

**Carnegie Mellon University**

Entertainment Technology Center

# **Adaptive Learning and Teacher Resources for Educational Games (Emphasizing *PuppyBot Rescue*)**

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# Talk Outline

- Prior ETC Games
  - Links and credits
  - Value of iterative playtesting ([playtestingworkshops.com](http://playtestingworkshops.com))
- *PuppyBot Rescue* game
  - HTML5 game for children ages 5-11
  - Scientific principles of balance
  - Adaptable level progression
  - As-needed scaffolding



# DARPA ENGAGE ETC Projects

- Scott Stevens, PI; with Bryan Maher, Sam Collier, Matt Champer, Ricardo Merchan, and many teams of ETC graduate students
- Emphasis: Science games for 5-11 year old children
- Some past efforts included socio-emotional learning and in-game predict-observe-hypothesize-explain steps as well
- Partners: CMU Human Computer Interaction Institute, Sesame Workshop

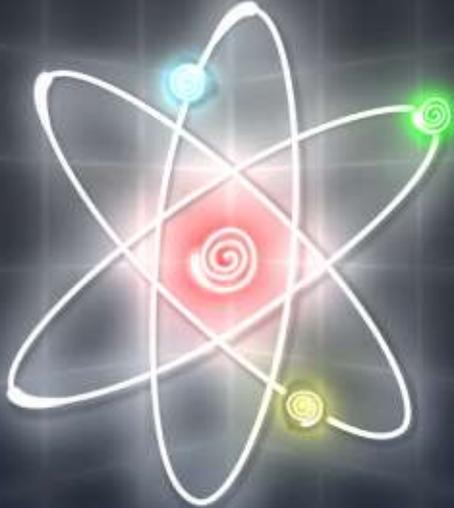


# ETC Project Contributors

- Parent page with links to contributions:  
<http://www.etc.cmu.edu/engage/>
- Illuminate, Fall 2011
- Sci-Fri, Spring 2012
- Torque It!, Fall 2012
- STEMPOWER, Fall 2012
- IMPACT!, Spring 2013
- PuppyBot Rescue (current effort)



# Illuminate



Sean Brice Matt Chamber Qiaosi Chen Luke Jayapalan Jing Jin

# Playtesting

First Half of Fall 2011 Semester

- Energy ball grows and turns yellow



- Gems arbitrary



# Playtesting

## Iterative Changes

- Energy ball absorbed, Gems light up



- Gems regularized



# Playtesting

- New goal visualization



# Playtesting

11/9/11 – ETC

1 girl

Age 6

Playtime: 1 hour

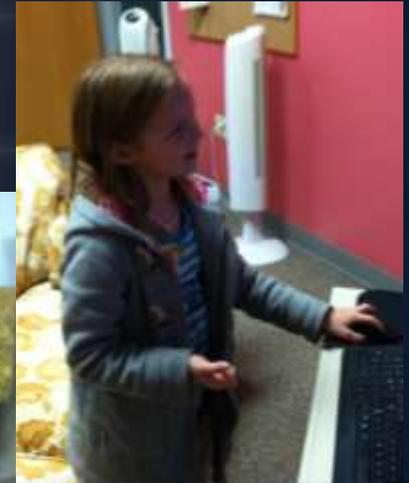
- New goal visualization works
- Energy ball visualization works
- Developmental differences
- Two-handed approach

11/10/11 – Children's Museum

10 kids – 9 boys, 1 girl

Ages 2 – 8

Playtime: 5-25 minutes



# Playtesting

11/19/11 – ETC

11 kids - 7 boys, 4 girls

Ages 5-8

Playtime: 45 minutes

- Game is fun!
- Level difficulty is appropriate
- Rotation video in tutorial is too fast
- Tutorial works well with and without voiceover
- Narrative understood and played key role in keeping children interested



# Playtesting



# RumbleBlocks, Lessons Learned 1

Narrative helped attract young players, kept them interested, and motivated them to achieve success



# RumbleBlocks, Lessons Learned 2

Scaffolding was subtle so players not offended by the help; it blended with the narrative (energy balls that guided placement of tower blocks to energize ship)



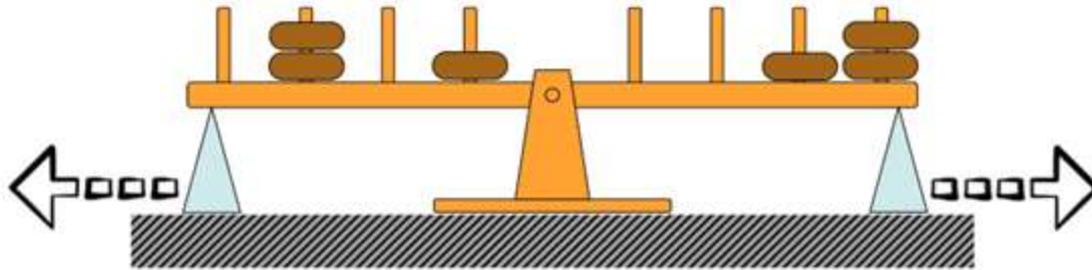
# RumbleBlocks, Lessons Learned 3

- Remember surprise, pleasure, “juiciness”
- Jesse Schell’s *The Art of Game Design: A Book of Lenses* (Burlington, MA: Morgan Kaufmann, 2008 1<sup>st</sup> ed, 2<sup>nd</sup> edition 2015 by CRC Press)



