MIT STEP/TEA

Learning Games Are Hard Fun

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STEP/TEA Pedagogical Frameworks

• What kind of learning environments?
  – Create highly **engaged**, motivated students
  – Provide **immersive** environments, **relevant** problems
  – Facilitate **collaborative, project-based** learning
  – Game-like, active, “**Hard Fun**”
    • A teacher heard one child using these words to describe the computer work: "It's fun. It's hard..." I have no doubt that this kid called the work fun **because** it was hard rather than in **spite** of being hard. [S. Papert, 2002]
  – Applicable to **formal** and **informal** settings, **extending learning** beyond walls of the school, beyond hours of the school-day
Learning Through Game Play and Creation
Games? Learning?

How many volts do I need for my laser cannon to kill 3 x 6 opponents?
The Legacy of Math Blaster

• Edutainment
  – Where play is the reward for learning
The Legacy of Math Blaster

• Edutainment
  – Gets kids to eat broccoli
  – But doesn’t promote healthy eating
  – What happens when the chocolate goes away?
The Legacy of Math Blaster

- Instead learning should be playful
The Joy of Gaming?
The Joy of Gaming = Hard Fun
Feedback?

• How can we provide more feedback?
Feedback

- **When** should we provide feedback?
  - Frequency and response type
Gamification Everywhere

Mr. Zichermann said. “We use game concepts to get them to focus on things.”

fits that description. After graduating from high school, Mr. Kroll said, he was overweight, living at home and playing World of Warcraft at least six hours a day. Things around after starting to work out at a gym regularly with the help of a friend on his iPhone called Fitocracy, in which badges are awarded by a robot.

who has lost about 75 pounds, says he plays video games less frequently now, enjoys the gamelike challenges that the app sets for him at the gym. He said the original was “the same satisfaction of getting points and leveling up” that he gets from

Sawder and her 9-year-old daughter, Emma, also know how well embracing games work. Ms. Sawder signed up for a service called Zamzee to encourage Emma to be physically active.

Each day, Emma wears a small motion sensor that records her activity level and tracks her for a brisk walk, an impromptu dance party in the living room and any other activity that might make a day feel like a game.
Learning Goals?

• Cognitive Skills
• Non-cognitive skills
  – Persistence
  – Grit
• Metacognitive skills
  – Reflection
  – Abstraction
Zone of Proximal Development

Vygotsky
Zone of Proximal Development

- Can/Will Do With Help
- Can’t Do/Won’t Do
- Can Do/Will Do
The Fun of Structure

Structured, goal-oriented, feedback-driven can be fun

In games we willingly submit to arbitrary rules and structures in pursuit of mastery, but only if we can continue to be playful.
The Fun of Structure

Structured, goal-oriented, feedback-driven can be fun.

In games we willingly submit to arbitrary rules and structures in pursuit of mastery, but only if we can continue to be playful.
Structure is Fun
Structure is Fun
Structure is Fun
Structure is Fun
Structure is Fun
Structure is Fun
Structure is Fun
Zone of Proximal Development

- Can/Will Do With Help
- Can’t Do/ Won’t Do
- Can Do/ Will Do
Zone of Proximal Development

- Can/Will Do With Help
- Can’t Do/ Won’t Do
- Can Do/ Will Do
Making Real Learning Games

- New technologies and pedagogies can create learning opportunities that are simultaneously fun and playful.
- Not just a superficial candy coating, they are linked at the deepest levels.
- Games can engage players in learning that is specifically applicable to “schooling.”
Ecology of School
Mobile Social Games
UbiqGames

- Designed for the Mobile Web
- Paced to encourage short and frequent game play
- Played in the “interstitial” spaces in school
- Connected to specific class learning goals through curriculum
The UbiqBio Project

• A two-year NIH-funded research study
• Four standards-based UbiqGames
• Designed to promote deep learning and strong engagement for intro biology students
• Played primarily during outside-of-class time
• Used in-class time to synthesize and discuss concepts
• Includes Teacher Portal to track student/class progress
UbiqBio Games

The Lab

Hands  Tail  Horns  Mouth

Orzine

Yall

The Lab

Hands  Tail  Horns  Mouth

Zygote Stage
Current mRNA codes for:

