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

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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

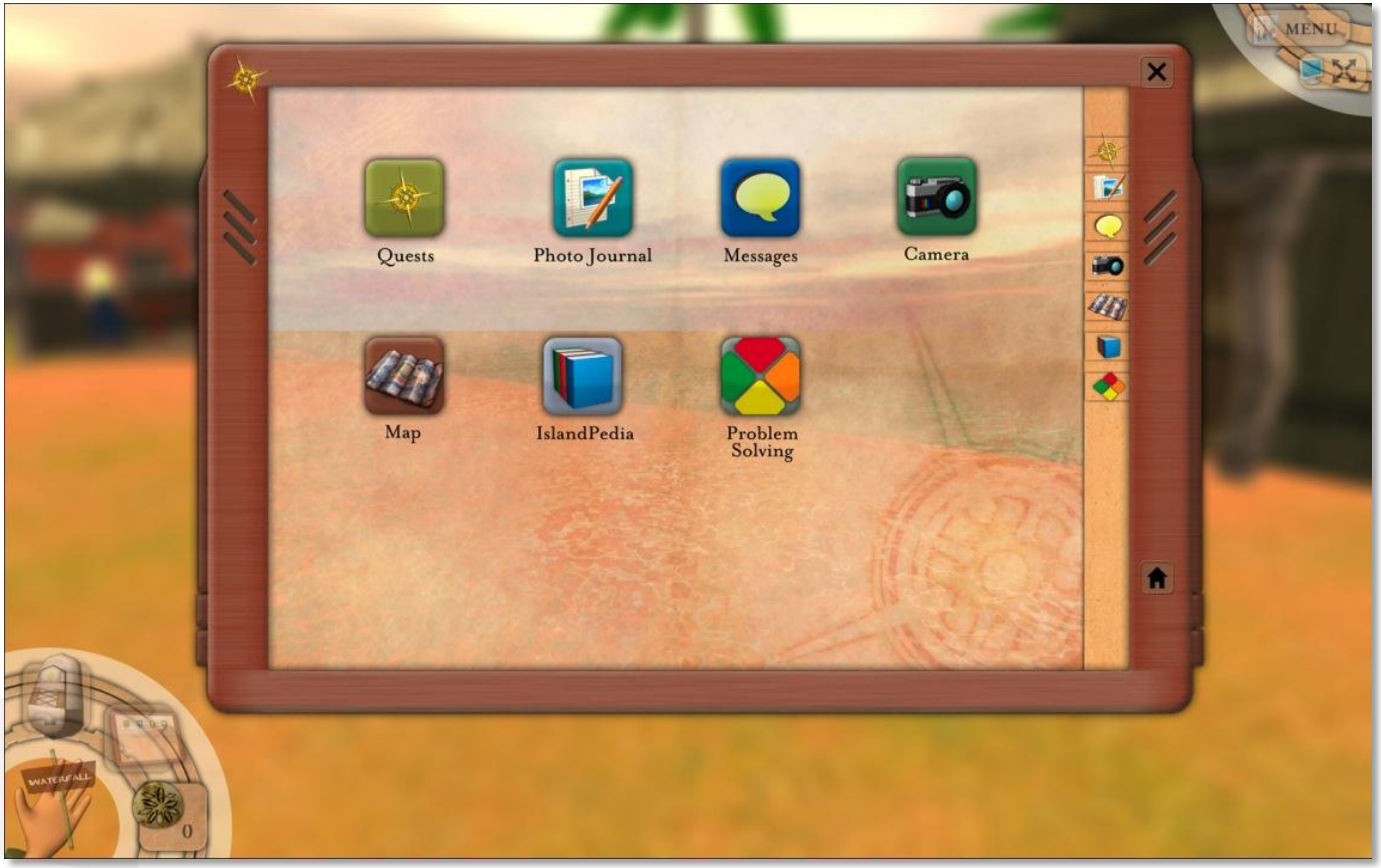
Content
- Landforms
- Maps, models & navigation

Story
- Adventurous adolescent
- Shipwrecked crew
- Complete quests to explore island