# Science Content for Remainder of Discussed Games

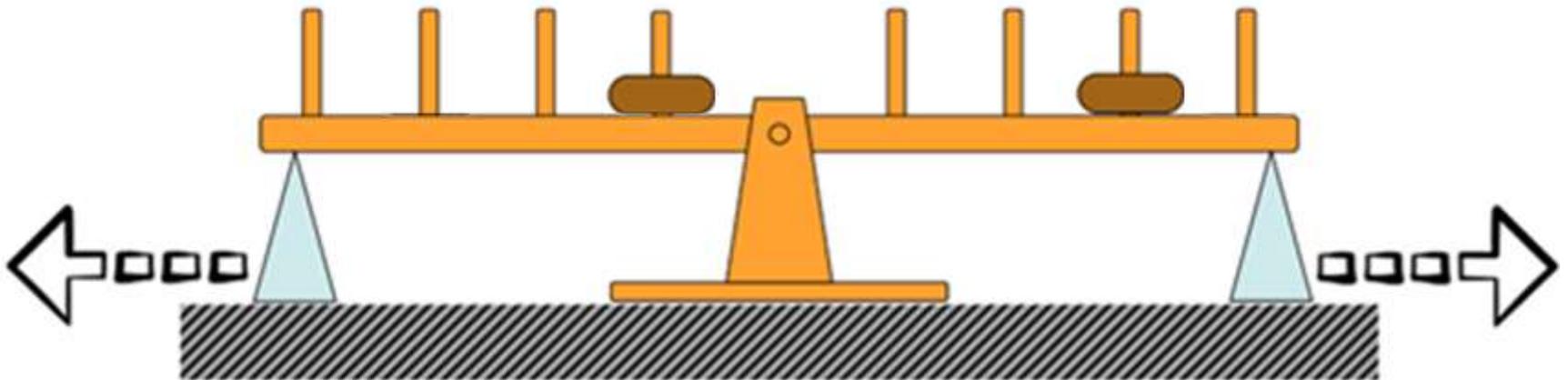
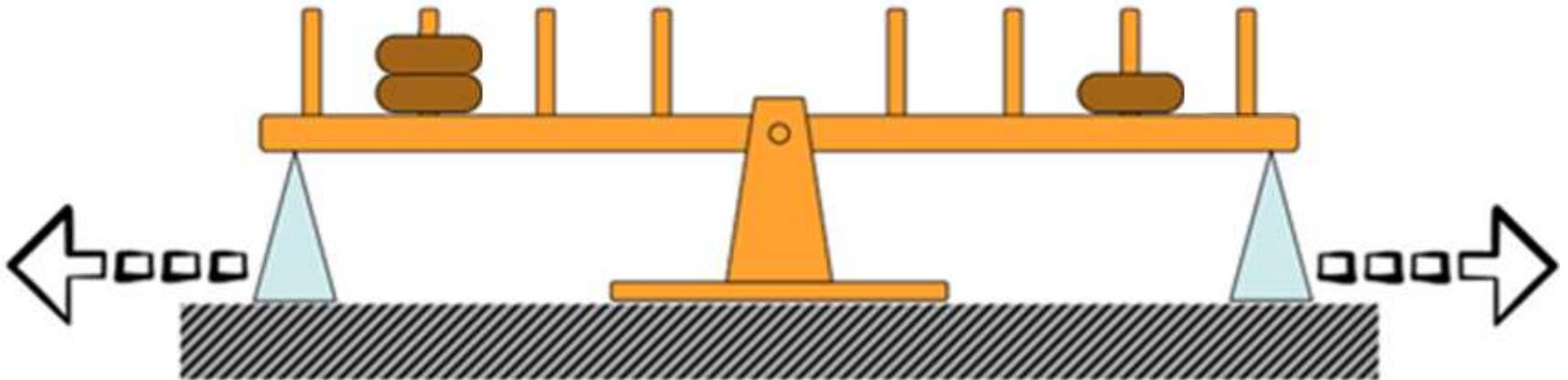
- Balance scale and sum of cross products
- Determine whether a scale will balance, given a particular configuration of weights on each side of the fulcrum



Siegler, R. S. (1976). Three aspects of cognitive development. *Cognitive Psychology*, 8, 481-520



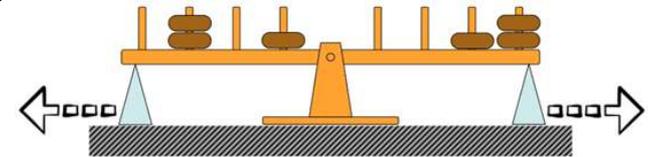
# Siegler "Rules"



# Objectives for Remainder of Discussed Games

Help learners progress through 4 increasingly sophisticated mental models identified by Siegler:

1. Learners only pay attention to weight, not distance.
2. Learners also consider distance, but only when the weight is equal on both sides.
3. Learners consider both weight and distance, but when the cues suggest different outcomes, they guess.
4. Learners consider both the amount of weight and distance of weights from the fulcrum; if the cues suggest different outcomes, they use the sum of cross products rule.



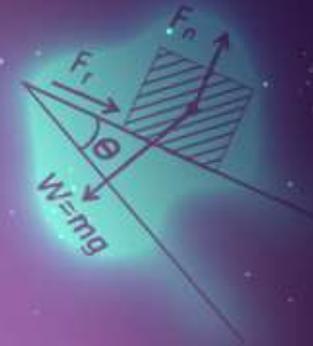
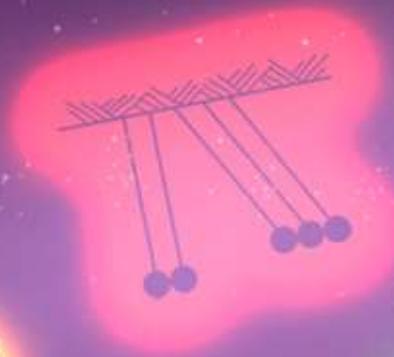
# Inquiry Reasoning and SEL

- From National Research Council framework, Scientific and Engineering Practices: construct explanations
- Socio-Emotional Learning (SEL) goals are to measure and support learners to:
  - “Ask for help” – Seek and/or accept assistance from others when encountering a problem
  - “Cooperate” – Cooperate with others to accomplish a joint task
  - “Discuss” – Solve problems through interactions and discussions with peers



# SCI-FRI

Science - friction



**John Balash**

**Nora Bastida**

**Chandana Bhargava**

**Sean Brice**

**Matt Champer**

**Danny Hausmann**

**Weiwei Huo**

**Xun Zhang**

**Scott Stevens**

**Mike Christel**

**Bryan Maher**

# PLAYTESTING: BEANSTALK

7 Playtests

57 students



# Beanstalk: Socio-Emotional Learning Focus Added

- Jack/Jackie: plays role of peer/friend to the player (e.g., reminds player of goal; directs player to ask birds for help)
- Chicken: eager to help (like young sibling), positive and excitable
- Crow: also likes to help, but preens when correct and likes to take credit for player's activity (sharper than Chicken but not as eager)



# Beanstalk Lessons Learned

- Respecting importance of narrative: keep beam balanced so Jack/Jackie can return teddy bear to creature above



- Providing scaffolding blending with narrative: increasingly complex problem states in later levels occurs through active pod slots and water inventory





# TORQUEIT!

FOR SCIENCE



WEICHUAN TIAN | JINGYI FENG | MENG HUI KOH  
MATT CHAMPER | QIANRU MA | SEAN BRICE | SAM COLLIER

## ADVISORS

SCOTT STEVENS | MIKE CHRISTEL

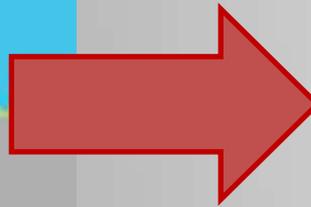
# Testing (Sesame Workshop)

- 11 children. 7 1<sup>st</sup> graders. 4 2<sup>nd</sup> Graders, 11/26/2012
- User interface was unclear
- Turn making was not clear
- Sharing is hard (some children resisted, emphatically!)
- Fatigued from confusion in UI
- Game titled “Teeter Totter Go”



# Changes Motivated by Playtest

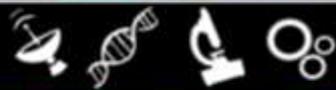
Streamlined interface (make clear what actions constitute a turn)



# More Changes from Playtesting

- Black outlines and contrasting colors to highlight foreground
- Music adjusted (longer track, volume lowered)





# Follow-Up Playtesting

- 12/3/2012, one week after test at Sesame Workshop, with 15 first graders
- Majority breezed through the game
- Enjoyed and understood the game
- Understood the need to share to succeed





# Playtests! (Slingshot vs. Tractor Beam)

- Feb. 13<sup>th</sup>
- 6 Pre-K Students;  
Children's School
- 3 boys, 3 girls
- Both mechanics work,  
need to pick one



# Playtests!

- Feb. 27<sup>th</sup>
- 8 Pre-K Students;  
Children's School
- 4 boys, 4 girls
- Most players asked  
for more levels to play



# Playtests!

- Mar. 13<sup>th</sup>
- 21 2nd grade students, 7-8 years old
- Testing for fun



# Playtests!

- April 13<sup>th</sup>
  - 6 Playtesters, 4 girls and 2 boys
  - Narrative well received
  
- May 3<sup>rd</sup>
  - 17 Playtesters, K-3<sup>rd</sup> grade
  - Game Well Received





# RUMBLE BLOCKS



Rumble Blocks is an educational game about saving several aliens by building stable structures in a sandbox environment. The aliens' mothership was damaged and they have to retreat to several different planets while they wait for another one to come save them. In the meantime, the player must build towers by manipulating a series of blocks to help them recharge their spaceships by building stable towers that capture the necessary energy. This game is designed to teach children ages 4-11 how to build and identify stable structures.

