **T**echnologies **(ASPECT)**

- Project goals:
  - Integrate Unity™ & Novint's Falcon®
  - Build & test a series of prototype ***haptically-enhanced science simulations***…forces and interactions
  - Clarify the construct of ***haptically-grounded cognition***…isolate & describe any differential impact haptic augmentation

Problem/Question

-- lack of opportunity in elementary school to even consider the invisible…"concrete thinkers“



-- abstractions (ideas not tied directly to the concrete and directly observable) beyond the students' grasp? (Metz, 1995).

--how to provide *conceptual encounters* (Shepardson & Britsch, 2006) with the invisible

--can force-feedback haptic devices help provide access to "forces" (foundational percept of the physical sciences)?

---surface logic to the use of haptics but very little known about its educational efficacy…does haptics influence the learning?

Study Framework

--***embodied cognition***…dynamic interactions b/t the body & the physical world (Barsalou, 2008; Barsalou et al., 2003; Gibbs, 2005; Glenberg, 1997; Han & Black, 2011; Lakoff & Johnson, 1999)

--physical interactions serve as ***cognitive grounding*** for understanding abstract ideas

-- our hypothesis…haptic force feedback + visualizations influences learners & that 'haptic grounding' facilitates the formation of concepts that are fundamentally different than ones formed from visual information alone…

Study Framework

--sinking/floating (S/F) is complex & often ***largely inaccessible*** in classrooms

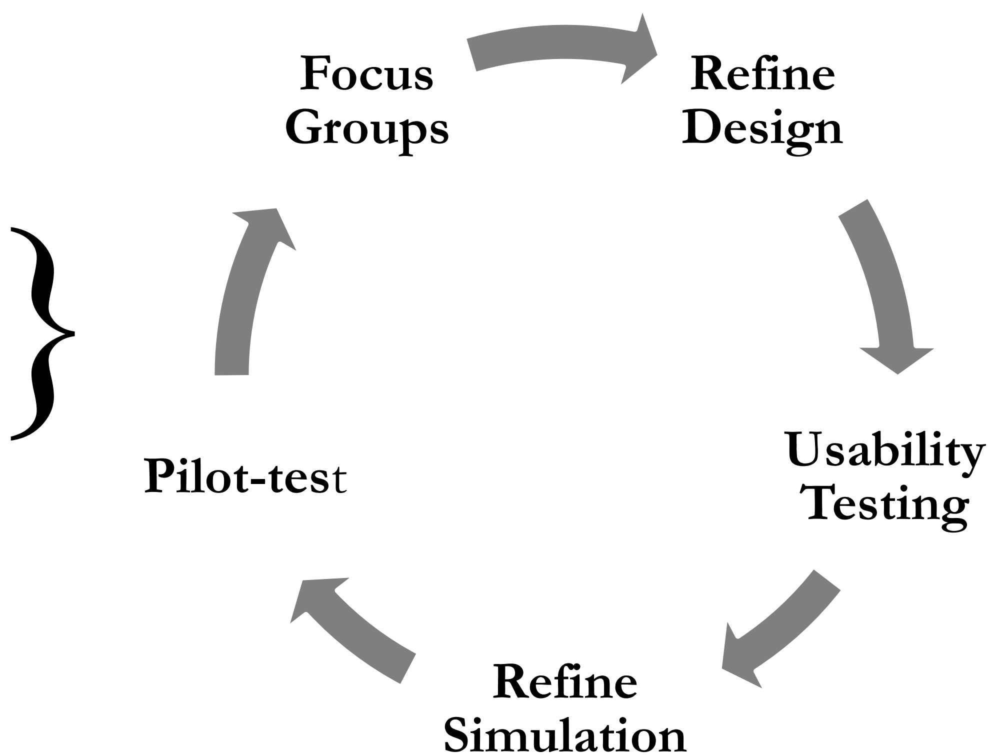
--S/F…domain-specific "relational knowledge" about….mass, volume, density, gravity, buoyancy, water displacement…