Crystal Island Video

Click for Crystal Island Year 2 Walkthrough Video

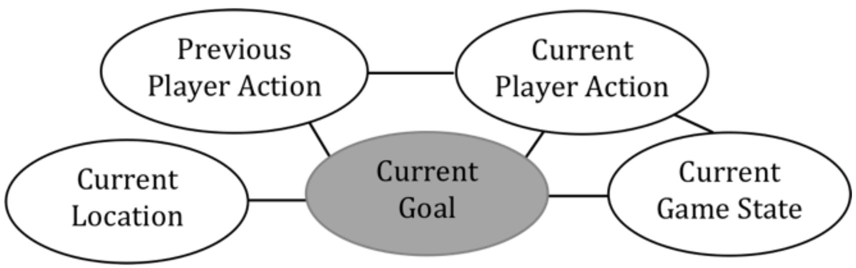
Virtual Tablet



IslandPedia App

Problem-Solving Guidance

Markov Logic Network
Goal Recognition Framework

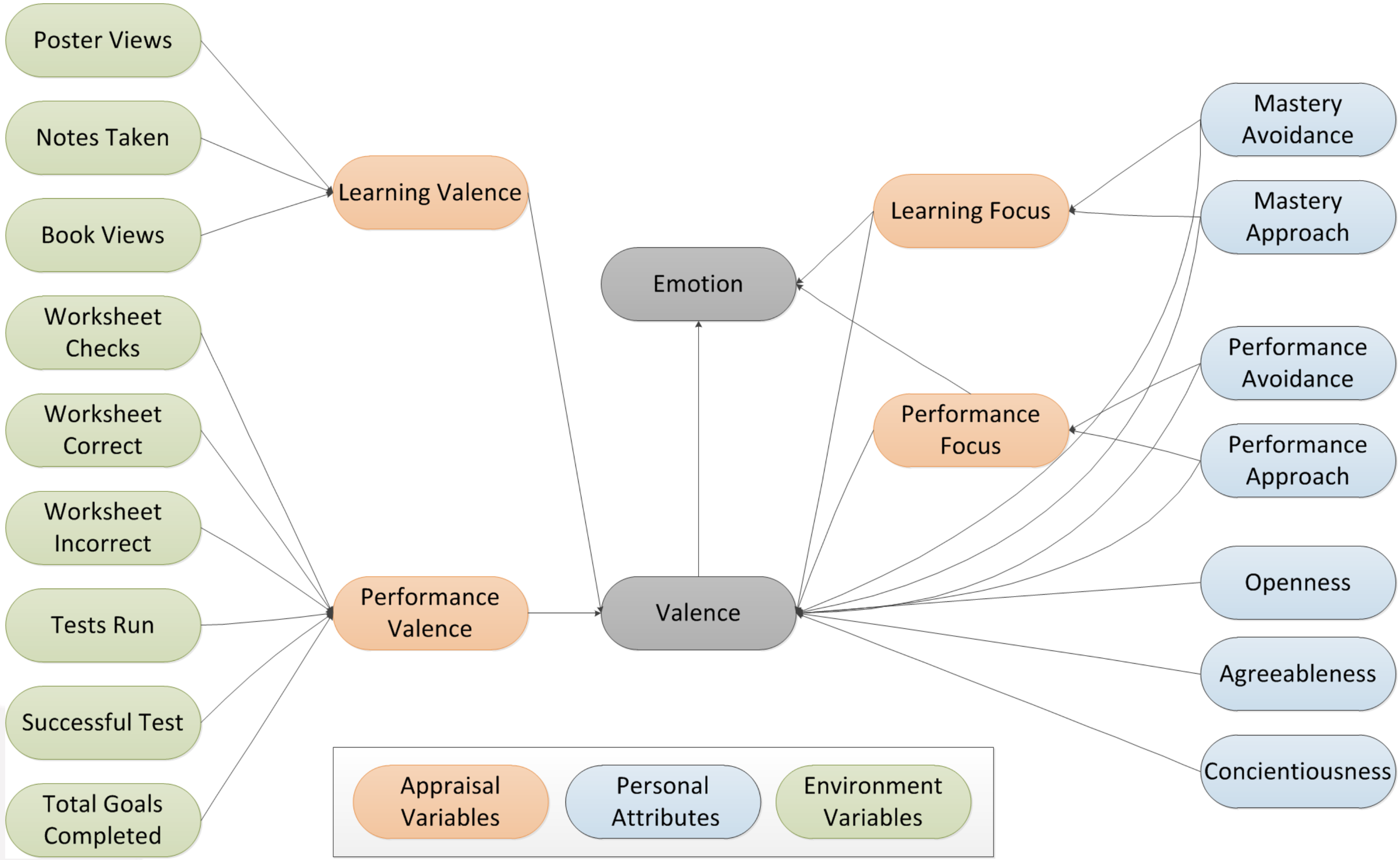


Formulae	Weights
$\forall\, t,a,g : action(t,a) \Rightarrow goal(t,g)$	0.7
$\forall\, t,a,s,g : action(t,a) \wedge state(t,s) \Rightarrow goal(t,g)$	1.5
$\forall\, t,a_1,a_2,g : action(t,a_1) \wedge action(t-1,a_2) \Rightarrow goal(t,g)$	2.3
…	…

- 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



J. Sabourin, B. Mott, & J. Lester, Modeling Learner Affect with Theoretically Grounded Dynamic Bayesian Networks, Proceedings of the 4th Intl. Conference on Affective Computing and Intelligent Interaction, pp. 286-295, 2011.

