Immersive Virtual Ecosystems for Learning and Assessment

Chris Dede
Harvard University
Chris_Dede@harvard.edu
www.gse.harvard.edu/~dedech
Perennial Challenges in Classrooms

- Classrooms are barren places without rich resources or ways to simulate the real world.
- Students are bored compared to the many forms of engagement they have in the rest of their lives.
- Teachers are the only way increasingly large numbers of students can get help personalized to their needs.
- Paper and pencil, item-based assessments cannot measure deep knowledge and sophisticated skills.
Situated Learning and Transfer

- constellations of architectural, social, organizational, and material vectors that aid in learning culturally based practices
  - apprenticeship (the process of moving from novice to expert within a given set of practices)
  - legitimate peripheral participation (tacit learning similar to that involved in internships)
  - high fidelity is not important unless essential for task (e.g., interpreting photographic images)
Next Generation Interfaces for “Immersive Learning”

- **Multi-User Virtual Environments:**
  Immersion in virtual contexts with digital artifacts and avatar-based identities

- **Virtual Reality**
  Full sensory immersion via head-mounted displays or CAVES

- **Ubiquitous Computing:**
  Wearable wireless devices coupled to smart objects for “augmented reality”

January 2009 issue of *Science*
EcoMUVE

- Funded by the Institute of Education Sciences of the U.S. Department of Education.
- Middle school science
  - Ecosystems, Causal complexity.
- Two MUVE-based modules implemented over two weeks within a four week ecosystems curriculum.
- Timeline: July, 2008 - July 2011
Project Overview

- Ecosystems have complex causal dynamics.
- Even after instruction, students often retain misconceptions.
- In our experience, MUVEs can help students engage in authentic science inquiry and gain deeper understanding.
- Our goal is to develop EcoMUVE as a MUVE that, as part of a larger curriculum, will enable a richer understanding of ecosystems and complex causality.
Focus on A Particular Suite of Understandings and Performances

Collaborative Problem Resolution via Mediated Interaction:

- Problem Finding Before Problem Solving
- Comprehension by a Team, Not an Individual
- Making Meaning Out of Complexity:
  - Utilizing sophisticated tools and representations
  - Recognizing and matching patterns
  - Judging the value of alternative formations
  - Communicating to others with differing perspectives
Expert Reasoning About Ecosystems Involves Reasoning About:

- spatial scales involving action at a distance, where impacts are felt far from their causes.
- time delays between causes and their effects.
- causes that can be non-obvious or act in concert with obvious causes.
- processes and steady states in contrast to event-based reasoning.
Why are MUVEs Promising for Teaching Certain Ecosystems Concepts?

- Zoom-in to the microbial world or out to macroviews (such as a population view).
- Ability to speed up time, slow down time, advance to different points in the past or future, illustrate scenarios.
- Ability to show parallel interacting objects/beings and their emergent effects (distributed causality).
- Ability to monitor the on-going state of systems.
- Ways to graph patterns, showing the relationship between individual behaviors and population level outcomes.
- Ways to illustrate different causal patterns in play.
## White-tailed Deer

*Odocoileus virginianus*

### Description:

The white-tailed deer is tan or brown in the summer. Its name comes from the white patch of fur on the underside of its tail. The male has antlers.

### Where They Live:

Whitetail deer are able to survive in many habitats, from the big woods of northern Maine to the deep saw grass swamps of Florida. They also inhabit farmlands, brushy areas and the cactus and thornbrush deserts of southern Texas and Mexico. Ideal whitetail deer habitat would contain dense thickets (in which to hide and move about) and edges (which furnish food).

### What They Eat:

Deer are primary consumers feeding on leaves, twigs, shoots, acorns, berries, and seeds, and they also graze on grasses and herbs. Deer have strong preferences for certain kinds of plants and when their population is high they may eat all of their favorite food from a certain area.
sparrow
Module 1: Pond Ecosystem

Modeled after Black’s Nook Pond in Cambridge, MA
Change over Time
TI Nspire
Non-Obvious Causes

Things have been pretty quiet in this duck pond. Oh boy – here come the bacteria. There are a lot of them down here. Bacteria are good at getting energy out of matter that other organisms consider waste. Through the process of respiration, they can get their energy from dead plants and animals. They break apart molecules that were once locked up in dead plants and animals. In this process of decomposition they make the atoms and molecules that were once a part of other organisms available to be used again.
Hi, I'm Manny. We've been working really hard to get the new housing development ready for the open house. I'm probably going to have to work overtime every day this week to get these lawns in shape! I think this extra fertilizer I picked up should do the trick.