--novices often ***focus on only one dimension*** of the sinking and floating phenomenon...does haptics help here? (Driver, Rushworth, & Wood-Robinson, 1994; Ginns & Watters, 1995; Halford, Brown, & Thompson, 1986; Hardy, Jonen, Möller, & Stern, 2006; Heywood & Parker, 2001; Kohn, 1993)

Our Approach

--exploratory (in all aspects)…modest…informant design (Scaife et al., 1997)…mixed methods

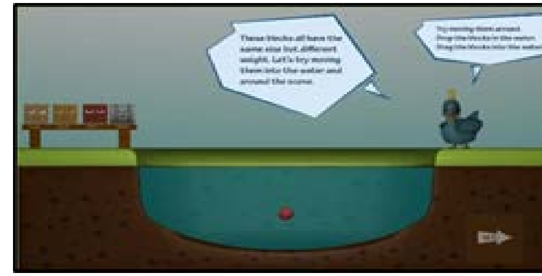
-- Research Cycle



Sinking & Floating Simulation

--interact w/virtual blocks & water in scenes (4)

Scene 1: Four objects same size different material



Scene 2: Four objects different size same weight

Scene 3: Two materials with two sizes

Scene 4: Two materials with multiple different shapes

Methods & Measures

--47 3rd (*N* = 28; 12 female, 15 male) & 5th (*N*= 20; 7 female, 13 male) graders

--randomized **pretest-posttest control group** design

--visual + haptic (H; *N* = 24) vs. visual only (NH;*N* = 23); **same interface**

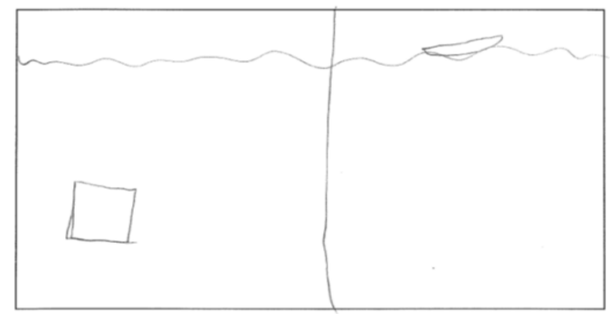
--*Things Sink and Float* (WTSF) prompt (Kennedy & Wilson, 2007)

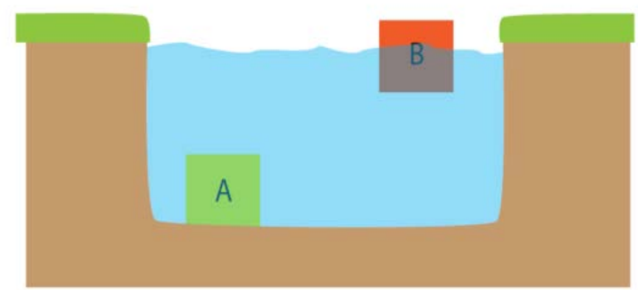
--two-tiered free-body diagraming task

--Fraps® real-time recordings of users' interactions

In the space below, ***explain why things sink and float.*** Write and/or draw as much information as you need to explain your answer. Use evidence and examples to support your explanation.

objects float and sink because of what its made of and because of the shape of the object, example: if a brick is in a shape of a block it will sink if its in a shape of a boat it will float.





Block **A** has sunk in the water and Block **B** is floating. Can you draw upward arrows ⬆ and downward arrows ⬇ on this illustration to explain why the blocks behaved the way that they did?

Explain why you did what you did.

