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Investigating an Intelligent Cyberlearning System for Interactive Museum-based Sustainability Modeling

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Abstract

This project will develop a prototype intelligent cyberlearning platform for middle school audiences at a science museum location to test and evaluate the use of virtual learning technologies. The educational subject for this demonstration project is sustainability, and the project's goal is to facilitate children's development of a conceptual model of the environment that incorporates the relationship between human activity and the physical, chemical, and biological processes within an environment. The prototype cyberlearning system will engage users in sustainability science issues that involve an examination of cause and effect relationships and systems modeling. Users will explore energy flows and conservation issues while gaining an appreciation for stability and change over time by exploring alternate courses of action within Future Worlds's virtual environment.

The prototype intelligent cyberlearning system will integrate an agent-based modeling simulation of environmental, social, and economic phenomena with three advanced learning technologies: game-based learning systems, intelligent tutoring systems, and narrative-centered learning systems. The game-based and narrative aspects of the project are embodied in the interactive time-travel focus of the 3D display on a multi-touch surface computing table. Users will play the role of environmental scientists who have been charged with helping earth become a sustainable, thriving planet. Users will travel through time to examine the consequences of their environmental decisions and explore alternate paths. The intelligent tutoring system will track user's problem-solving activities in the simulated world. As users make decisions, the intelligent tutoring system will draw inferences about their level of understanding of key environmental concepts within the themes of energy, water, and food. Given the current problem-solving goal (e.g., reduce carbon emissions) and the current state of the environment (e.g., climatological state, human population, factory emissions), the intelligent tutoring system will draw on its knowledge of common environmental misconceptions to assist students as they progress through a branching sustainability narrative. The intelligent tutoring system will receive the updated state from the agent-based simulation, which will then provide explanatory comments and feedback through an animated pedagogical agent. Similarly, during the course of decision-making, users will be able to request advice, and the same computational framework will drive the pedagogical agent's advice generation capabilities.

The project will design, develop, deploy, and evaluate the prototype intelligent cyberlearning platform for sustainability. Because all users interactions will be accompanied by an animated pedagogical agent who will narrate their journeys and offer problem-solving advice, users will be afforded rich learning opportunities that support independent inquiry but also provide guided exploration of complex science topics. With a focus on group learning experiences in an out-of-school setting, the animated pedagogical agent will answer questions that engage groups of users in a collaborative effort to understand the dynamics of rich environmental systems that impact sustainability. The project will demonstrate the transformative potential of intelligent cyberlearning systems that integrate agent-based modeling with game-based learning, intelligent tutoring systems, and narrative-centered learning in an out-of-school setting to enable users to experience science in fundamentally new ways.

Research Objective

Develop and evaluate a prototype intelligent cyberlearning platform focused on sustainability in a science museum setting for middle school audiences.

Educational Strategy Games

Civilization V, Take-Two Interactive Software

Budget Hero, American Public Media

ElectroCity, Genesis Energy

Energyville, Chevron Corporation

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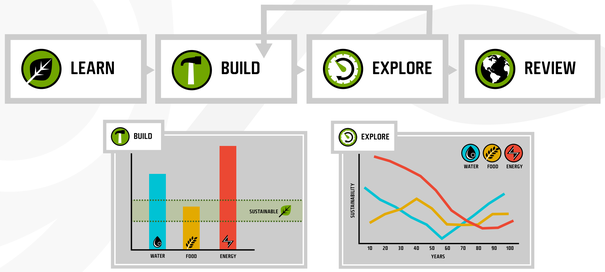
Research Thrusts

- Create a prototype intelligent cyberlearning platform for sustainability education.
- Develop and deploy a prototype intelligent sustainability cyberlearning museum exhibit.
- Evaluate the impact of the intelligent cyberlearning platform on sustainability education in a science museum setting.

Research Areas

- Adaptive pedagogy
- Tutorial planning
- Pedagogical agents
- Learning effectiveness
- Agent-based modeling
- Multimodal interfaces
- Explanation generation
- Narrative planning
- Game-based learning
- User modeling
- Individual differences
- Narrative-centered learning
- User engagement
- Surface computing



Design-Based Research

"Test-beds for innovation whose intent is to investigate the possibilities for educational improvement by bringing about new forms of learning in order to study them."
(Cobb, et al., 2003, p. 10).