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

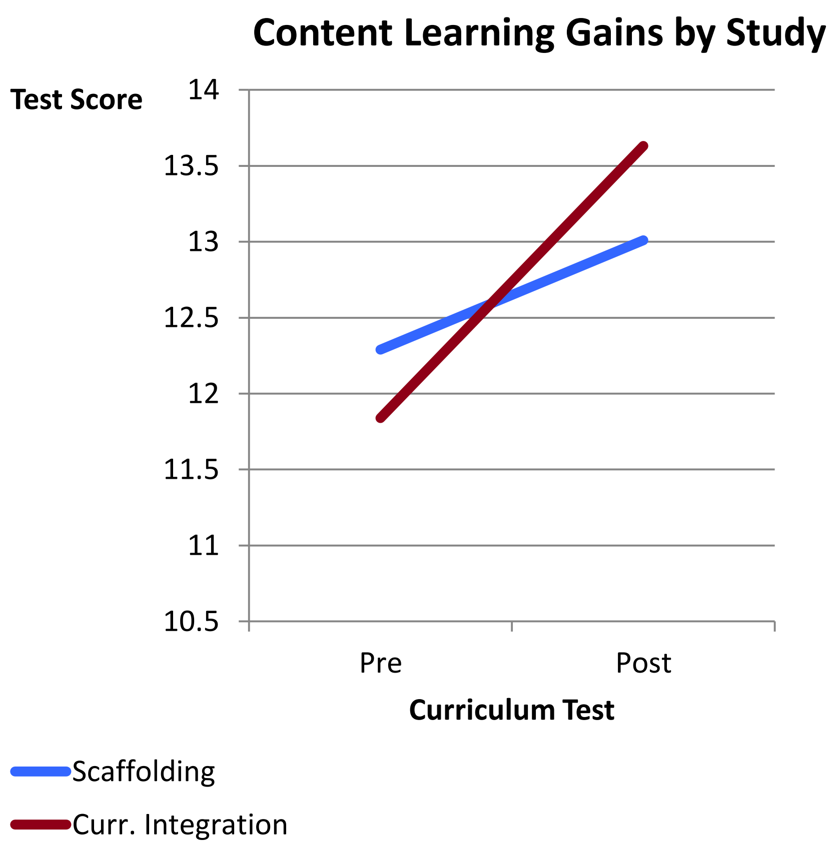
Findings

- 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.



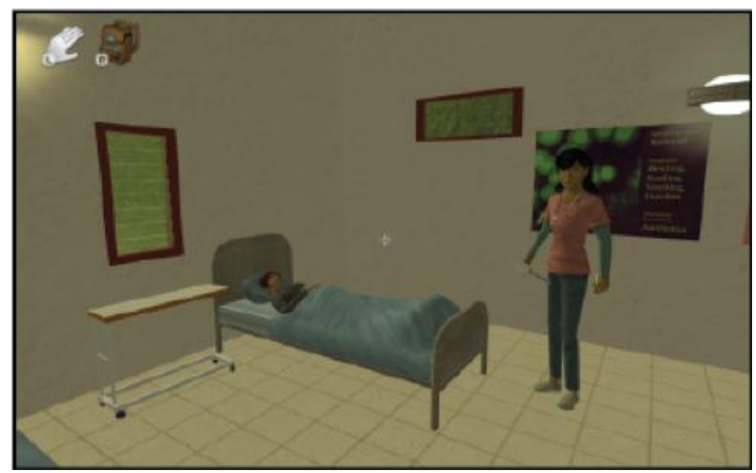
Curriculum Integration Findings

- 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, $r=.31$, $p<.05$

CRYSTAL ISLAND
Elementary School Landforms

CRYSTAL ISLAND
Middle School Microbiology

CRYSTAL ISLAND
Middle School Science & Literacy



CRYSTAL ISLAND
Middle School Computational Thinking

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

	Scaffolding Study	**Curriculum Integration Study**
Self-Efficacy	Science self-efficacy (r = .37)	Landform self-efficacy (r = .33) Models self-efficacy (r = .28)
Goal Orientation	Mastery approach (r = .29)	Mastery approach (r = .31)
Performance Attribution	Effort (r = .13)	Effort (r = .23)
Quests Completed	Total quests completed (r = .44)	

* All findings significant at $p < .05$