We Know More than We Can Tell: How Game-based Learning Assessments Help Students Demonstrate their Knowledge

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Today’s Perspectives

• Characterizing *implicit learning*

• Exemplar: Implicit Learning in a Physics Game

• On the horizon
Disclaimer

These opinions are our own, they are not the opinions of MIT, any of the project funders, nor (with the exception of co-authored previously published work) our collaborators

Secondary disclaimer:

“It’s tough to make predictions, especially about the future!”

~ Attributed to Woody Allen, Yogi Berra, Niels Bohr, Vint Cerf, Winston Churchill, Confucius, Disreali [sic], Freeman Dyson, Cecil B. Demille, Albert Einstein, Enrico Fermi, Edgar R. Fiedler, Bob Fourer, Sam Goldwyn, Allan Lamport, Groucho Marx, Dan Quayle, George Bernard Shaw, Casey Stengel, Will Rogers, M. Taub, Mark Twain, Kerr L. White, etc.
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Related Publications


Reprints available from: projects.informatics.mit.edu/rti
Combining Education-, Cognitive- & Information- Sciences
Characterizing Implicit Learning
Implicit Learning
What Lies Below?
We know more than we can say - Polanyi (1966)

Explicit Knowledge
- What we can say

Behaviors
- What we do
- How we respond

Implicit Knowledge
- What we know
Explicit Knowledge

External Assessments

Implicit Knowledge

Neurophysical Sensors

Data Mining Game Behaviors

Bridging
Mining Digital Games

Why?

• Games are sticky
• Digital games create digital footprints
• Reveal implicit learning through behaviors
• Inclusive assessments

How?

1. Ground games in salient phenomena
2. Use data analytics to watch implicit learning
3. Provide support for educators to bridge implicit to explicit
Implicit Learning in a Physics Game
Revealing the Invisible
Welcome to IMPULSE
Evidence of Learning

Game Behaviors

Data mining models identify when players demonstrate implicit understanding of salient phenomena
Implicit Game-Based Learning Assessments

- Human Coding and Analysis
  - Audio/Video
  - Screen capture
- Build assessment mechanics
  - Data logging
  - Data distilling
- Validate assessment mechanics
  - Pre/post tests
  - Data mining
DataArcade

Multimodal Data Architecture for Game-Based Learning Analytics
### Intended Strategic Move

<table>
<thead>
<tr>
<th>Strategic Move</th>
<th>Kappa</th>
<th>AUC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Float</td>
<td>0.738</td>
<td>0.901</td>
</tr>
<tr>
<td>Move Toward Goal</td>
<td>0.757</td>
<td>0.907</td>
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<tr>
<td>Stop/Slow Down</td>
<td>0.512</td>
<td>0.779</td>
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<tr>
<td>Keep Player Path Clear</td>
<td>0.865</td>
<td>0.967</td>
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<tr>
<td>Keep Goal Clear</td>
<td>0.772</td>
<td>0.943</td>
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<tr>
<td>Buffer</td>
<td>0.759</td>
<td>0.928</td>
</tr>
</tbody>
</table>

**EDM Findings for Game-Based Assessments of Physics Learning In Impulse**

- Mass Differentiation consistent with implicit understanding of Newton’s 1st Law
- Mass Differentiation consistent with implicit understanding of Newton’s 2nd Law
Evidence of Attention

Awareness of All Objects

Longer Fixations on Gameplay Relevant Objects

Inattentiveness to relevant game events can be used as a filter

Implicit learning may be indicated by attending longer to more gameplay critical objects
Tracking Attention in Impulse
Event Related Potentials

Error Negativity (Ne)

Negative ERP typically occurring 50-80 ms following an erroneous response

Error Positivity (Pe)

Positive ERP typically occurring 100-200 ms following an erroneous response

Feedback Error Negativity (fNe)

Negative ERP typically occurring 250-300 ms following the presentation of feedback that an error has occurred
Does player understand game mechanic?

Multimodal Research

Is player attending to the game?

Awareness of All Objects

Does player exhibit understand how to be successful in the game?

Game Behaviors

Feedback Error Negativity (fNe)

Error Negativity (Ne)

Error Positivity (Pe)

Longer Fixations on Relevant Objects

Does player understand game mechanic?
Every object in a state of uniform motion tends to remain in that state of motion unless an external force is applied to it.

- Fixate
- Potential Colliders
- Fixate Path
- Game Behaviors
- Float
- Stop/Slow
- Clear Path
- Fixate Clear Path
- Fixate Potential Colliders
- ERP
- Ne following an action leading to a collision (prior to colliding)
- Ne and Pe following an action leading to a collision (prior to colliding)
- fNe following a collision due to poorly placed impulse
- Attention

25
The acceleration of an object as produced by a net force is directly proportional to the magnitude of the net force, in the same direction as the net force, and inversely proportional to the mass of the object.
On the Horizon
Navigation and Go/No Go Task
Pilot
Pilot

• Training leads to improvements on navigation and go/no go tasks

• Will training improve learning outcomes?

• Will improvements persist for students with EF disorders?
Far Transfer

• Full four week training protocol

• Pre/post eye tracking during reading and search tasks

• Looking for fewer regressions, fewer saccades to distractors and fixation durations guided by target processing

• Improvements signal the potential for downstream gains on real-world academic tasks
Whats on Horizon

- Curricular Materials
- Tools
- Sensors
Curriculum Resources

- High-quality interactive math-and science simulations for education
  
  [PhET](https://phet.colorado.edu/)

- Games to promote scientific discovery, STEM learning, cognitive skill training, and games that explore collective over individual intelligence.

- Curriculum toolkit – lesson plans

[Center for Game Science](http://centerforgamescience.org/games/)
Curriculum Resources

- library of uniquely interactive virtual manipulatives for K-12 mathematics instruction
  
  http://nlvm.usu.edu/en/nav/vlibrary.html

- The home of the beloved Zoominis
  - Free-choice STEM learning games

  Edge.terc.edu

- STEM learning games
- Based on research from Create Labs
  (http://create.nyu.edu/)
Physiological Sensors

fNIRS

Facial Recognition

Eye-tracking EEG Headsets

Haptics/Embodied Learning

Executive Function

Emotion

Attention
Emerging Commodity Technologies

- Motion and heart-rate
- Virtual / augmented reality
- Face Tracking
- Eye tracking
- FNIR -- EEG
Commodity Technologies Available Now

Motion and heart-rate

- Measures physical activity and arousal, relevant to immersion, emotion, attention
- Decreasing size & cost
- Increasing battery life, accuracy, connectivity
- Electrodermal monitoring sensors emerging

VR, MR, and AR

- Decreasing size & cost
- Increasing portability
- Can capture body position, head position
- Offers new interaction affordances
- Emerging eye-tracking integration
VR Potential for Instruction and Information Interaction
Commodity Technologies Coming Soon

Face Tracking
- Face recognition hardware & api’s increasingly common in mobile devices
- Face tracking not yet commonly available

Eye & Gaze Tracking
- Eye tracking hardware rapidly decreasing in price
- 60Hz consumer hardware readily available
- Robustness over individuals is a challenge – may go off track
- Not for real time adaptation
Technologies On the Horizon

EEG

• Needed for measurements of memory activity
• Consumer products are emerging, but not yet much above “toy” grade

FNIR

• Research grade pricing drop significantly
• Consumer products emerging in Japan
• Pre-frontal cortex – cognitive burden, processing load
References

For More Information

Project Website:

projects.informatics.mit.edu/rti

youtu.be/5lp7Mf84saQ
edge.terc.edu

videohall.com/p/659
www.landmark.edu/institute