Professional Turf Fertilizer (40 lbs.) Contains nitrogen, phosphorus and potassium – nutrients essential for plant growth. Apply 1 pound for every 1,000 square feet of turf. Apply only as directed. Avoid applying before it rains to prevent loss of nutrients before they are taken up by plants.
You have 13 out of 52 Connections.
**Interaction between Biotic and Abiotic Factors**

Runoff causes increased phosphate levels, leading to increased plant growth. Plant decomposition by bacteria consumes oxygen, causing the eventual fish kill.

[www.ecomuve.org](http://www.ecomuve.org)
Design-Based Research

Early pilot tests conducted in the spring of 2010 with students in 7th and 8th grade

Focus on Complex Causal Factors

- Spatially Local versus Action at a Distance
- Obvious vs. Non-Obvious Causes
- Immediate vs. Time Delayed Effects
- Event-Based versus Process-Oriented Causality
Survey to Assess Changes in Causal Understanding

Each statement indicates the mayor’s tendency to believe that causal agents must be 1) in close proximity to the effects, 2) temporally immediate, and 3) clearly visible. The three statements are:

- “We need to focus on the area right around the pond. The fish probably died because of something that’s in the pond or right next to it.”
- “We need to focus on the last couple of days. The fish probably died because of something that just happened in the last day or two.”
- “We need to focus on the things that we can see. The fish probably died because of something that’s obvious if we just look for it.”
Changes in Causal Understanding

Number of Students (n=69)

<table>
<thead>
<tr>
<th>Category</th>
<th>Pre</th>
<th>Post</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effects over Distance</td>
<td>20</td>
<td>40</td>
</tr>
<tr>
<td>Changes over Time</td>
<td>30</td>
<td>60</td>
</tr>
<tr>
<td>Non-obvious Causes</td>
<td>60</td>
<td>60</td>
</tr>
</tbody>
</table>

Legend:
- Pre
- Post
In Summary

- The initial expected reasoning patterns were revealed for “action at a distance” and “event-based causal reasoning.” Students were adept at identifying non-obvious causes (signaled by an effect.)

- The domino, narrative patterns in students’ post-test explanations suggest directions for possible modifications and for how we design the teacher guide and discussion of EcoMUVE.
Jenkins’ Framework for New Literacies

- **Play** — Experimenting with one’s surroundings in problem solving
- **Performance** — Adopting alternative identities for improvisation and discovery
- **Simulation** — Interpreting and constructing dynamic models of real-world processes
- ** Appropriation** — The ability to meaningfully sample and remix media content
- **Multitasking** — Scanning one’s environment and shifting focus to salient details
- **Distributed cognition** — Fluently using tools that expand mental capacities
- **Collective intelligence** — Pooling knowledge with others toward a common goal
- **Judgment** — Evaluating the reliability and credibility of different information sources
- **Transmedia navigation** — The ability to follow the flow of stories and information across multiple modalities
- **Networking** — The ability to search for, synthesize, and disseminate information
- **Negotiation** — The ability to travel across diverse communities, discerning and respecting multiple perspectives, and grasping and following alternative norms
Leu’s Characteristics of New Literacies

1. Emerging ICT tools, applications, media, and environments require novel skills, strategies, and dispositions for their effective use.

2. New literacies are central to full economic, civic, and personal participation in a globalized society.

3. New literacies constantly evolve as their defining ICT continuously are renewed through innovation.

4. New literacies are multiple, multimodel, and multifaceted.
Assessing Sophisticated Performances Based on Rich Observations
NSES Model of Inquiry

- Identify questions that can be answered through scientific investigation (not independent of knowledge)
- Design and conduct a scientific investigation
- Use appropriate tools and techniques to gather, analyze, and interpret data
- Develop prescriptions, explanations, predictions, and models using evidence
- Think critically and logically to make the relationships between evidence and explanations
- Recognize and analyze alternative explanations and predictions
- Communicate scientific procedures and explanations
- Use mathematics in all aspects of scientific inquiry
An Immersive Model

• Student takes on identity of a scientist

• Students complete quests

• 90 Minutes

• Four Phases:
  1. Orientation
  2. Problem Identification
  3. Experimentation
  4. Competing Explanations
Setting Modifiable for Experimentation

