Immersive Game-based Learning for Middle Grade Computational Fluency

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Game-based Learning Environments

- Interplay of cognition and affect
  - Performance impacts affective states
  - Affective states impact performance

- Long term effects
  - Motivation
  - Self-efficacy

- Supporting motivation
  - Natural component of tutoring
  - Keystone of effective learning
Personalized Game-based Learning Conjecture

Affect-Informed AI + Games Technologies → Highly Motivated, Highly Effective Learners
Narrative-Centered Learning Environments

- Game-based learning environments in which learners:
  - Actively participate in “story-centric” problem-solving activities
  - Immersed in captivating, highly tailored narratives

- Revolve around:
  - Believable characters
  - Compelling virtual worlds
  - Rich stories
CRYSTAL ISLAND
CI: Introduction

1. Student plays the role of a new visitor to the island.

2. Student discovers that several team members have fallen sick.

Kim:

Thank goodness, you’re here. I’m Kim, the camp nurse.

People on the island are getting sick, and we don’t know why. Please, can you help us?
3. Student views microbiology-themed posters.

4. Student reads books about different types of pathogens.
5. Student gathers clues from sick team members.

6. Student asks the camp’s pathogen experts about microbiology concepts.

Teresa:

Every morning I eat some eggs, toast, and have a glass of milk.

Robert:

Bacteria are the smallest type of living organism, as small as 200 nanometers. They’re bigger than viruses, but still very small.
7. Student conducts tests using laboratory equipment.

8. Student interacts with the lab technician to view microscopic images of pathogens.
9. Student records findings using portable communicator device and a diagnosis worksheet.
10. Student presents findings and recommended treatment to camp nurse.
Example Study of Learning & Engagement

- 153 middle school participants used Crystal Island
  - 13.3 years old (SD = 0.48)
  - 50% Caucasian, 32% African American, 13% Hispanic or Latino, 5% Other

- Secondary analysis from a study investigating scaffolding in narrative-centered learning environments
Study Procedure

- **Measures**
  - Microbiology content pre-test and post-test
    - 16 multiple-choice questions
    - 8 factual questions,
      8 application questions
    - Created by interdisciplinary team of researchers
  - Presence Questionnaire
  - Perceived Interest Questionnaire
  - In-Game Score

- **Intervention**
  - CRYSTAL ISLAND
  - Sessions lasted until:
    - Student completed scenario, OR
    - 60 minutes elapsed
Presence Questionnaire

- 32-items, divided among three subscales [Witmer & Singer, 1998]
  - Involved/control
  - Naturalism of experience
  - Interface quality
- Measured on 7-point Likert scale

**Example Items:**

*How compelling was your sense of moving around inside the virtual environment? [Involved/Control]*

*How much did your experiences in the virtual environment seem consistent with your real-world experiences? [Naturalism]*

*How much did the visual display quality interfere or distract you from performing assigned tasks or required activities? [Interface Quality]*
Situational Interest

- Adapted from Perceived Interest Questionnaire [Schraw, 1997]
- 10 items measured on a 5-point Likert scale

Example Items:

- I got absorbed playing Crystal Island without trying to.
- I thought Crystal Island's topic was fascinating.
- Crystal Island really grabbed my attention.
In-Game Score

- **Rewards:**
  - Efficient goal completion
  - Demonstration of content knowledge
  - Deliberative hypothesis formulation and testing

- Penalizes guessing and "gaming the system"
- Presented in upper-left corner of screen

<table>
<thead>
<tr>
<th>Action</th>
<th>Points (pts)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Overall Mystery Solution</strong></td>
<td></td>
</tr>
<tr>
<td>Correct Solution</td>
<td>500 pts</td>
</tr>
<tr>
<td>Solution Efficiency</td>
<td>(7500 / elapsed time) pts</td>
</tr>
<tr>
<td>Incorrect Solution Attempt</td>
<td>-100 pts</td>
</tr>
<tr>
<td><strong>In-game Quiz Questions</strong></td>
<td></td>
</tr>
<tr>
<td>First Attempt Correct</td>
<td>25 pts</td>
</tr>
<tr>
<td>Second Attempt Correct</td>
<td>10 pts</td>
</tr>
<tr>
<td>Second Attempt Incorrect</td>
<td>-10 pts</td>
</tr>
<tr>
<td><strong>Object Contaminant Testing</strong></td>
<td></td>
</tr>
<tr>
<td>Test Milk for Pathogens</td>
<td>200 pts</td>
</tr>
<tr>
<td>Incorrect Object</td>
<td>-10 pts</td>
</tr>
<tr>
<td>Incorrect Contaminant</td>
<td>-25 pts</td>
</tr>
<tr>
<td><strong>Character Interactions</strong></td>
<td></td>
</tr>
<tr>
<td>Talk to Kim</td>
<td>(25 / elapsed time) pts</td>
</tr>
<tr>
<td>Talk to Teresa</td>
<td>(50 / elapsed time) pts</td>
</tr>
<tr>
<td>Talk to Ford</td>
<td>(125 / elapsed time) pts</td>
</tr>
<tr>
<td>Talk to Robert</td>
<td>(125 / elapsed time) pts</td>
</tr>
<tr>
<td>Talk to Quentin</td>
<td>(125 / elapsed time) pts</td>
</tr>
<tr>
<td><strong>Pathogen Labeling Activities</strong></td>
<td></td>
</tr>
<tr>
<td>Correct Answer</td>
<td>10 pts</td>
</tr>
<tr>
<td>Incorrect Answer</td>
<td>-10 pts</td>
</tr>
<tr>
<td><strong>Total Maximum Points</strong></td>
<td>~ 1665 pts</td>
</tr>
</tbody>
</table>
Findings

