Intelligent Narrative-Centered Learning Environments

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AI-Enriched Learning
Personalized Learning Assistants for Lifelong Learning
One-on-One Tutoring
Design Challenge

“Provide a teacher for every learner”

- Learn at their own pace
- Receive continuous, customized and meaningful feedback and assessment
- Acquire new skills in a way that is compelling and engaging
Design Challenge

“... provide learning environments that approach the effectiveness of one teacher for every learner. Such systems, properly used, can produce a significantly better-educated populace by combining advances in learning sciences with advances in information technology.”
Narrative-Centered One-on-One Learning
Personalized Learning Hypotheses

Intelligent Story + Pedagogical Agents

Motivational Support

Growth Mindset

Interest

Persistence

Learning

Cognitive Support

Growth Mindset

Interest

Persistence

Learning
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
Affect-Rich Learning Environments

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

- Supporting affect
  - Natural component of tutoring
  - Keystone of effective learning

- Long term effects
  - Motivation
  - Self-efficacy
Intelligent Tutoring in Game-Based Learning Environments

- Affect-rich characters
- Problem-solving guidance
- Context-sensitive feedback
- Dynamic problem selection
- Tailored explanations
Crystal Island Narrative-Centered Learning Environment

- **Curricular Focus**
  - Eighth grade microbiology
  - NC Standard Course of Study

- **Story**
  - Investigate outbreak on remote island
  - Recover notes from earlier investigation
  - Identify illness and recommend treatment

- **Evolution**
  - ~10 years iterative refinement
  - Many laboratory and classroom studies
Crystal Island: Lost Investigation

1. Design a suite of intelligent game-based learning environment technologies for middle grade science + literacy education.

2. Create an implementation program to provide an account of middle grade students’ acquisition of science and literacy skills as they interact with intelligent game-based learning environments.
Tailoring Events in Narrative-Centered Learning Environments

- Game elements have dual roles
  - Pedagogical
  - Narrative

- Multiple forms of narrative-centered tutorial events
  - Side quests for knowledge remediation
  - Narrative events for embedded assessment

- Dynamically tailored sequences of embedded assessments
Explore Virtual Environment
Laboratory Equipment
Diagnosis Worksheet
Informational Texts

What is a Mutagen?

The genetic change in an organism caused by a physical or chemical agent is called a mutation. The physical or chemical agent is called a mutagen. Not all mutations are caused by mutagens. A naturally occurring mutation may occur because of an error in DNA replication. This is called spontaneous mutation.

Mutagens may cause cancer. An agent that causes cancer is called a carcinogen. A carcinogen may be mutagen, and a mutagen may be a carcinogen.

History of Mutagens

Hippocrates first studied physical changes in living things around 500 B.C. He observed tumors and called them karikinos, which is the word that cancer is derived from. Genetic changes were first linked to mutagens in 1927. Hermann Muller discovered that electromagnetic radiation, commonly called x-rays, could cause genetic mutations in fruit flies. The next generation of fruit flies had a clear change in the chromosomes from the parental chromosomes.

It was later shown that the use of x-rays also could change the genetic makeup of humans too. It was not until the 1940s that chemicals, like x-rays, were shown to cause mutations in living cells. These first studies were also done on fruit flies.

Types of Mutagens

Mutagens may be found as physical, chemical, or biological agents. An example of a physical mutagen is radiation, such as x-rays or gamma radiation. Chemicals, such as benzene or arsenic, may also create changes to DNA, as well as processes associated with DNA replication.

DNA is the basic genetic code of a cell. Biological agents, which can act as mutagens, include viruses and bacteria. For example, a virus can insert its DNA into a cell and cause problems for the cell. Some bacteria may also cause mutations by interfering with cellular
Informational Texts

What is a Mutagen?

The genetic change in a living organism, as well as a change in the chromosome from the parental heredity, is caused by a physical or chemical agent. Mutagens may occur naturally in the environment. They may be caused by mutation, which is a genetic change. Mutagens cause cancer, and the genetic change may be a carcinoma.