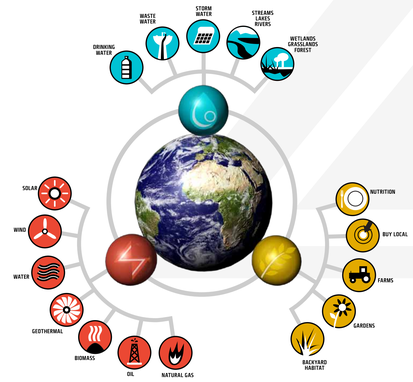
- Pragmatic
- Grounded
- Interactive
- Iterative & flexible
- Integrative
- Contextual

Future Worlds Learning Environment

- Subject Matter: Sustainability
- Environmental Themes: Energy, Food, Water
- Goal: Given an unsustainable environment, re-configure the environment to make it sustainable
- Genre: God game with real-time strategy elements
- Participants:
  - Manipulate simulation variables using a surface computing (touch-based) interface
  - Explore and analyze effects of human behavior on sustainability
  - Move through time to observe effects of human behavior on the environment
  - Receive guidance and feedback from an animated pedagogical agent

Issues of Sustainability

WATER	Drinking water	Clean drinking water supply
	Wastewater	Treatment; Discharge to local water bodies
	Stormwater	Contaminated runoff; Flooding due to impervious cover
	Streams/lakes and rivers	Eutrophication; General pollution/contamination; Overfishing and its effect on food supply Importance of wetlands/grasslands and forests Habitat destruction, Natural Cleansing Process; Environmental engineers mimic environmental processes
	Groundwater	Hydro fracturing (for natural gas extraction) and local water supply, Groundwater contamination of nitrates from petroleum based fertilizers due to farming practices; Failing septic systems leading to high bacteria counts in well water
	Oceans	Acidification and sea-level rise; Dead zones due to high nutrient loads; Ballast water from ships introducing invasive species
FOOD	Land-use	A diet rich in meat and dairy requires more land to support than a traditional diet of grains
	Buy-local	Trade-off between buying local and non-local
	Farms/farming practices	Impacts of fertilizers, herbicides, and other chemicals on human health, aquatic ecosystems, local water quality, etc.
	Gardens	Inner city green spaces; food miles
	Backyard habits	Promotes education; naturalized neighborhoods.
NON-RENEWABLE ENERGY	Coal	Mining, Acid mine drainage
	Natural gas	Hydro fracturing (for natural gas extraction) and local water supply; Habitat destruction
	Oil and petroleum products	Impacts of extraction and refining; National security threats; Environmental contaminants introduced into the atmosphere; Time required for the earth to replenish these fuel sources
	Uranium (nuclear)	Nuclear waste generation; Water use during nuclear power generation; Local water contamination from power plant discharge
	Global warming	Carbon Footprint
RENEWABLE ENERGY	Solar	Payback period; Efficiency
	Geothermal	Various types; Concept of available energy from geothermal sources
	Hydroelectric	Impact on surrounding aquatic life
	Biomass	Land-use for food versus fuel versus habitat
	Wind	Wind quantities; Effects on local habitats (birds)
	Global warming	Environmental trade-offs



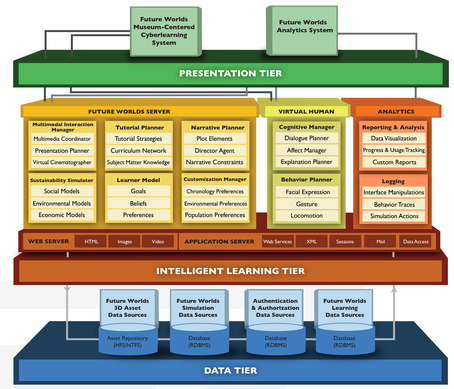
Future Worlds Implementation

- Virtual environment: Unity 3D Game Engine
- Multimodal interface: Microsoft Surface SDK and Runtime
- Platform: Samsung SUR40 for Microsoft Surface

Animated Pedagogical Agent

- Personalized tutorial support
- Customized problem-solving advice
- Cognitive and affective scaffolding
- Multimodal explanations and feedback
- Emotional expression generation
- Gesture planning and coordination
- Locomotion and animation planning
- Dialogue planning

Future Worlds Architechture



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