Rumble Blocks has been formally evaluated with several hundred guests. In our research, we have found that this age group has difficulty in understanding principles of stability, specifically making correct predictions and explaining them. In order to discover whether learning is occurring in-game, we implemented "Contrasting Case" levels, where the player has to select which tower is more stable - these have shown that enhanced learning of principles of stability and balance is occurring. Rumble Blocks has shown to foster learning and engagement.

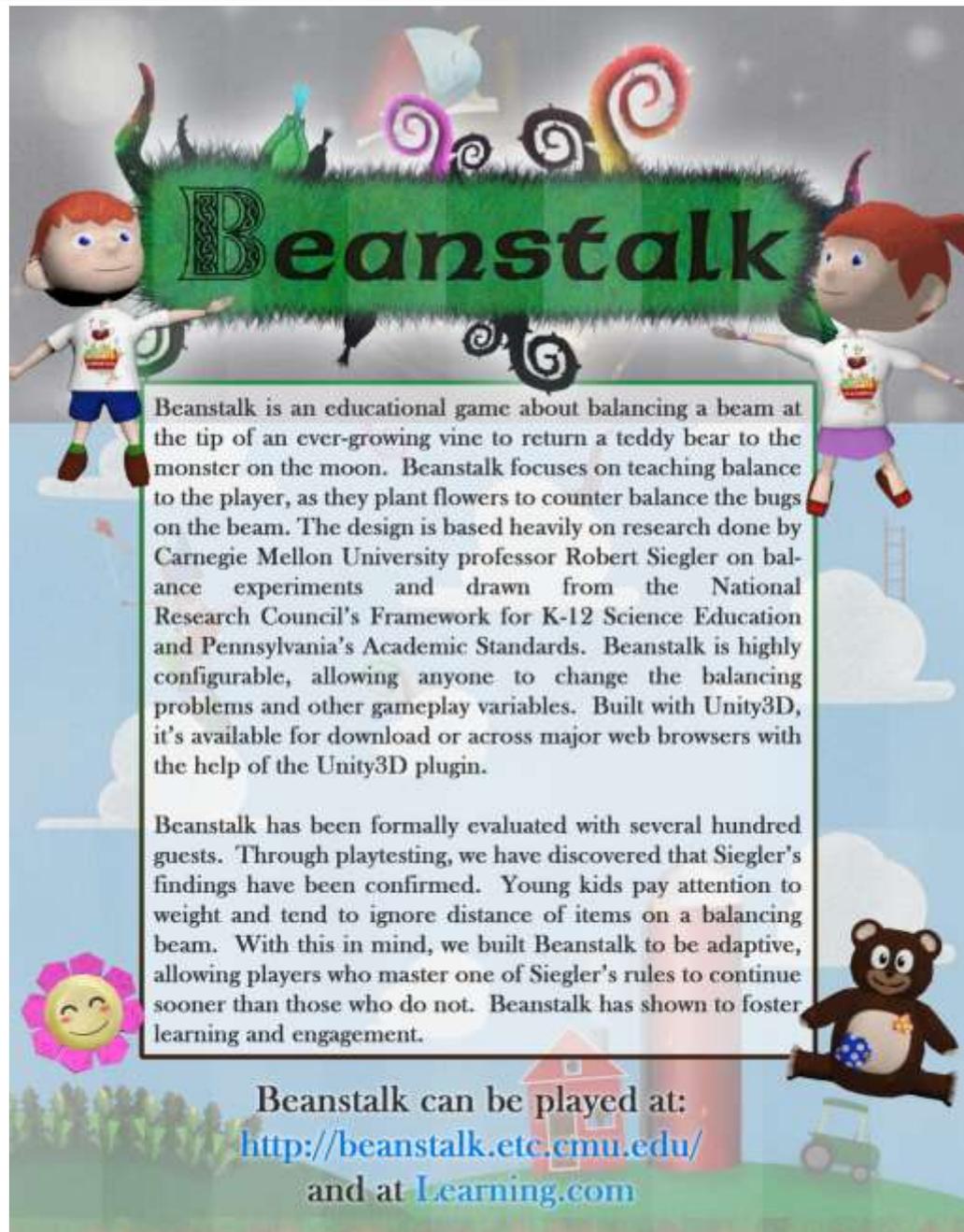


RumbleBlocks can be played at:

<http://rumbleblocks.etc.cmu.edu/>

and is also available on [Learning.com](http://Learning.com) and [CS2N.org](http://CS2N.org)



The background of the slide features a whimsical illustration. At the top, a green beam with a large, stylized letter 'B' is supported by two cartoon children with red hair, wearing white t-shirts with a bear on them and shorts. The beam is decorated with colorful swirls and flowers. Below the beam, a large text box contains two paragraphs of text. To the left of the text box is a smiling sun with a face, and to the right is a brown teddy bear sitting on a small green tractor. The background also shows a blue sky with clouds, a red barn, and a green field with a tractor.