History of Mutagens

Hippocrates discovered the concept of mutation in 350 B.C. He termed it neoplasia, which means that cancer is derived from genetic changes. In 1927, Wilhelm Knorre discovered the concept of radiation, called x-rays, which could cause genetic mutations in fruit flies. The next generation of fruit flies had a clear change in the chromosomes from the parental heredity.

It was later shown that the use of x-rays also affects the genetic makeup of humans. Not until the 1940s that chemicals, such as benzene and arsenic, were shown to cause mutations in cells. These first studies were also done on fruit flies.

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**Concept Matrices**

<table>
<thead>
<tr>
<th>Mutagen</th>
<th>Mutagen</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Definition</strong></td>
<td>Causes genetic change</td>
</tr>
<tr>
<td><strong>Characteristic</strong></td>
<td>May be a carcinogen</td>
</tr>
<tr>
<td><strong>History</strong></td>
<td>Studied with Fruit Flies</td>
</tr>
<tr>
<td><strong>Scientist</strong></td>
<td>Hermann Muller</td>
</tr>
<tr>
<td><strong>Example</strong></td>
<td>Radio waves</td>
</tr>
</tbody>
</table>

**What is a Mutagen?**

The genetic change in an organism brought about by a physical or chemical agent is called a mutation. The physical or chemical agent is called a mutagen. Not all mutations are caused by mutagens. A naturally occurring mutation may occur because of an error in DNA replication. This is called spontaneous mutation.

Mutagens may cause cancer. An agent that causes cancer is called a carcinogen. A carcinogen may be a mutagen, and a mutagen may be a carcinogen.

**History of Mutagens**

Hippocrates first studied physical changes in living things around 500 B.C. He observed tumors and called them karkinos, which in Greek means crab. The word that cancer is derived from. Other changes were first linked to mutagens. Hermann Muller discovered that electromagnetic radiation, common x-rays, could cause genetic mutation.
Multimodal Character Dialogues

Ford:
Virus structures have only a capsid and genetic material. They are NOT cells, so they have a very different structure than cells.

Your Response:
What are viruses?
How large are viruses?
What shape are viruses?
What structure do viruses have?
Are viruses alive?
Nevermind.
Adapting to Affect in in Narrative-Centered Learning

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Empathetic Scaffolding in Narrative-Centered Learning

Elise: I’m a visitor here too, like you. A few years ago I was on another remote research station where an illness broke out, and I helped solve the mystery. I learned a lot about how to solve science problems! I’ll hang out with you and we can figure out why people are getting sick.

Elise: Here we are, back in the lab.

Student: Ugh, negative again.

Student: I was sure it was a virus! I’m terrible at science.

Elise: Even the best scientists in the world have to put lots of effort into solving science problems because it’s hard. But every time, you learn and get better at it.

Elise: Now let’s talk through what we already know, ok?

Student: Ok.

Student: self-explains, and then works with Elise to gather remaining data and solve the problem.
Wizard-of-Oz Narrative-Centered Learning Studies

Multimodal Sensors
- Facial video camera
- Galvanic skin conductance-recording bracelets
- Depth camera
- Gaze tracker
- Microphone

Dialogue Moves
- Wizard selects one of six dialogue act categories.
- Wizard chooses from a predefined set of utterances for the chosen dialogue act category.
Dialogue Act Modeling in Narrative-Centered Learning

- **Story Interaction**
- **Narrative trace logs**
- **Action unit trace logs**
- **Multimodal data stream**
- **FACET**
- **Dominant hand**
- **Galvanic skin response trace logs**
Embedded Assessment in Narrative-Centered Learning
Narrative-Centered Learning Analytics

- Real-time trace data
- Window into student motivation
- Triangulation: learning processes + outcomes
- Designing for scale
ENGAGE: Game-based Learning for Middle School Computational Thinking

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ENGAGE: Game-based Learning for Middle School Computational Thinking

Curriculum
- Middle school computer science education
- AP Computer Science Principles

Platform
- Unity game engine
- FLARE user interface toolkit
  [Mott et al., 2014]
Design Challenge Reformulated

Affect-Informed AI

Game-Driven Interactive Narrative

Highly Motivated, Highly Effective Learners
Intelligent Narrative-Centered Training

