The Role of Computer Games in Informal STEM Education and Learning

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Science Learning Games (SLG) for Informal STEM Education at Regional Science Centers

• Physical interaction quest game: *DinoQuest*
  - Life-size dinosaurs models (e.g. T-Rex, Argentinosaurus, Velociraptors)
  - Family-based problem-solving and collective learning in physical environment
  - Game progress tracked via user-controlled IR transmitters that activate embedded sensor net

• Web-based SLG: *DinoQuest Online*
  - Addresses CA science education standards for K-6 grades
  - Interoperates with *DinoQuest*
  - Designed for internationalization
  - Developed by UCI GameLab
Objective

• How best to employ networked computer game technology in ways that integrate
  – social learning opportunities
  – scientific visualization methods
  – external scientific datasets
  – science work practices
  – open source software community dynamics
  – playful fun

  to develop, deploy, and evolve single/multi-player games for informal K-12 STEM
  education in different disciplines.
But first, some background on science learning games
Contemporary SLGs

-- *Droidworks* (electro-mechanical system design)

-- *KineticCity* (life science)

-- *Genius Task Force Biology* (ecology simulation, in *German*)

-- *Industry Player* (commodity trading system)

-- *GTR* (motorsports racing simulation)

-- *NASCAR 2007* (motorsports racing simulation)
#1 The Slippery Slope

**Mission Briefing:**
Get your droid through the security exit door at the top of the cliff. In the area nearby, there are objects that can help your droid reach its goal. The speed and weight of your droid are important factors.

**Droid Info**

**Mission Goals**
- #1 The Slippery Slope
  - pass through security exit door
  - Droid Requirements
    - treads and wheels

**Ranking:**
- Apprentice
- Designer
- Master
KineticCity Body System Identification Game Play-to-Learn techniques

• Given prompt (e.g., Circulatory/Respiratory system) select, drag, and place system components into correct locations
  – System component identification (e.g., heart, arteriole-venal network, esophagus, lungs) and location
    • By iconic form/shape (no names)

• Placing all correct system components allows advancement to next system; any mistake resets (removes) placed components requiring iterative play.
  – Failure-driven (trial+error iteration) and spatial-shape reasoning
  – Play-learning anomalies
    • Some components resize, others don’t
      – Nerve and arteriole-venal networks resize on placement (automatically), but bones don’t
    • Systems are partial--why some components, but not others?
    • Which system -- cardio-pulmonary system vs. “circulatory/respiratory” system?
Spielbeginn: Mustergenuss
Region: Zentralafrika
Klima: Afrikanische Savanne
Katastrophen: Diamantenträger, Quecksilbergruben
Malaria: 100% der Kaffeerotation, Milben und Quecksilbergruben
vollständig bestritten
Copper
Current Price = $30.96
Market Price = $30.96
Price Level = 129%
Capac./Demand = 77.7%
ROE = 89.2%
# GTR Racing Simulation

**Strategy, Gearing, and Brakes**

<table>
<thead>
<tr>
<th>Tyres</th>
<th>Medium</th>
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</thead>
<tbody>
<tr>
<td>Starting Fuel</td>
<td>17.2 gal (9 Laps)</td>
</tr>
<tr>
<td># of Stops</td>
<td>3</td>
</tr>
<tr>
<td>1st Stop</td>
<td>17.2 gal (9 Laps)</td>
</tr>
<tr>
<td>2nd Stop</td>
<td>17.2 gal (9 Laps)</td>
</tr>
<tr>
<td>3rd Stop</td>
<td>17.2 gal (9 Laps)</td>
</tr>
<tr>
<td>Weight Dist.</td>
<td>40.0:60.0</td>
</tr>
<tr>
<td>Steering Lock</td>
<td>20.0 Degrees</td>
</tr>
<tr>
<td>Rev Limit</td>
<td>6700</td>
</tr>
<tr>
<td>Engine Temp</td>
<td>-460 °F.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Gears</th>
<th>RPM</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st Gear</td>
<td>16/40 (7.703)</td>
</tr>
<tr>
<td>2nd Gear</td>
<td>19/35 (5.680)</td>
</tr>
<tr>
<td>3rd Gear</td>
<td>23/33 (4.424)</td>
</tr>
<tr>
<td>4th Gear</td>
<td>26/30 (3.553)</td>
</tr>
<tr>
<td>5th Gear</td>
<td>28/28 (3.083)</td>
</tr>
<tr>
<td>6th Gear</td>
<td>29/26 (2.764)</td>
</tr>
<tr>
<td>Final</td>
<td>12/37 (Bevel 1/1)</td>
</tr>
<tr>
<td>Reverse</td>
<td>16/40 (7.703)</td>
</tr>
</tbody>
</table>