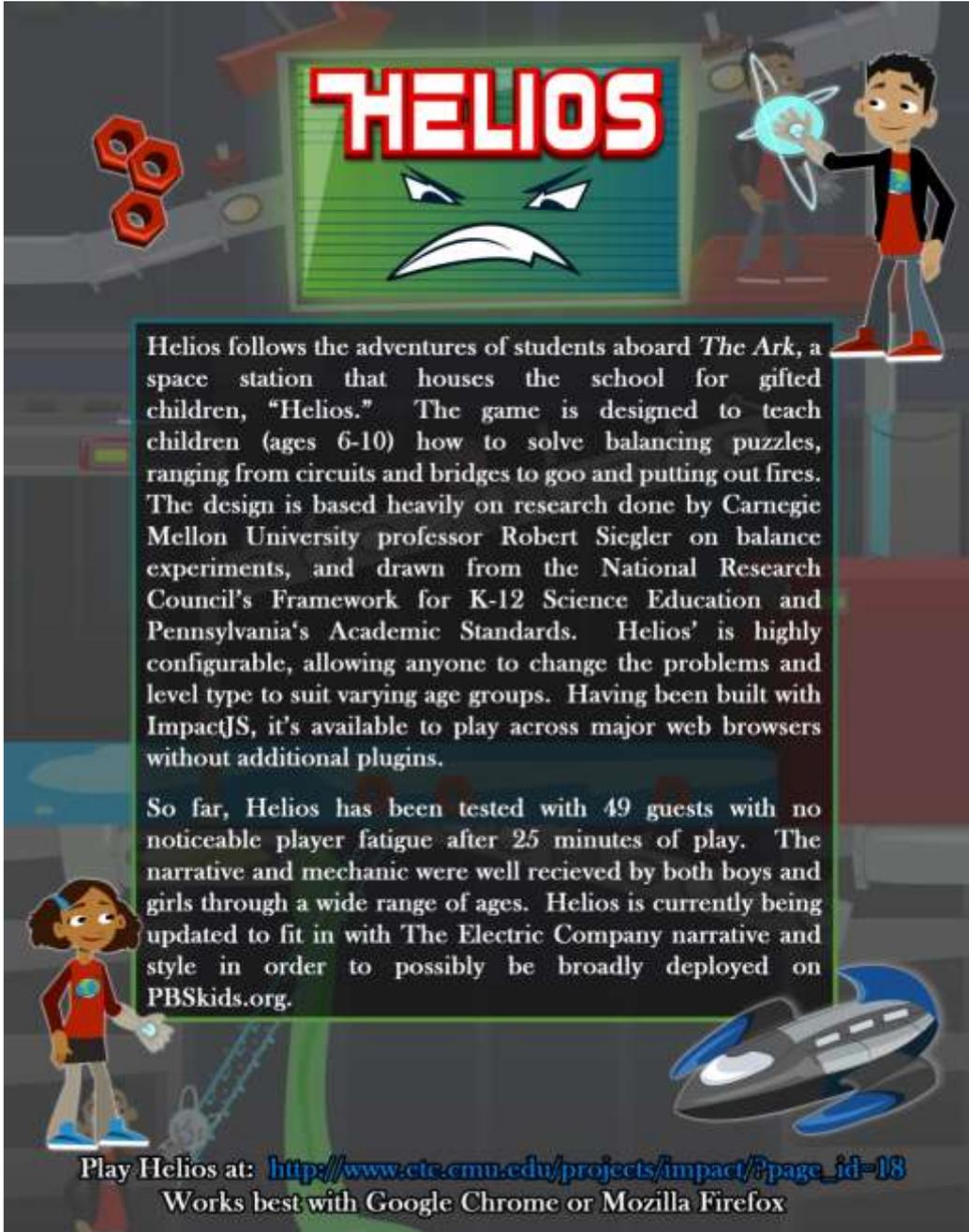
# Beanstalk

Beanstalk is an educational game about balancing a beam at the tip of an ever-growing vine to return a teddy bear to the monster on the moon. Beanstalk focuses on teaching balance to the player, as they plant flowers to counter balance the bugs on the beam. The design is based heavily on research done by Carnegie Mellon University professor Robert Siegler on balance experiments and drawn from the National Research Council's Framework for K-12 Science Education and Pennsylvania's Academic Standards. Beanstalk is highly configurable, allowing anyone to change the balancing problems and other gameplay variables. Built with Unity3D, it's available for download or across major web browsers with the help of the Unity3D plugin.

Beanstalk has been formally evaluated with several hundred guests. Through playtesting, we have discovered that Siegler's findings have been confirmed. Young kids pay attention to weight and tend to ignore distance of items on a balancing beam. With this in mind, we built Beanstalk to be adaptive, allowing players who master one of Siegler's rules to continue sooner than those who do not. Beanstalk has shown to foster learning and engagement.

Beanstalk can be played at:  
<http://beanstalk.etc.cmu.edu/>  
and at [Learning.com](http://Learning.com)



The image shows a screenshot of the Helios game interface. At the top center, the word "HELIOS" is written in large, bold, red-outlined white letters. Below the title is a green rectangular area containing a stylized, angry face with white eyes and a white, jagged mouth. To the right of this face, a cartoon boy with dark hair, wearing a black jacket over a red shirt and blue pants, is holding a glowing blue sphere. In the background, another cartoon boy is visible, and there are some red hexagonal shapes on the left. At the bottom left, a cartoon girl with brown hair, wearing a red shirt and blue pants, is holding a glowing blue sphere. At the bottom right, there is a blue and white rocket ship. The background is a dark, industrial-looking space station interior.

