Developing Science Problem-Solving Skills and Engagement Through Intelligent Game-Based Learning Environments

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Intelligent Game-Based Learning Environments
Adaptive Story-Centric Games

- Game-based learning environments in which learners:
  - Participate in “story-centric” problem-solving activities
  - Immerse themselves in tailored narratives
- Revolve around:
  - Believable characters
  - Expansive virtual worlds
  - Rich stories
Intelligent Tutoring in Game-Based Learning Environments

- Affect-rich characters
- Problem-solving guidance
- Context-sensitive feedback
- Dynamic problem selection
- Tailored explanations
Research Question

How can intelligent game-based environments promote *problem solving* and *engagement* in STEM learning for upper elementary students?
CRYSTAL ISLAND – Upper Elementary Science

Subject
- 5th grade science
- Standards aligned

Content
- Landforms
- Maps, models & navigation

Story
- Adventurous adolescent
- Shipwrecked crew
- Complete quests to explore island
Click for Crystal Island Year 2 Walkthrough Video
Virtual Tablet
IslandPedia App
Problem-Solving Guidance

Here are some suggested problem solving strategies. Choose one that you think will help you.

- Guess and Check
- Make an organized list
- Draw a picture or a diagram
- Look for a pattern
- Solve a simpler problem
Markov Logic Network
Goal Recognition Framework

- Machine learning techniques for detecting students’ problem-solving goals
- Goal recognition models introduce opportunities for tailoring problem-solving guidance
- 82% improvement over baseline approaches

E. Ha, J. Rowe, B. Mott, & J. Lester, Goal Recognition with Markov Logic Networks for Player-Adaptive Games, Proceedings of the 7th Conference on Artificial Intelligence and Interactive Digital Entertainment, pp. 32-39, 2011.
Predicting Student Emotions

Game-Based Learning Studies
Classroom Studies

Scaffolding Study
- Onsite at 4 schools
- 379 fifth grade students
- 52% Caucasian, 25% African American, 11% Latino, 12% Other
- 2x2 factorial experiment comparing alternate in-game scaffolding methods

Curriculum Integration Study
- Onsite at 8 schools
- 831 fifth grade students
- 62% Caucasian, 14% African American, 8% Asian, 16% Other
- Teacher-driven implementation in classrooms
## Findings

- **Significant learning gains**

**Scaffolding**
- Pre-test \( (M=12.3, SD=3.8) \)
- Post-test \( (M=13.0, SD=4.0) \)
- \( t(330)=5.70, p<.01 \)

**Curriculum Integration**
- Pre-test \( (M=11.8, SD=4.1) \)
- Post-test \( (M=13.6, SD=3.7) \)
- \( t(716)=17.70, p<.01 \)

- Significant gains replicated across multiple classroom studies.

- Greater learning gains observed in teacher-driven implementations.
Curriculum Integration Findings

- Significant gains on problem-solving model application task, $t(713)=3.72, p<.01$
- Significant gains in science self-efficacy, $t(713)=7.06, p<.01$
- Significant gains in landforms self-efficacy, $t(713)=6.77, p<.01$
- Significant correlation between mastery approach goal orientation and curriculum post-test, $r=.31, p<.05$
Future Directions

- Adaptive quest generation and sequencing
- Embedded assessment capabilities
- Dynamic explanation generation and feedback
- Enhanced collaboration functionalities
- Emotionally adaptive virtual characters
- Extended classroom deployments
Conclusions

- Game-based learning environments can produce significant STEM learning gains.
- Game-based learning environments can be effectively deployed in classrooms with standards-aligned curricula.
- Game-based learning environments hold considerable promise for promoting significant content learning gains, problem solving and sustained engagement.
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# Findings

## Significant Bivariate Correlations with Curriculum Post-test by Study

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<thead>
<tr>
<th></th>
<th><strong>Scaffolding Study</strong></th>
<th><strong>Curriculum Integration Study</strong></th>
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</thead>
<tbody>
<tr>
<td><strong>Self-Efficacy</strong></td>
<td>Science self-efficacy (r = .37)</td>
<td>Landform self-efficacy (r = .33)</td>
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<td></td>
<td>Models self-efficacy (r = .28)</td>
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<tr>
<td><strong>Goal Orientation</strong></td>
<td>Mastery approach (r = .29)</td>
<td>Mastery approach (r = .31)</td>
</tr>
<tr>
<td><strong>Performance Attribution</strong></td>
<td>Effort (r = .13)</td>
<td>Effort (r = .23)</td>
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<tr>
<td><strong>Quests Completed</strong></td>
<td>Total quests completed (r = .44)</td>
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</tbody>
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* All findings significant at p < .05