**Brake Bias**

- Front brake disc temp: -460 °F.
- Front brake wear remaining: 0.00 in
- Rear brake disc temp: -460 °F.
- Rear brake wear remaining: 0.00 in

**RPM Chart**

- RPM Range: 0 to 15,000
- MPH Range: 0 to 300

- Graph showing RPM increase over time.
NASCAR Racing 2007
Typical SLG development costs – 1995-2005

• $500K--$5M
• 1-2+ year development schedule
• No major differences in time or cost to develop whether done by commercial game studio or non-commercial (academic) R&D team
DinoQuest at DSC
Fast Facts about Discovery Science Center
• Located in Santa Ana, California
• 80,000 Sq. Ft.
• Budget: $6,000,000  Earned Income: 82%  Contributed Income: 18%

At the Center:
• 425,000 annual visitors (2007)
• 88,000 annual field trip visitors from schools
• Provide in-service science teaching training to 1,100 K-12 teachers/yr.

In the Schools:
• 150,000 annual students in science outreach programs
Inspire Youth of Today in Fields of Science

Science Adventure Quests

• Blending Video Game Culture and Physical Exhibits
• Putting Visitors into a Science Adventure Video Game
• $7 Million Expansion at DSC
• Dinosaur Themed, but focused on Life Science
Discovery Science Center Goals

Create a physical exhibit that blends:
- Natural History Museum Collection,
- Science Center Hands-on Exhibits,
- Video Game Culture,
- Science research practices via “collaboratories”

Create a Cyberinfrastructure for distance learning over the Internet.

Engage and explain CA Science Education Standards.

Create electronic performance tracking ability for better evaluation capabilities.

Workforce Development

Create a mechanism that continues to drive visitors between a brick & mortar science center and the Internet/Web site multiple times.

Increase repeat usage of science center exhibits and increase visitation.

Create a replicatable and sustainable model.
DinoQuest at DSC
The IR Transmitter!

- Picking up information throughout the DQ site.
- Tracking visitor’s success on missions.

**IR transmitter, sensor network technology, and interactive media** from Creative Kingdoms, Inc.
Technology:
Embedded Sensors and Transmitter Activation
8 Educational Missions:
• Aimed at California Science Education Standards for grades K-6
• Mission topics: Predator / Prey, Trace Fossils, Anatomy, Habitats, Identification
• Each mission focuses on a different collaboratory and field of science
• Missions selected, tracked, and completed at networked multi-media kiosks
DinoQuest Research Team and Collaboratories: Diverse Science Role Models (ethnicity, age, gender)
Role play (see oneself as a scientist)

After selecting a mission, head out to the dig site!
Situated role play

Search dig site and identify objects in the mission.

Computer and sensor network automatically tracks your success.
“Upload” data collected to collaboratories via on-site networked kiosks

- Earn Research Points for each item found.
- Obtain fossils with encoded DNA as reward for completing each mission.

Ability to save data and come back another day.
DinoQuest Online

Online Science Learning Games

• Distance learning,
• Expands on science topics,
• Additional, in-depth science missions,
Earn points and Dino DNA by completing missions.
• Level-up into multi-player dinosaur ecology simulation (Dinosphere)

UCI
University of California, Irvine
DinoQuest Online (released in Summer 2007)

- Log in with password online or from DSC
- Go to each collaboratory
- http://www.dqonline.org
  - register OR enter “demo” “demo”

- Same scientists as DinoQuest at DSC
- Expand upon science education standards in each lab
Multiple Science Learning Games: 
*Dinosaur Dig Pit* Field Site Collab Game

- Different objectives for each game.
Multiple Science Learning Games: Narrative Content

Backbones and Ribs

Vertebrae provide structure for the animal and are divided into sections depending on where they are located along the back. Thoracic vertebrae are in the chest area and provide attachment points for the ribs. Ribs make up a bony case that protects many important internal organs, such as the heart and lungs. Bony projections on the vertebrae are attachment points for muscles. The Apatosaurus, being more massive, had larger processes on its vertebrae than the Allosaurus. Many of the larger dinosaurs, such as Apatosaurus and Allosaurus also had “belly ribs,” called gastralia, that were not attached to the backbone or the other ribs. The purpose of the “belly ribs” are not specifically known.