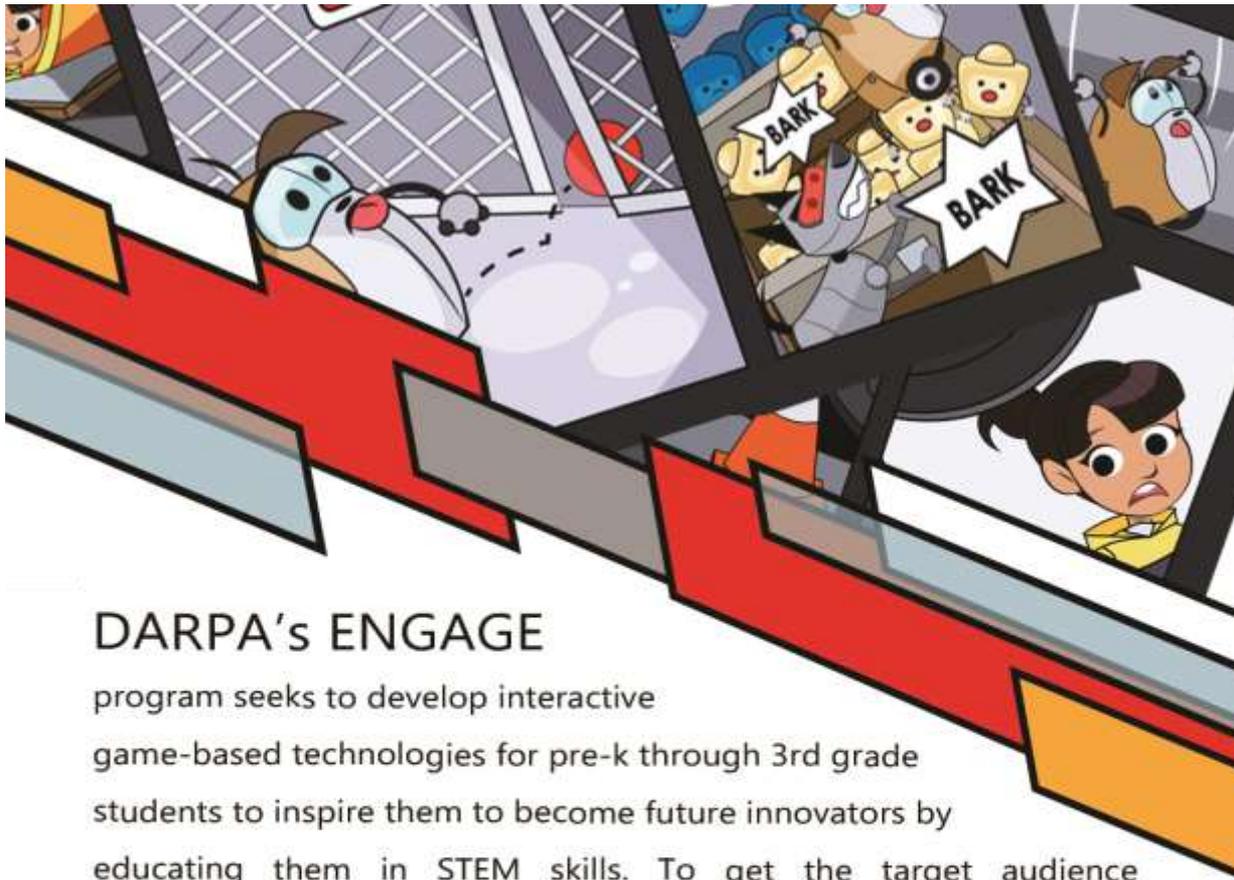
# HELIOS

Helios follows the adventures of students aboard *The Ark*, a space station that houses the school for gifted children, "Helios." The game is designed to teach children (ages 6-10) how to solve balancing puzzles, ranging from circuits and bridges to goo and putting out fires. The design is based heavily on research done by Carnegie Mellon University professor Robert Siegler on balance experiments, and drawn from the National Research Council's Framework for K-12 Science Education and Pennsylvania's Academic Standards. Helios' is highly configurable, allowing anyone to change the problems and level type to suit varying age groups. Having been built with ImpactJS, it's available to play across major web browsers without additional plugins.

So far, Helios has been tested with 49 guests with no noticeable player fatigue after 25 minutes of play. The narrative and mechanic were well received by both boys and girls through a wide range of ages. Helios is currently being updated to fit in with The Electric Company narrative and style in order to possibly be broadly deployed on PBSkids.org.

Play Helios at: [http://www.etc.cmu.edu/projects/impact/?page\\_id=18](http://www.etc.cmu.edu/projects/impact/?page_id=18)  
Works best with Google Chrome or Mozilla Firefox





## DARPA's ENGAGE

program seeks to develop interactive game-based technologies for pre-k through 3rd grade students to inspire them to become future innovators by educating them in STEM skills. To get the target audience to play, these games must meet the highest standards for quality and entertainment. The goal is to create games that improve over time by analyzing play across a large population of anonymous users. As a result, ENGAGE hopes to not only produce valuable game-based teaching tools, but to also provide insights into teaching techniques that can be applied to future products and classroom STEM learning. Our games can be found at: [etc.cmu.edu/engage](http://etc.cmu.edu/engage)



# Summary

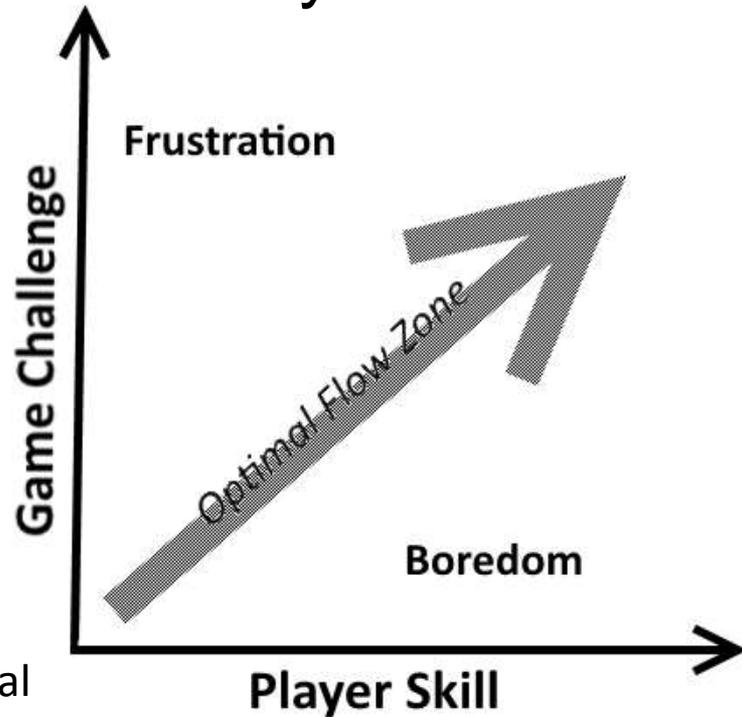
- ETC DARPA ENGAGE projects producing games to teach science concepts to children: <http://www.etc.cmu.edu/engage>
- Testing with children helps to preserve the fun
- Important elements include:
  - Interesting story narrative
  - Gentle, adaptive level progression (attention to problem flow)
  - Scaffolding that fits with narrative
  - Frequent interaction points, emphasis on touch-optimized for tablet usage
  - Remember the surprise, pleasure, juiciness (often via art and sound)



# Flow

## Mihaly Csikszentmihalyi\* and “Flow Theory”:

- Being completely absorbed in an activity
- For *PuppyBot Rescue*, level complexity increasing ideally to let the child player enjoy rewarding experience to remain engaged and feel a sense of achievement without undue frustration



\*M. Csikszentmihalyi, *Flow: The Psychology of Optimal Experience*. New York, NY: Harper and Row, 1990.

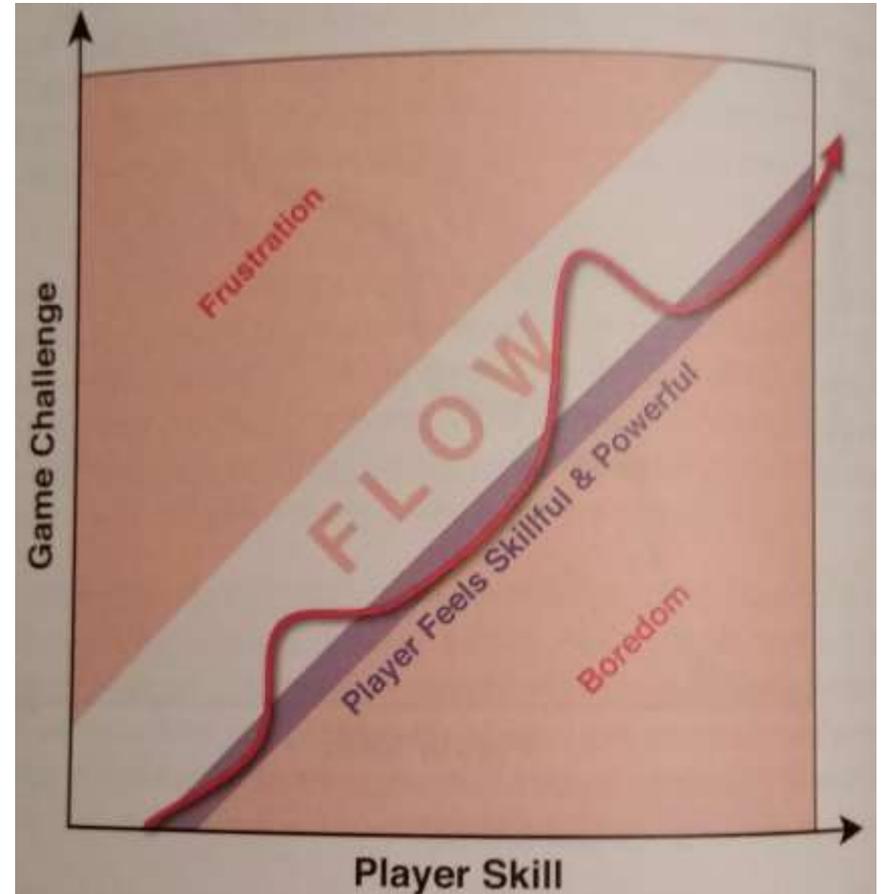


# Flow, in More Detail

Jeremy Gibson\*:

- Player must be “out of flow” a bit at times to feel skillful
- Playtesting can help test for player boredom/frustration

\*Jeremy Gibson, Introduction to Game Design, Prototyping, and Development. Upper Saddle River, NJ: Addison-Wesley, 2014.