- Rich personalized story-centered training driven by AI
- Example: Collaboration with ARL and Columbia University
- Leverage machine learning to induce models
  - Integrate trace data, sensor data, and field observations of trainee emotions
  - Predict emotions accurately and efficiently

Source: www.ecsorl.com
Affect Detection in Combat Medic Training

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Affect-Informed Learning in Narrative-Centered Training

Affect Recognition
- Self-efficacy
- Emotional State
- Frustration

Affect Understanding
- Informed Pedagogical Planner

Affect Expression
- Empathy
- Pedagogical Intervention

Student
Narrative-Centered VR Training for First Responders
DeepGen: Reinforcement Learning-based Training Scenario Generation

- Automated scenario generation is invisible to learners
- Training scenarios are dynamically tailored to learner traits, knowledge, and performance
- Scenario generation improves as more data is provided to DeepGen
Narrative-Centered Learning

- Narrative Tutorial Planning
- Real-Time Narrative Planning
- Goal Recognition
- Character Dialogue Generation
- Off-Task Behavior
- Self-Regulated Learning
- Presence
- Note-Taking
Narrative-Centered Learning
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Goal Recognition in Narrative-Centered Learning
Narrative-Centered Learning
Narrative-Centered Learning
Narrative-Centered Learning
Narrative-Centered Learning
Narrative-Centered Learning
Narrative-Centered Learning in Informal Learning Contexts

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Multimodal Narrative-Centered Learning Analytics

- Science centers and museums
- Investigating visitor engagement
  - Cognitive
  - Affective
  - Behavioral
- Multimodal sensor streams
Multimodal Narrative-Centered Learning Analytics
Narrative-Centered Learning for Health Behavior Change

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Intelligent Narrative-Centered Classrooms of the Future

I-ACT: Intelligent Augmented Cognition for Teachers

- K-12 STEM Teachers
- Intuitive Augmented Cognition for Teaching
  - Prospective Pedagogical Guidance
  - Concurrent Pedagogical Guidance
  - Retrospective Pedagogical Guidance
- I-ACT Lesson Design & Implementation
- I-ACT Classroom Teaching
- I-ACT Post-Teaching Reflection

Technology-Rich Inquiry Teaching

Outcomes
- Improved Teacher Performance
  - Teacher-Student Interaction
  - Students-Student Interaction
  - Lesson Design & Implementation
  - Propositional Pedagogical Knowledge
  - Procedural Pedagogical Knowledge
- Improved Teacher Work-Life
  - Teacher Job Satisfaction
  - Teacher Self-Efficacy
Intelligent Narrative-Centered Classrooms of the Future

I-ACT: Intelligent Augmented Cognition for Teachers
Future of Narrative-Centered Learning

**Intention Recognition**

- **Previous Player Action**
- **Current Location**
- **Current Player Action**
- **Current Goal**
- **Current Game State**

Formulas:
- \( \forall s, a : \text{action}(s, a) \Rightarrow \text{goal}(t, g) \) 0.7
- \( \forall s, a, t, a' : \text{action}(s, a) \land \text{state}(t, s) \Rightarrow \text{goal}(t, g') \) 1.5
- \( \forall s, a, t, a' : \text{action}(s, a) \land \text{action}(t, a') \Rightarrow (s, a) \Rightarrow \text{goal}(t, g) \) 2.3

... 

**Self-Regulated Learning**

- Graph showing data trends over time.

**Tutorial Dialogue**

- **Student**
- **Tutor**

- Arrows indicating task actions and textual dialogue.

**Affect Modeling**

- Confusion Transitions graph with mastery and performance metrics.
Scaling Narrative-Centered Learning

- **Goal:** Design robust story-rich pedagogical support for learner-adaptive interactions
- **Potential Impact:** Narrative-tutorial planning generalized from training populations to unseen students for high engagement
Conclusions

- Personalized learning poses significant computational challenges.
- Designing narrative-centered environments holds considerable promise for fine-grained, real-time in-classroom and out-of-classroom learning.
- Integrating rich cognitive student modeling and affective student modeling offers considerable potential for personalized learning.
- Narrative-centered learning with adaptive scaffolding offers promise for supporting engaging learning experiences on a broad scale.
Acknowledgements

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