The Development and Testing of a Force & Motion Simulation

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"To be able to teach effectively, teachers need to be given the opportunity to learn (or relearn) physics in a manner consistent with how they are expected to teach." (McDermott, 2006, p. 759).

Context

- An interactive mouse-driven simulation for force & motion
- Built using Unity 5.6.7 & and deployed as a browser-based WebGL project in Qualtrics

Usability Testing

- N= 21 preservice teachers
- Freshman = 8, Junior = 1, Senior = 12

Conceptual Stumbling Blocks

- an object in motion has a **force within it** which keeps it going
- **constant motion** requires a **constant force** or else the moving object will gradually stop as the "**force gets used up**"
- **net force** as an "extra" **real** force in addition to the actual forces on an object
- **acceleration** is the **same as velocity** & always in the **same direction**
- if velocity is zero then acceleration must be zero
- acceleration always means that an object is speeding up

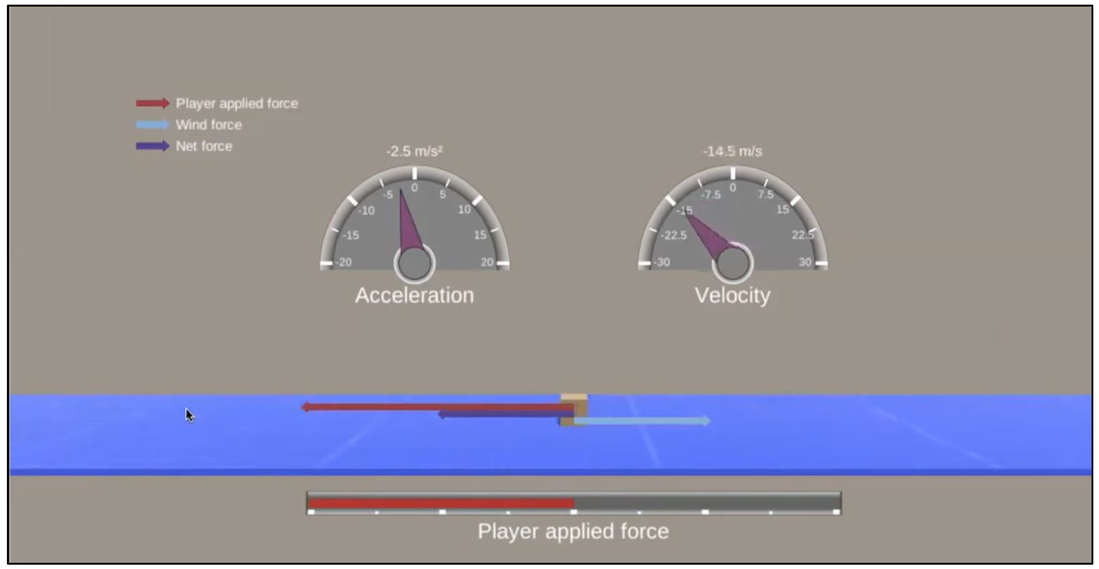
Graham, Berry, & Rowlands, 2013; Halloun & Hestenes, 1985; Hast & Howe, 2013; Mulhall & Gunstone, 2012; Rosenblatt & Heckler, 2011; Thijs, 1992; White, 2012

Engaging

- "I really liked watching the **acceleration** & **velocity gauges** & **watching the arrows** as I applied different amounts of force"
- "Seeing the **correlation** between the applied forces & velocity & acceleration was very cool."

Frustrations

- **Nature of the Forces:** "Many prompts stated which forces were applied but not if those were the only forces"; "I found it hard at first to exactly line up forces to be opposing and equal. As wind is a set value but the user-selected force is on a continuum."
- **Two box Questions:** "I thought it was a bit confusing when prompted with thinking about two boxes, when two boxes were not available in the simulation."

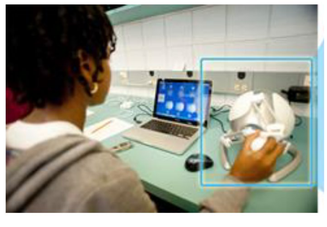


Functionalities

- users apply a horizontal force to move the object on a frictionless surface; "player applied force" arrow stretches to the left or right
- a force with the indicated magnitude & direction is applied
- the user can turn a wind force on/off to introduce a separate constant force to affect the object's motion
- the motion of the object is computed based on the sum of the forces
- the user can change the size of the box
- the simulation can be paused at any point

Current SIM

- added a friction force
- task-based prompts
- now haptically-enabled…we integrated a Novint Falcon force-feedback device



Choose the smallest box and turn on the low friction. Move the box to the left. What do you notice?

Reset the simulation. Now try the same thing with a larger box. What do you notice? How does this compare with the smaller box?

Reset the simulation. Choose the smallest box and turn the wind force on. Try to make the box stop moving to the right? Explain what you did below.

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Science Ideas

What science ideas do you think that the simulation was trying to teach you about?

Science Idea	Frequency	Science Idea	Frequency
forces	17	Newton's Laws	4
motion	13	mass/weight/size	4
acceleration	10	speed	2
velocity	8	force acting on object	2
physics	6	net force	2

What did you notice about the relationship between velocity & acceleration?

Surface-level responses: (33%) "they (velocity & acceleration) are not the same, they are totally different concepts but they are related"; "they work together"; "they depend on each other"
Direct Relationship: (28%) acceleration as the driver ("the greater the acceleration, the greater the velocity"); (19%) suggested some version of "as velocity increases so does acceleration"
Forces at Play: (19%) brought force into the relationship…"the acceleration (meter) would only move when force was being applied" and "when I added a force, velocity and acceleration increased"
Speed: 29% of the responses mentioned "speed", despite our avoidance of this term in the simulation…intuitive understandings rooted in bodily experiences that learners lean on when reasoning about force and motion

Try Out the Simulation Here!

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