# More Lessons Learned



- Important to market educational games
- Adaptive learning works to keep remaining players performing well: Tier N-1 skill before Tier N
- Socio-emotional learning (SEL) elements weakened in-game testing (POHE)
  - Recede the story set-up into the background
  - Balancing should be the focus



# Research Paper References

- Christel, M., et al. RumbleBlocks: Teaching Science Concepts to Young Children through a Unity Game. *Proc. 2012 17th International Conference on Computer Games (CGAMES)* (Louisville, KY, July-Aug. 2012), pp. 162-166.
- Aleven, V., et al. Supporting Social-Emotional Development in Collaborative Inquiry Games for K-3 Science Learning. *Proc. Games+Learning+Society Conference 9.0* (Madison, WI, June 2013).
- Christel, M., et al. Helios: An HTML5 Game Teaching Proportional Reasoning To Child Players. *Proc. 2013 18th International Conference on Computer Games (CGAMES)* (Louisville, KY, July-Aug. 2013), pp. 96-102.
- Christel, M., et al. Beanstalk: A Unity Game Addressing Balance Principles, Socio-Emotional Learning and Scientific Inquiry. *Proc. 2013 International Games Innovation Conference (IGIC)* (Vancouver, BC, Sept. 2013), pp. 36-39.
- Christel, M., et al. Lessons Learned from Testing a Children's Educational Game through Web Deployment. *Proc. 2014 ACM International Workshop on Serious Games (with ACM Multimedia Conf.)* (Orlando, FL, Nov. 2014), pp. 45-50.



# More References

- <http://workingexamples.org>
- "Playtesting Educational Games with Children: Preserving the Fun," talk at *Playful Learning 2014 Summit*, Ohio University, Athens, OH: April 10, 2014.
- "Helios: An HTML5 Game about Balance," talk at *Edugaming Conference 2014*.



# PuppyBot Rescue

- Current effort, building from other games
- Developed with Sesame Workshop



# PuppyBot Rescue

- Developed in concert with Sesame Workshop to do the following:
  - Emphasize Siegler balance principles, dropping out socio-emotional learning
  - Use HTML5 (createjs)
  - Optimize for touch: increase interactivity beyond the level established by IMPACT! team for its *Helios* game
  - Adapt game level progression, because what works for 5 year olds won't work for 11 year olds and vice versa



# PuppyBot Rescue Playtests

- Conducted by Sesame Workshop (as were tests with Teeter Totter Go game) with children in New York City
- Conducted in Pittsburgh area schools as well
- Dozens of children tested in grades K-3
- Young children struggled, older ones were bored before adaptive level progression was added
- Tests in Spring 2014 with tens of children show adaptive strategy is working as expected
- *More details to follow in concluding slides*



# PuppyBot RESCUE!





# PuppyBot Rescue



- Work done in collaboration with Sesame Workshop over the past year
- Major lessons for games for children:
  - Make objects interesting and appealing
  - Personality makes a world of difference
  - Emphasize the beam