XML file for setting data values and turning on/off objects

```xml
<asset ID="140" name="Water by Glacier" visibility="true">
  <properties>
    <salinity text="31 psu" tooltip="Salinity"/>
    <nitrates text="5.1 μM" tooltip="Nitrates"/>
    <population text="not available" tooltip="Population"/>
    <temp text="14° C" tooltip="Temperature"/>
    <turbidity text="13 mg/L" tooltip="Turbidity"/>
  </properties>
</asset>

<asset ID="141" name="Water by Forest" visibility="true">
  <properties>
    <salinity text="31 psu" tooltip="Salinity"/>
    <nitrates text="5.1 μM" tooltip="Nitrates"/>
    <population text="not available" tooltip="Population"/>
    <temp text="14° C" tooltip="Temperature"/>
    <turbidity text="14 mg/L" tooltip="Turbidity"/>
  </properties>
</asset>

<asset ID="144" name="Water by Wharf" visibility="true">
  <properties>
    <salinity text="32 psu" tooltip="Salinity"/>
    <nitrates text="5.1 μM" tooltip="Nitrates"/>
    <population text="not available" tooltip="Population"/>
    <temp text="14° C" tooltip="Temperature"/>
    <turbidity text="14 mg/L" tooltip="Turbidity"/>
  </properties>
</asset>
```
Performance Palettes for Explanation

Flash–based Performance Palettes:  *Explanation Builder*

**Explanation Builder**

*Directions:* We want you to complete the following statement with a reasonable explanation of why the kelp is dying. Use the data you collected as evidence. Complete the statement by dragging the appropriate evidence, objects, and effects to the empty spaces in the statement.

**Evidence**
- nitrate
- salinity
- population
- temperature
- turbidity

**Objects**
- sea otters
- power plant drainage
- wharf
- glacier
- logging operation

**Effects**
- no change
- increase
- decrease

My evidence shows that the...
- of the Kelp has **decreased** and that there has been a(n) **in**
Actions as Basis for Assessments

Logfiles Indicate with Timestamps

- Where students went
- With whom they communicated and what they said
- What artifacts they activated
- What databases they viewed
- What data they gathered using virtual scientific instruments
- What screenshots and notations they placed in team-based virtual notebooks
- What hints they accessed