- Significant learning gains

- Learning gains independent of gender (i.e., no gender effect observed)

- Engagement significantly associated with learning
  - Contrasts with view that places engagement and learning at odds with one another
  - Relationship is independent of background knowledge and game-playing characteristics
Narrative-Centered Learning
CRYSTAL ISLAND for New Student Populations and Subject Matters

CRYSTAL ISLAND — Middle School Microbiology

CRYSTAL ISLAND — Elementary School Landforms

CRYSTAL ISLAND — Middle School Literacy

CRYSTAL ISLAND — Middle School Computational Thinking
CRYSTAL ISLAND: ENGAGE

- Middle-grade CS Principles focus
- Compelling computational challenges arise organically within storyworld
- Narrative game-based environment supports relevance and connecting computing
Learning Computing in a Game-Based Environment

- Societal Relevance of Computing
  - Compelling narrative

- Collaboration and Creativity
  - Teamwork in “real” and virtual worlds
ENGAGE Scenario #1

The team learns that pirates aim to breach the network in hopes of intercepting communications about the location of valuable supplies. Secure the network against pirate attacks by implementing encryption.

Computing topics:
- Iterative algorithm design
- Security and privacy
- Mathematics of computing

CS Principles “Big Ideas”:
- Digital devices, systems, and networks
- Cybersecurity
- Algorithm design
- Representation, storage, security, and transmission
ENGAGE Scenario #2

Analyze population trends for the Amber Warbler, an endangered bird on the island.

Computing topics:
• Visualizing data
• Iterative algorithm design

CS Principles “Big Ideas”:
• Modeling & abstraction
• Data & information create knowledge
• Computing enables innovation in other fields
ENGAGE Scenario #3

A mineral deep inside Crystal Island’s cave system is believed to be contaminating the water supply on the island. The cave cannot be safely traversed by humans.

Task: Develop an algorithm for a robot to traverse the cave system and take samples of the mineral.

Computing topics:
• Evaluating algorithms
• Ethical issues in innovation

CS Principles “Big Ideas”:
• Programs created to help
• Algorithm efficiencies
• Impact of computing
Integrating Games and Computer Science Problem Solving

Integrated problem-solving environment:
- Algorithm design
- Implementation framework
- Data analysis & visualization
Strategic Challenges

- Curriculum design with multiple goals:
  - Learning, motivation, diversity short-term
  - Continued study of computing long-term
  - Adoption in middle schools (integrate with other STEM curricula?)
- ENGAGETOTEACH professional development
- Assessment
Asking the Questions

- What is the educational innovation?
  Games and gaming
- Who are the actors?
  Teachers and students
- What is the context?
  Computers and mobile computing devices in traditional classrooms
Context

Teacher - Student - Instructional Platform - Classroom

Computing Device
Gaming Environment
Curricular Content
Student+Instructional Platform

Framework: Learning the result of rich cognitive and affective interactions

- Learning
- Engagement
- Motivation
- Self-Efficacy
- Usability and Usefulness

Computing Device
Gaming Environment
Curricular Content

Behavior Trace Data
Teacher

Cognitive Components

- Technological Knowledge (TK)
- Pedagogical Knowledge (PK)
- Content Knowledge (CN)

TPACK

Mishra & Koehler, 2006

Affective Response
Framework:
Human Factors-Organizational Psychology Model of People / Technology / Organizational Interaction
Measures

- Students
  - Affect
    - Surveys
    - Interviews
  - Cognition
    - Embedded Assessment
    - Pre-Post
  - Instructional Platform
    - Log data for affective and cognitive outcomes

- Teachers
  - Affect
    - Surveys
    - Interviews
  - Cognition
    - TPACK

- Classroom
  - Video
  - Interviews
**Benefits of Game-Based Learning for CS Principles**

**Hypotheses**
1. Learning
2. Computing self-efficacy and interest
3. Engagement
4. Particularly for women, underrepresented minorities, and low SES

**Design**
- Treatment condition: *Game-based learning*
- Control condition: *Traditional classroom*
- Diversity: SES, ethnicity, gender, urban vs. rural, achievement levels

**Dependent Variables**
- CS Principles content knowledge
- Self-efficacy
- Goal orientation
- Computer science attitudes
- Engagement
Concluding Remarks

- Game-based learning environments hold significant potential for developing computational thinking
- Effective learning will emerge from the artful integration of cognition and affect in gaming technologies
- Future plans for scaling from the classroom to national adoption

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