Razor Claws
Serrated Tail
Normal Horns
Normal Mouth

Develop

Contract

Pay Beetles

| Beetles | $39 | 3 HA | Hairy

Beetles in Shipping Box:

| $52 | 4 WA | 0/3 in Shipping Box

| $52 | 4 AA | 0/3 in Shipping Box

| $30 | 3 HA |

| $40 | 4 RA |

Mating Cage

7363
Hairy HH

7374
Hairy Hh

Hatch Challenge
Responsive Design
Teacher/Researcher Portal

- **Teachers**
  - create class rosters
  - observe game play
  - track student progress

- **Researchers**
  - log game play patterns
  - collect student data
Game Play by Gender

Male vs. Female Gameplay by Game

<table>
<thead>
<tr>
<th>Game</th>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td>BB*</td>
<td>200</td>
<td>350</td>
</tr>
<tr>
<td>Beasties</td>
<td>50</td>
<td>100</td>
</tr>
<tr>
<td>Island Hoppers</td>
<td>100</td>
<td>150</td>
</tr>
<tr>
<td>Chomp!**</td>
<td>20</td>
<td>30</td>
</tr>
</tbody>
</table>

Mintes Played
Game Impact on Test Scores

Control vs Experimental Quiz Scores by Game

<table>
<thead>
<tr>
<th>Game/Topic Area</th>
<th>Quiz Subscore</th>
</tr>
</thead>
<tbody>
<tr>
<td>Genetics</td>
<td>Control Mean</td>
</tr>
<tr>
<td>Evolution</td>
<td>Control Mean</td>
</tr>
<tr>
<td>DNA</td>
<td>Control Mean</td>
</tr>
<tr>
<td>Ecology</td>
<td>Control Mean</td>
</tr>
</tbody>
</table>

* Denotes a statistically significant difference.
Leveling Up?

- How is score on each section impacted by...
  - Time spent playing
  - Levels completed

<table>
<thead>
<tr>
<th></th>
<th>Genetics</th>
<th>DNA</th>
<th>Evolution</th>
<th>Ecology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time (10K)</td>
<td>-.039</td>
<td>.0647</td>
<td>-.223</td>
<td>x</td>
</tr>
<tr>
<td>Level</td>
<td>.245</td>
<td>x</td>
<td>.0138</td>
<td>x</td>
</tr>
</tbody>
</table>
Do Games Work?

- Not all games are the same
What Makes Games Work?

<table>
<thead>
<tr>
<th></th>
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<th>Ecology</th>
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<td>.245</td>
<td>x</td>
<td>.0138</td>
<td>x</td>
</tr>
</tbody>
</table>

The table shows the relationships between different factors and their impact on games. The graph further illustrates the data, with lines representing different difficulty levels.
Games as Treatments?
The Medical Model
Radix - An MMO for STEM Learning
Pinetreek

The Radix
Endeavor
Why an MMOG

(Massively Multiplayer Online Game)

- Self-directed
- Collaborative
- Role-playing
- Inquiry-based
- Contextual
Deion: I have a quest for you.
Mark: Try the EcoSim.
Figure 16: 16 Experiments of type A, Ab, and B flower breeding.
Home Screen

- Shows the progress of students on a quest.
  - **Number of successes**
  - **Number of attempts**
  - Color coded where red means no success and green means always successful
  - Blue indicates a student has started a quest
  - Grey indicates a student has never started the quest.
  - Class average computed at top.