Written Responses…SOLO (Biggs & Collis, 1982)

Level	Task/Context Specific Description	Sample Student Responses
Uni-structural	A ***single useful aspect*** of sinking/floating is mentioned. Useful concepts include weight/mass, size, shape, material, & force.	*Things float when they have a little weight.*
Multi-structural	***Two or more useful aspects*** have been mentioned ***but not integrated***. Useful concepts include weight/mass, size, shape, material and/or force.	*Things sink and float because of 3 thing matter, shape, and size without them we couldn't make things float or sink!*
Relational	***Two or more useful aspects*** are included and together they contribute to an explanation of sinking/floating. The response ***attempts to explain how/why*** weight/mass, size, shape, and/or forces contribute to sinking/floating.	*I think thinks sink and float because of their material, shape, size, and weight, Even though the material is made out of heavy things the shape and size can effect it.*

--gain scores on WTSF…independent t-tests (alpha=.05)

--3rd grade (H) *M* gain .85…(NH) *M* gain .64 (Cohen's d 0.35…modest effect size)

--no effect in 5th graders

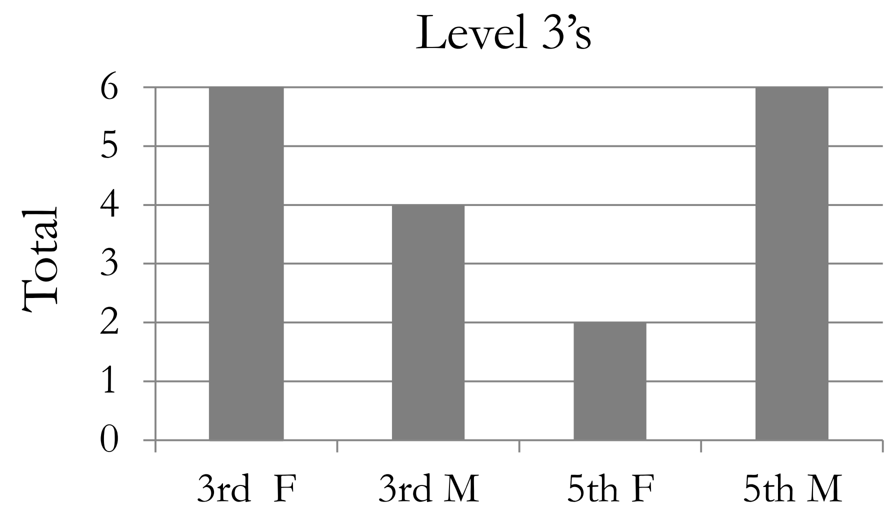
--modest effect size by gender (female M= 0.60; male M= 0.87; Cohen's d 0.27)

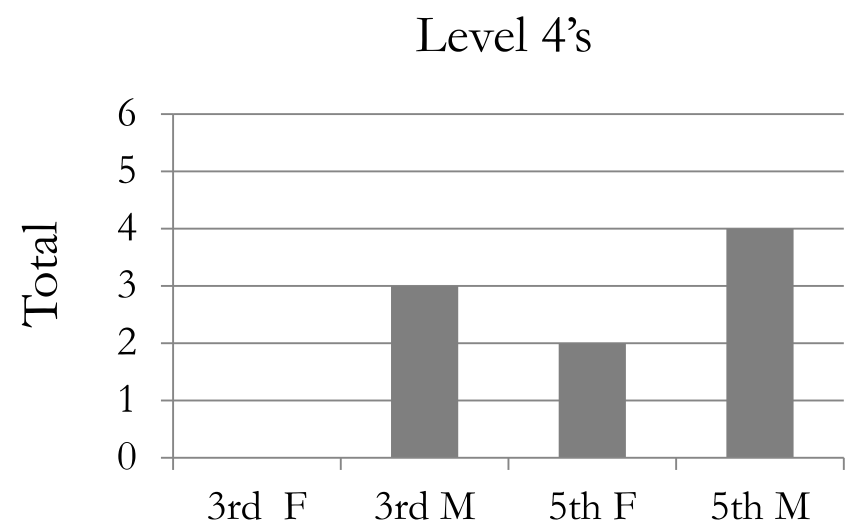
Analyses & some Findings

--regardless of treatment, students moved on the SOLO… 3rd 0.75 points; 5th 0.95 points…3's & 4's…