In 1987, amateur paleontologist Stan Sacrison discovered "Stan," a T-rex embedded in the Hell Creek Formation in South Dakota. 199 fossilized bones were recovered, including the best preserved and most complete T-rex skull ever found. Stan’s bones showed evidence of healed injuries: broken ribs and vertebrae, damaged facial bones, and a large hole in the back of its skull.
DinoQuest Online Reconstruction Lab
3. Rotate objects with this tool.

4. Keep track of your progress here.

2. Move the fossils out to the anchors.

1. Your goal is to rebuild this.
Multiple Science Learning Games: Zoology and Systems Collab Games

- Build a working digestive system out of available organs and “connectors”

- Move Oxygen and CO2 through a cardio-pulmonary system
Multiple Science Learning Games: *Ecology/Habitat* Collab Game

- Gain points by matching prey/predator and food chain relations via *Tetris*-like game play

It's dinner time for the herbivores, I see. Good thinking, those plants won't be taking up all the space anymore! Let's take some of the hair eaten termite back to the lab for analysis.
Multiple Science Learning Games: *Biomechanical* Collab Mini Games

- Mass and balance
- Proportion and speed
- Matching anatomical structures to diet
Multiple Science Learning Games:
Resource Interaction Collab Game Spaces

*MyLab* - shows missions completed both online and at the DSC

*DinoSphere* – allows building of your own Dinosaur with DNA collected from missions.

Go back online or go to DSC to obtain different DNA by completing more missions!
Evaluation Potential

DinoQuest and DinoQuest Online allow for the following evaluations:

*Player Centered:* scores and missions completed identify progress and provide feedback in context.

*Exhibit Centered:* ability to test content comprehension by player quiz upon completing mission.

*Independent Evaluation:* to ask which method is best and why: physical exhibit, online learning games, or both?

Challenge the Professor
DSC+UCI working to develop network of SLG-based science centers

Tier 1: Individual player connection: your Internet connection at home.
Tier 2: Local institutional connection: library, science center, school.
Tier 3: Regional science center provides local exhibit content connected online.
Tier 4: “Gateway” science centers provide open interfaces and content.
Tier 5: Science Center Network for Massively Multiplayer Online Science Learning Games (MMOSLGs).
Cyberinfrastructure for Science Centers

Cyberinfrastructure allows for:

- Can be applied in multiple scientific, technological, or engineering domains.
- Can be further developed and expanded with open source software components, infrastructure, and open content.
- Ties into existing networks of STEM online learning materials.
Transforming STEM Learning via
*The Game/Virtual Worlds Web*

• Future STEM games can employ advanced scientific models, simulations, visualizations
  – Global Climate Systems Science game engine
  – Nanotechnology-based “incredible machines”
  – Environmental ecology preservation/restoration
  – Supply chain/infrastructure transformation quest

• Game Web environments can become platforms for experimentally interacting with emerging scientific models, business processes, and domains of expertise

• STEM Learning Games represent a new engine for innovation!
Incredible (nanotech) machines
Plasma fusion simulation exploration game
CERN Quantum Game

TOOLS

Accelerate the Particle

![Diagram of particle accelerator with alternating positive and negative charges]

[PLAY GAME]

(may take a few moments to load)

game created by CERN

THE HEART OF THE MATTER

Research at CERN that garnered a Nobel Prize in 1984: Carlo Rubbia and Simon Van der Meer for the discovery of the "W and Z particles, communicators of the weak interaction."
UCI Game Lab Partners and Sponsors

- California Institute for Telecommunications and Information Technology: Calit2 at UCI-UCSD
- UCI Institute for Software Research
- UCI Arts, Computation, and Engineering (ACE) Program
- UC Humanities Research Institute
- Discovery Science Center, Santa Ana, CA
- Daegu Global R&D Collaboration Center, Daegu, South Korea
- National Science Foundation
- Intel
- Sun Microsystems
- EON Reality
- and others

For further information, see http://cgvw.ics.uci.edu