<table>
<thead>
<tr>
<th>Students</th>
<th>Box Builder Part 1</th>
<th>Box Builder Part 2</th>
<th>Box Builder Part 3</th>
<th>Box Builder Part 4</th>
<th>Scale Figure Drawing</th>
<th>Correct Map Part 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class</td>
<td>63%</td>
<td>46%</td>
<td>56%</td>
<td>48%</td>
<td>61%</td>
<td>57%</td>
</tr>
<tr>
<td>Alpha</td>
<td>2/2</td>
<td>3/4</td>
<td>5/5</td>
<td>1/2</td>
<td>1/1</td>
<td>1/2</td>
</tr>
<tr>
<td>Bravo</td>
<td>0/4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Charlie</td>
<td>2/4</td>
<td>0/5</td>
<td></td>
<td></td>
<td>2/2</td>
<td>1/3</td>
</tr>
<tr>
<td>Delta</td>
<td>4/4</td>
<td>3/3</td>
<td>1/1</td>
<td>1/4</td>
<td>0/4</td>
<td></td>
</tr>
<tr>
<td>Echo</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1/1</td>
<td>1/3</td>
</tr>
<tr>
<td>Foxtrot</td>
<td>1/1</td>
<td>1/1</td>
<td>2/5</td>
<td>2/4</td>
<td>1/4</td>
<td>1/5</td>
</tr>
<tr>
<td>Golf</td>
<td>2/3</td>
<td>0/4</td>
<td></td>
<td></td>
<td>3/5</td>
<td>1/5</td>
</tr>
<tr>
<td>Hotel</td>
<td>1/5</td>
<td>0/3</td>
<td></td>
<td></td>
<td>1/4</td>
<td>2/2</td>
</tr>
<tr>
<td>India</td>
<td>3/4</td>
<td>1/3</td>
<td>2/5</td>
<td>1/2</td>
<td>4/5</td>
<td>0/5</td>
</tr>
<tr>
<td>Juliet</td>
<td>1/5</td>
<td>2/5</td>
<td>1/2</td>
<td>2/4</td>
<td>1/1</td>
<td>1/2</td>
</tr>
<tr>
<td>Kilo</td>
<td>4/4</td>
<td>2/3</td>
<td>1/3</td>
<td>4/4</td>
<td>3/4</td>
<td>1/1</td>
</tr>
<tr>
<td>Lima</td>
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<td>2/5</td>
<td></td>
<td></td>
<td>3/3</td>
<td></td>
</tr>
<tr>
<td>Mike</td>
<td>1/5</td>
<td>3/4</td>
<td>4/4</td>
<td>4/5</td>
<td>1/3</td>
<td>4/5</td>
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<tr>
<td>November</td>
<td>4/4</td>
<td>1/5</td>
<td>1/1</td>
<td>0/3</td>
<td>1/1</td>
<td>1/1</td>
</tr>
<tr>
<td>Oscar</td>
<td>3/4</td>
<td>0/4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Papa</td>
<td>3/3</td>
<td>2/2</td>
<td>1/1</td>
<td>0/2</td>
<td>1/1</td>
<td>1/4</td>
</tr>
<tr>
<td>Rome</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1/3</td>
<td>2/4</td>
</tr>
<tr>
<td>Sierra</td>
<td>0/4</td>
<td></td>
<td></td>
<td></td>
<td>4/4</td>
<td>1/2</td>
</tr>
<tr>
<td>Tango</td>
<td>3/3</td>
<td>1/3</td>
<td>2/2</td>
<td>3/3</td>
<td>3/4</td>
<td>4/4</td>
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<tr>
<td>Uniform</td>
<td>4/5</td>
<td>1/3</td>
<td>1/3</td>
<td>0/1</td>
<td>1/1</td>
<td>4/5</td>
</tr>
<tr>
<td>Victor</td>
<td>3/3</td>
<td>4/4</td>
<td>2/5</td>
<td>1/5</td>
<td>4/4</td>
<td>2/4</td>
</tr>
<tr>
<td>Whiskey</td>
<td>2/2</td>
<td>2/4</td>
<td>0/3</td>
<td></td>
<td>0/3</td>
<td></td>
</tr>
<tr>
<td>Yankee</td>
<td>2/4</td>
<td>3/4</td>
<td>2/3</td>
<td></td>
<td>5/5</td>
<td>5/5</td>
</tr>
<tr>
<td>Zulu</td>
<td>1/1</td>
<td>2/3</td>
<td>1/2</td>
<td>1/3</td>
<td>1/2</td>
<td>2/3</td>
</tr>
</tbody>
</table>
AA stands for "angle, angle" and means that the triangles have two of their angles equal.

If two triangles have two of their angles equal, the triangles are similar.

For example, these two triangles are similar:

If two of their angles are equal, then the third angle must also be equal, because the triangle \textit{always add to make 180°}.

In this case the missing angle is \(180° - (72° + 35°) = 83°\).

So AA could also be called AAA.
Augmented Reality Games

- Computer simulation on mobile device triggered by real world context
Kids Making Games
BioGraph

Graphical programming for constructing complex systems understanding in biology
Science is Not Just for Scientists Anymore...