--moving beyond 'things sink/float because they are heavy/light…considering multiple factors (mass, size, shape, material)

--***phenomenon-based reasoning*** to ***relation-based reasoning ?*** (Driver et al., 1996)





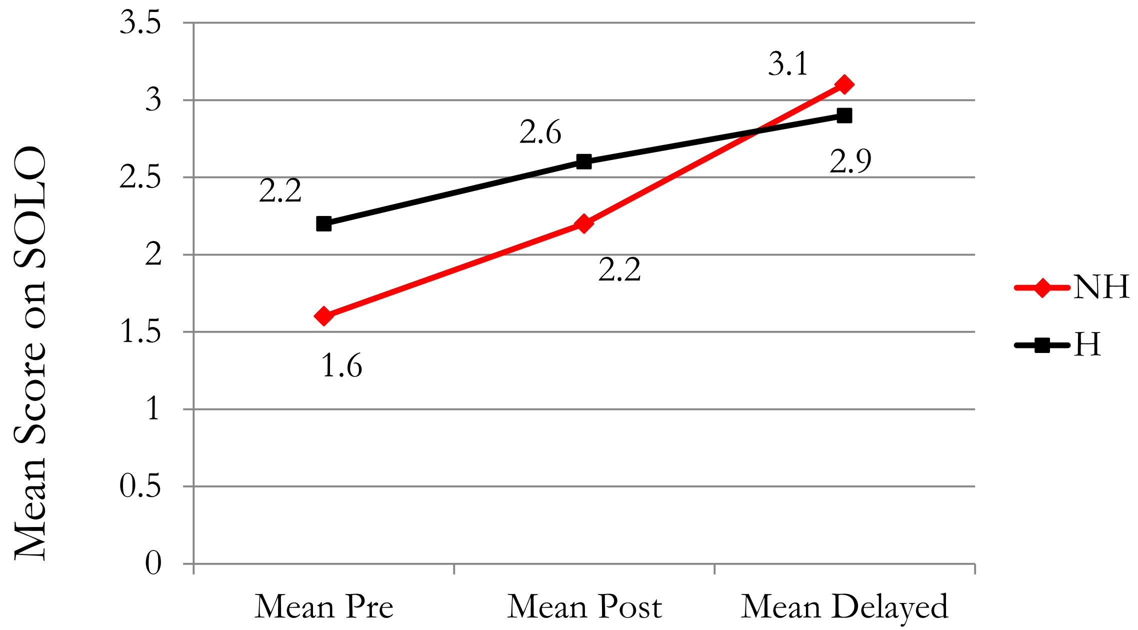
Analyses & some Findings

Delayed posttest…

--20 3rd graders (10 H; 10 NH)

--WTSF…4 months later

--stable scores for 35%…no student moved backwards



Analyses & some Findings

Delayed posttest…

--more H users mentioned 'pressure' when explaining the sinking/floating phenomenon… (66.7% of all mentions had the force-feedback)

"too much PRESHOR"

"a lot of weight ON IT"

"water can't hold it up"

"heavy and have a lot of pressure"