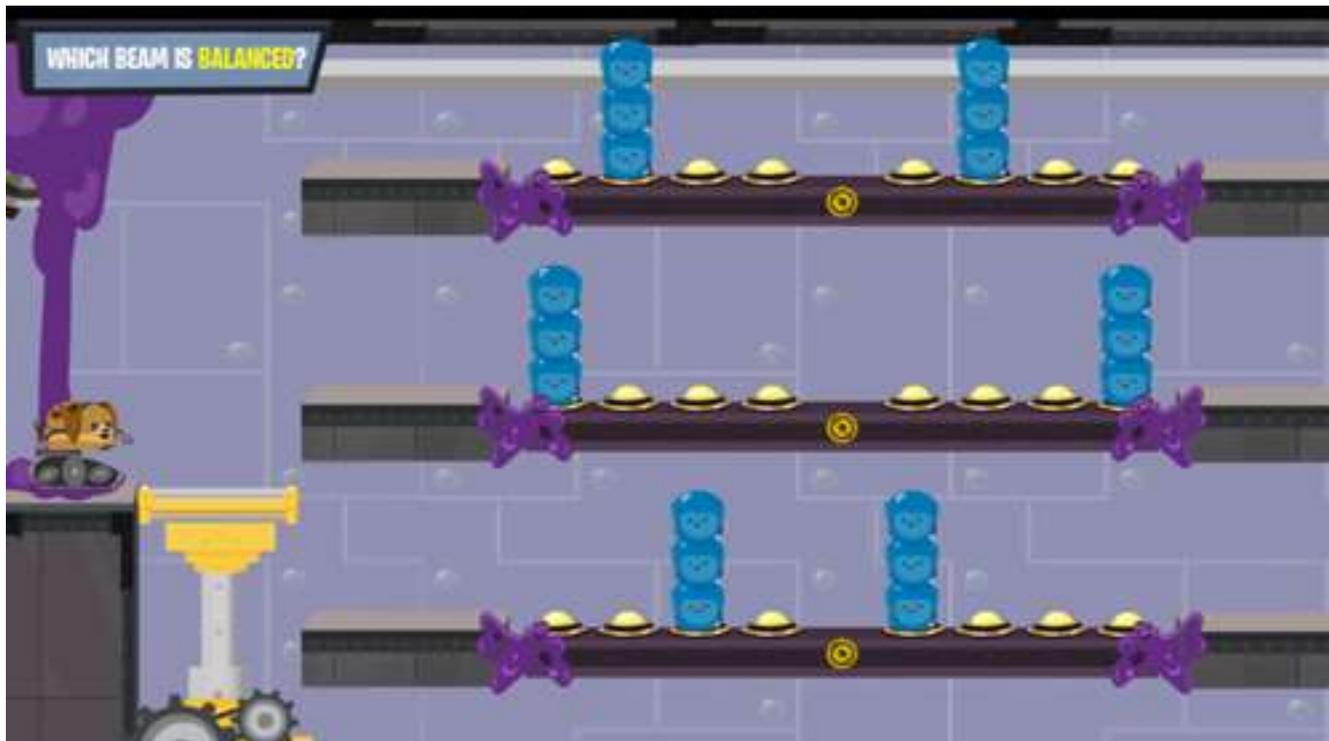
# PuppyBot Rescue

Help bot out of sewer by balancing the beam



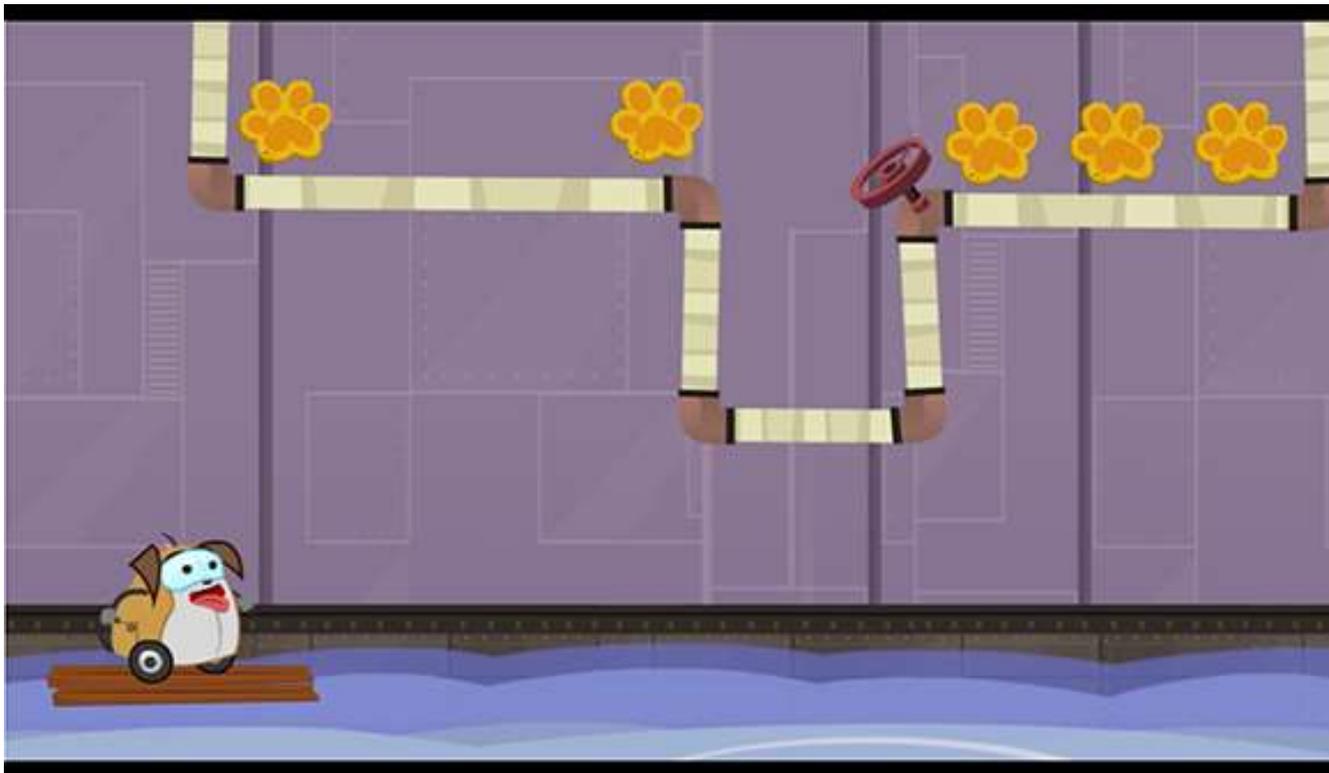
# Mini-Game - Old

Half of users had trouble with elevator (especially with mouse instead of touch)