• Current public controversies
  – Global climate change
  – Evolution and origins of life
  – Spread of emerging diseases
• Are these simulations to be believed?
• Understanding these and future issues in science and society require understanding systems and simulations
Our Primary Goal

• Enable/empower students to “think scientifically”
  – Use the tools of scientists
  – Develop the habits of mind of scientists

• Science is driven by modeling and simulation

• How do we make this accessible conceptually & technically to students?
Our Secondary Goal

• Increase interest/understanding of programming
  – Interest in **building careers** in much needed area
  – Understanding for **all users** of computers from macros to troubleshooting

• Yet, programming is on the decline
  – Programming **classes are disappearing** and relegated to those who are already interested
  – Outside of school opportunities are also scarce due to missing expertise and perceived interest
New Paradigms for New Ideas

• Traditional pedagogies and technologies make some ideas accessible

• But leave others unapproachable

“In this demonstration, the students have isolated the effect of single variables on the growth of a bean plant”

“In this experiment, the students have ignited a forest fire to study the effects of tree density on the spread of fires.”
Islands of Science

- Science is traditionally thought of as islands of topics
- We learn bits of facts within subjects, and few connections between subjects
Complex Systems Connections

- Complex systems is a way of learning that transcends particular concepts and classes
- Understanding the common themes that arise in natural, artificial, and social systems
- Improve science understanding through CS

- Complexity
- Ecology
- Genetics
- Molecular biology
- Osmosis
- Chemistry
- Energy
What Color is Your Box?

Black Box

Glass Box

• Using simulations in the classroom has a lot of benefits (e.g. Phet, Pedagogica, Gizmos)

• Getting inside of them can change classroom practice and perspective and depth of student learning
Constructivist Computational Heritage

• Seymour Papert
  – Programming/Logo
  – Learning to think through programming

• Hard fun
  – It is fun because it is hard

• Constructionism
  – Learning by creating

• New directions in a new millennium
StarLogo TNG

- Easy and Playful
- 1\textsuperscript{st} and 3\textsuperscript{rd} person perspectives
- Blurring games and simulations
Understanding Complex Systems

• Connecting individual actions to system-level behaviors

• Exploring many complex systems
  • Biological Systems
  • Social Systems
  • Etc.

• Analyzing data, assessing risk, designing and testing solutions
Cycles of Doing & Learning

Games & Simulation Cycle

- **Engineering Design**
  - Design
  - Build
  - Test/Tinker/Play
  - Observe/Collect Data
  - Generate Questions

Scientific Method

No single investigation needs to span the whole spectrum from design to building to data collection, but multiple experiences with different parts of this process contribute to an understanding of the role of simulations broadly.

Action Reflection Cycle

- **Feedback, Support, Debrief, Focus, Action, Challenging**

The Action-Reflection Cycle of Experiential Learning is a philosophical framework that closely matches much of the contemporary theory around using games in a classroom.
BioGraph Learning Model

- Develop 21st Century skills
- Learn biology concepts better
- Develop complex system and computational thinking

Predictability, Processes, Order, and Emergence and Scale
# BioGraph Sequence

Integrating biology and complex systems learning in a defined sequence (with constraints)

<table>
<thead>
<tr>
<th>Scale and Emergence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemistry of Life</td>
</tr>
<tr>
<td>Population Ecology</td>
</tr>
<tr>
<td>Evolutionary Biology</td>
</tr>
<tr>
<td>Community Ecology</td>
</tr>
</tbody>
</table>

- **Chemistry of Life**: Random Interactions of Atoms, Organization of Molecules
- **Population Ecology**: Individual Behaviors, Population Cycles
- **Evolutionary Biology**: Individual Actions, Evolution of Populations
- **Community Ecology**: Species/Environment Interactions, Ecosystem Organization

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*MIT STEP/TEA 68*
Ex: Sugar Transport (chemistry of life)

Biology Learning Objectives:
• Understand that nutrients move from the intestine through the epithelial cells into the blood stream.
• Understand that there are different types of transport proteins. Some allow nutrients to flow (facilitated transport/facilitated diffusion). Others use energy to force nutrients to flow (active and co-transport).

Complex Systems Learning Objectives:
• Understand that random processes can lead to predictable results.
“WebLogo”
Thanks to:

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