Analyses & some Findings

Free-body Q…regardless of treatment group…

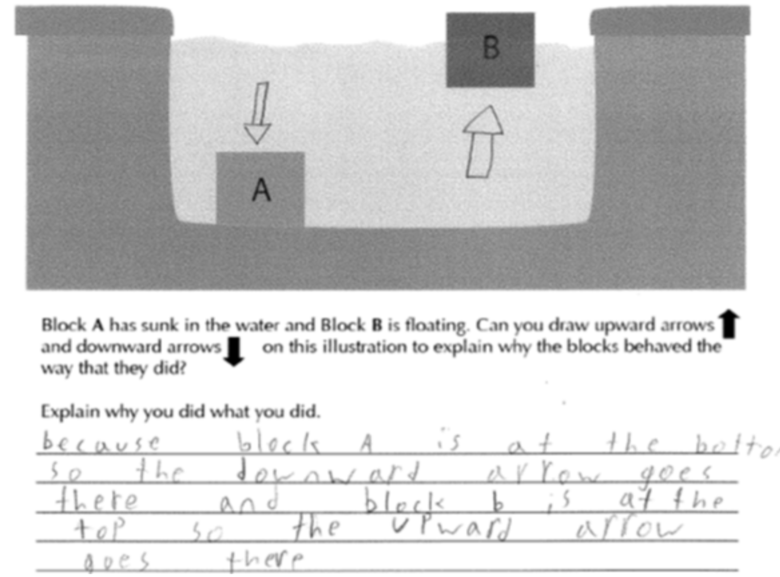
--5 students (10%) didn't draw any arrows

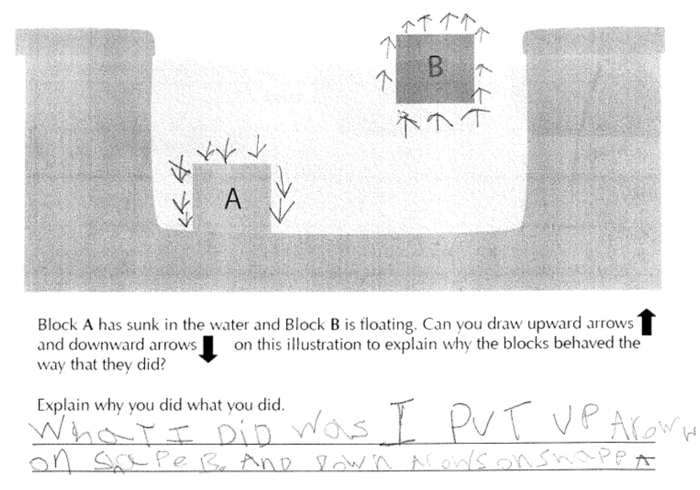
--39 (81%) drew one arrow on each object (downward for the sunken block and upward under the floating block)

--4 (8%) drew multiple arrows surrounding each of the blocks

--**no student drew opposing forces**

--students don't innately think about invisible 'forces in action' (e.g. Driver, Rushworth, & Wood-Robinson, 1994; Heywood & Parker, 2001)





Continuing Analyses

--post-hoc content analysis...responses to the WTSF prompt

--feed a theory of "language-mediated haptic cognition"

--written language…an indispensable psychological tool…bridges the gap between lower & higher mental functions (Kozulin, 1990; Vygotsky, 1978)

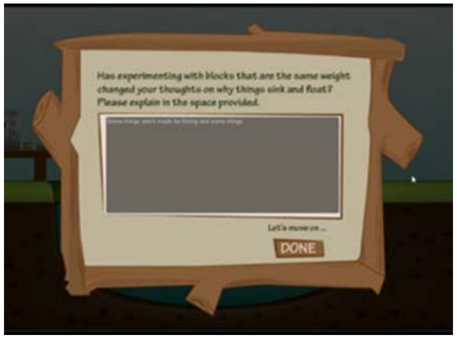
"haptically grounded" terms	
Nouns	material
	mass
	volume
	size
	shape
	density
	force
	gravity
Adjectives	heavy/light
	more/less dense
	air inside
Verbs	balance(d)
	push
	pull
	hold up