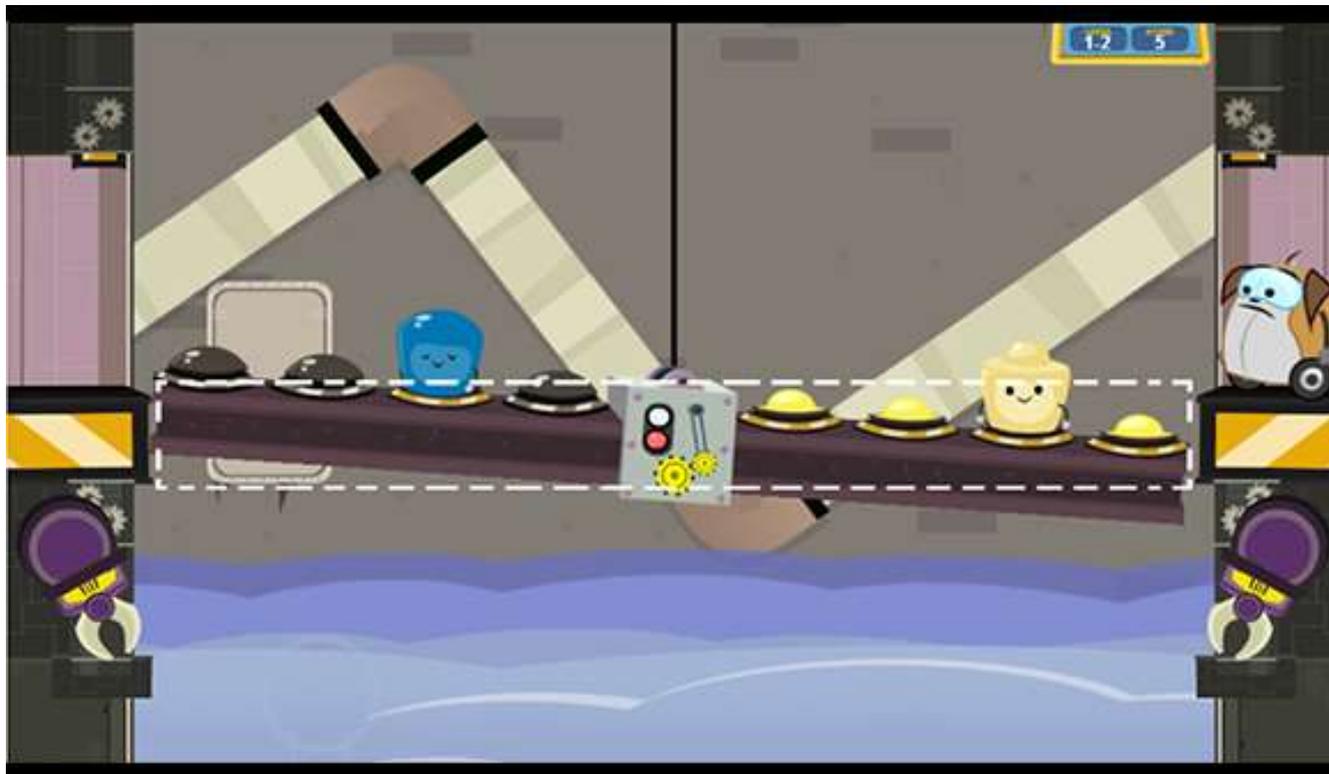
# Mini-Game, New

Simple, fun mini-game with no penalties



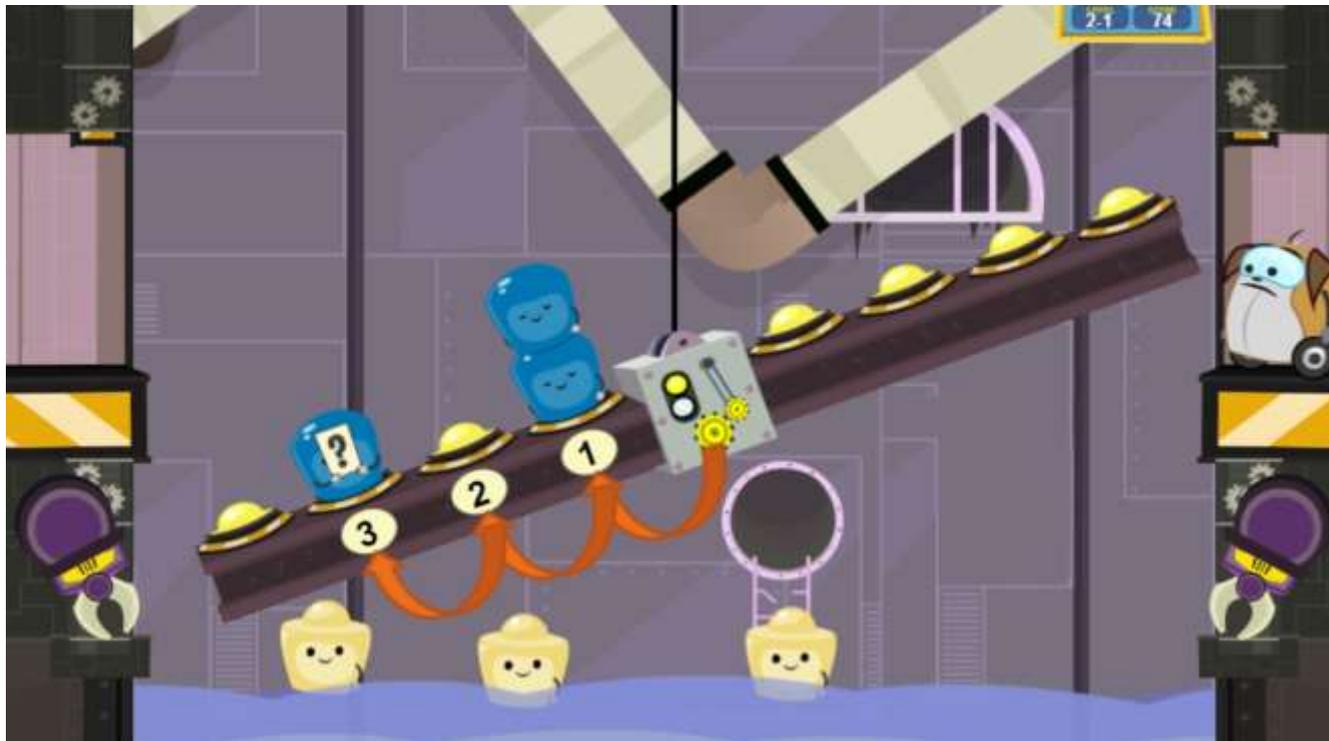
# Hinting System

Hints added where data showed a need



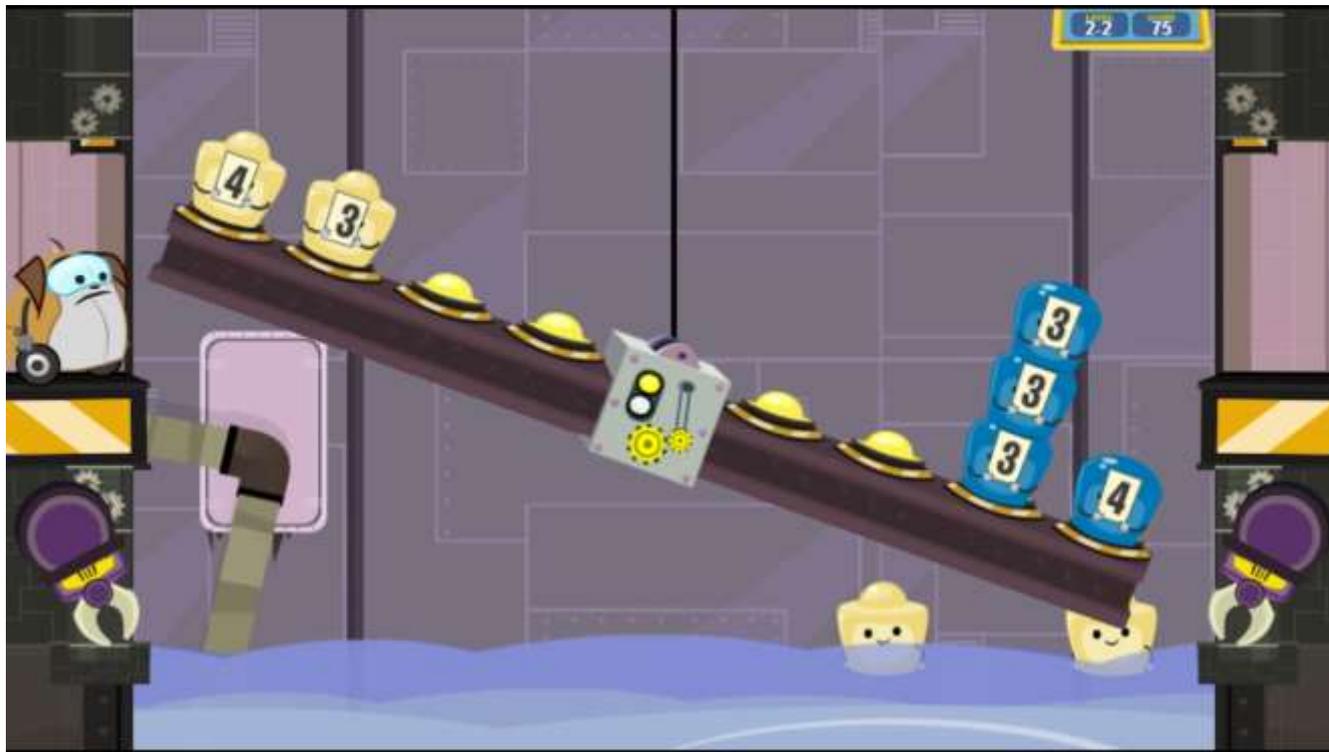
# Detailed Scaffolding

Successive fails trigger deeper hinting



# Detailed Scaffolding, Continued

Block effect shown with number sign



# Teacher-Requested Sandbox

Specific problems can be set up and discussed



# Adaptive Learning

- PuppyBot Rescue has 27 levels/problems
- Young children may only progress through Siegler rules 1 and 2 (e.g., grades K, 1)
- Older children need to progress more quickly to keep interest (graded 2, 3)
- Success on current set of 3 (plus history) dictates difficulty for next problem set
- “Perfect!” score reward to limit guess-and-check behavior



# Next Steps

- Coordinate verification work for *PuppyBot Rescue* with UCLA
- Games are available at <http://www.etc.cmu.edu/engage/>
- Take advantage of opportunities to field *PuppyBot Rescue* on other educational portals