Continuing Analyses

Fraps® Analysis… a typology of User Interactions

Action Type	Observable Behavior	Description	Dimension(s) of Interest
Phenomenon-based	Picking Up Objects	At a minimum, all users picked up and put down some of the objects; our typology presupposes this. Haptic users could feel the weight/mass of objects.	object being picked up; frequency
	Dropping Objects	This behavior provides visual feedback for sinking and floating. Haptic users also felt the object being released.	frequency of drops; object being dropped; drop height; subsequent action
Relation-based	Stacking Objects	This behavior suggests a deeper level of engagement with the objects in the scenario. Haptic users that push and/or lift stacked objects could feel differences in the magnitude of the forces (gravitational and buoyant).	frequency; duration; objects being stacked; order of objects; stacked objects lifted; stacked objects pushed down; subsequent actions
	Pulling Objects into the Water	This behavior provides the haptic user with force feedback representing the gravitational and buoyant forces at the moment of submersion, providing a unique opportunity to consider these opposing forces. The user can also see the water level rise and fall, suggesting a relationship between water displacement and buoyant force.	frequency; duration; object being pulled; subsequent action
	Holding/moving Objects Underwater	This behavior provides the haptic user with force feedback representing the combined gravitational and buoyant forces on the object while submerged.	frequency; duration; object being submerged; subsequent action

Analyses & some Findings



--not much difference… ***Visual Dominance?*** (Klatzky, Lederman, & Matula, 1993)

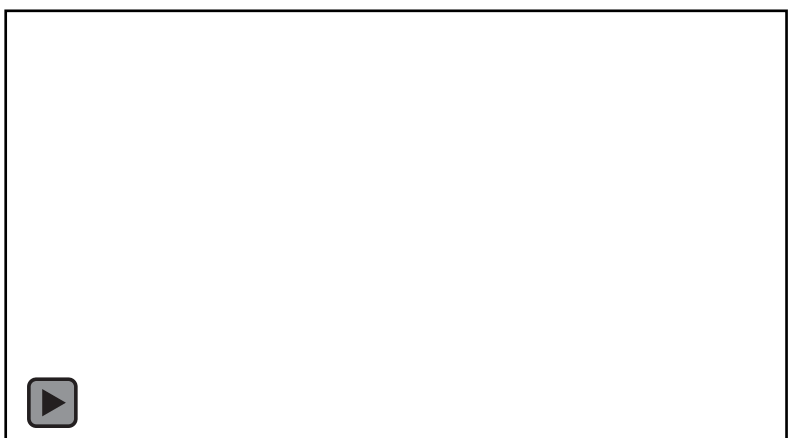
--***phenomena-based*** vs. ***relational-based***…stepping stone concepts (Wiser, 2009)…

-- presence of ***grounding terms*** in delayed posttest

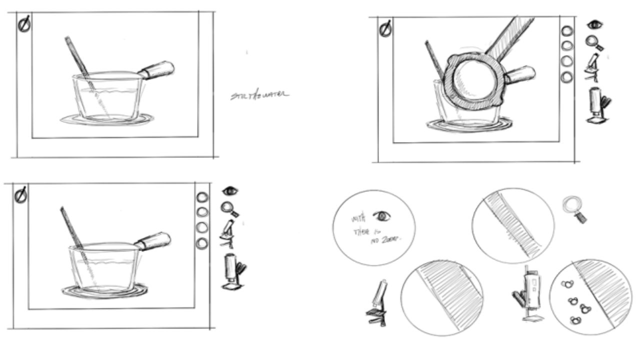
--**forces in action**???...more explicit cueing…problems of privilege?

--**"Productive Failures"**

- -in-sim Qs…**play time : type time** ratios
- -user control issues
- -no access to background information
- -no way to record their findings…reason with multiple factors in their heads…



Contributions & Current Work



--Three (3) usable taxonomies

-Simulation Specific SOLO

-Grounding Term coding scheme

-User Interaction Typology (phenomena vs. relation based reasoning)

-- HCI lessons

-- still looking at YR 1 data…

--designing & building YR 2 simulation (Phase Change & IMF)

--*Children's Beliefs about Matter* protocol (Nakhleh & Samarapungavan, 1999)

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