http://virtualassessment.org/
**Logfiles: Events, Chats, Notebooks...**

**Database of Logdata** - Track students’ behaviors: where they went, what data they collected, path to solve problem

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
<th>I</th>
<th>J</th>
<th>K</th>
<th>L</th>
<th>M</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>adminstrat testID</td>
<td>eventID</td>
<td>stage</td>
<td>timestamp</td>
<td>locationX</td>
<td>locationY</td>
<td>locationz</td>
<td>locationY</td>
<td>detail</td>
<td>studentID</td>
<td>Description</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>314152</td>
<td>497</td>
<td>0</td>
<td>0</td>
<td>2009-12-06</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>102282</td>
<td>assessment started</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>314152</td>
<td>497</td>
<td>1</td>
<td>1</td>
<td>2009-12-06</td>
<td>364</td>
<td>23</td>
<td>-76</td>
<td>0</td>
<td>2</td>
<td>10</td>
<td>102282</td>
</tr>
<tr>
<td>4</td>
<td>314152</td>
<td>497</td>
<td>2</td>
<td>1</td>
<td>2009-12-06</td>
<td>263</td>
<td>10</td>
<td>-6</td>
<td>270</td>
<td>2</td>
<td>10</td>
<td>102282</td>
</tr>
<tr>
<td>5</td>
<td>314152</td>
<td>497</td>
<td>3</td>
<td>1</td>
<td>2009-12-06</td>
<td>263</td>
<td>8</td>
<td>-6</td>
<td>270</td>
<td>14</td>
<td>1</td>
<td>102282</td>
</tr>
<tr>
<td>6</td>
<td>314152</td>
<td>497</td>
<td>4</td>
<td>1</td>
<td>2009-12-06</td>
<td>263</td>
<td>7</td>
<td>-6</td>
<td>270</td>
<td>14</td>
<td>2</td>
<td>102282</td>
</tr>
<tr>
<td>7</td>
<td>314152</td>
<td>497</td>
<td>5</td>
<td>1</td>
<td>2009-12-06</td>
<td>267</td>
<td>8</td>
<td>-397</td>
<td>0</td>
<td>143</td>
<td>20</td>
<td>102282</td>
</tr>
<tr>
<td>8</td>
<td>314152</td>
<td>497</td>
<td>6</td>
<td>1</td>
<td>2009-12-06</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>11</td>
<td>102282</td>
</tr>
<tr>
<td>9</td>
<td>314152</td>
<td>497</td>
<td>7</td>
<td>1</td>
<td>2009-12-06</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>13</td>
<td>102282</td>
<td>stage ended ungracefully</td>
</tr>
<tr>
<td>10</td>
<td>314152</td>
<td>497</td>
<td>8</td>
<td>1</td>
<td>2009-12-06</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>3</td>
<td>102282</td>
</tr>
<tr>
<td>11</td>
<td>314152</td>
<td>498</td>
<td>0</td>
<td>0</td>
<td>2009-12-06</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>102282</td>
</tr>
<tr>
<td>12</td>
<td>314152</td>
<td>498</td>
<td>1</td>
<td>1</td>
<td>2009-12-06</td>
<td>364</td>
<td>23</td>
<td>-76</td>
<td>0</td>
<td>2</td>
<td>10</td>
<td>102282</td>
</tr>
<tr>
<td>13</td>
<td>314152</td>
<td>498</td>
<td>2</td>
<td>1</td>
<td>2009-12-06</td>
<td>263</td>
<td>10</td>
<td>-6</td>
<td>270</td>
<td>2</td>
<td>10</td>
<td>102282</td>
</tr>
<tr>
<td>14</td>
<td>314152</td>
<td>498</td>
<td>3</td>
<td>1</td>
<td>2009-12-06</td>
<td>263</td>
<td>8</td>
<td>-6</td>
<td>270</td>
<td>14</td>
<td>1</td>
<td>102282</td>
</tr>
<tr>
<td>15</td>
<td>314152</td>
<td>498</td>
<td>4</td>
<td>1</td>
<td>2009-12-06</td>
<td>263</td>
<td>7</td>
<td>-6</td>
<td>270</td>
<td>14</td>
<td>2</td>
<td>102282</td>
</tr>
<tr>
<td>16</td>
<td>314152</td>
<td>498</td>
<td>5</td>
<td>1</td>
<td>2009-12-06</td>
<td>263</td>
<td>7</td>
<td>-6</td>
<td>270</td>
<td>14</td>
<td>3</td>
<td>102282</td>
</tr>
<tr>
<td>17</td>
<td>314152</td>
<td>498</td>
<td>6</td>
<td>1</td>
<td>2009-12-06</td>
<td>263</td>
<td>7</td>
<td>-6</td>
<td>270</td>
<td>14</td>
<td>4</td>
<td>102282</td>
</tr>
<tr>
<td>18</td>
<td>314152</td>
<td>498</td>
<td>7</td>
<td>1</td>
<td>2009-12-06</td>
<td>263</td>
<td>7</td>
<td>-6</td>
<td>270</td>
<td>14</td>
<td>2</td>
<td>102282</td>
</tr>
<tr>
<td>19</td>
<td>314152</td>
<td>498</td>
<td>8</td>
<td>1</td>
<td>2009-12-06</td>
<td>263</td>
<td>7</td>
<td>-6</td>
<td>270</td>
<td>14</td>
<td>1</td>
<td>102282</td>
</tr>
<tr>
<td>20</td>
<td>314152</td>
<td>498</td>
<td>9</td>
<td>1</td>
<td>2009-12-06</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>11</td>
<td>102282</td>
</tr>
<tr>
<td>21</td>
<td>314152</td>
<td>498</td>
<td>10</td>
<td>1</td>
<td>2009-12-06</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>13</td>
<td>102282</td>
</tr>
<tr>
<td>22</td>
<td>314152</td>
<td>498</td>
<td>11</td>
<td>0</td>
<td>2009-12-06</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>3</td>
<td>102282</td>
</tr>
<tr>
<td>23</td>
<td>314152</td>
<td>498</td>
<td>12</td>
<td>0</td>
<td>2009-12-06</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>102282</td>
</tr>
<tr>
<td>24</td>
<td>314152</td>
<td>499</td>
<td>1</td>
<td>1</td>
<td>2009-12-06</td>
<td>364</td>
<td>23</td>
<td>-76</td>
<td>0</td>
<td>2</td>
<td>10</td>
<td>102282</td>
</tr>
<tr>
<td>25</td>
<td>314152</td>
<td>499</td>
<td>2</td>
<td>1</td>
<td>2009-12-06</td>
<td>263</td>
<td>10</td>
<td>-6</td>
<td>270</td>
<td>2</td>
<td>10</td>
<td>102282</td>
</tr>
<tr>
<td>26</td>
<td>314152</td>
<td>499</td>
<td>3</td>
<td>1</td>
<td>2009-12-06</td>
<td>263</td>
<td>8</td>
<td>-6</td>
<td>270</td>
<td>14</td>
<td>1</td>
<td>102282</td>
</tr>
<tr>
<td>27</td>
<td>314152</td>
<td>499</td>
<td>4</td>
<td>1</td>
<td>2009-12-06</td>
<td>263</td>
<td>7</td>
<td>-6</td>
<td>270</td>
<td>14</td>
<td>3</td>
<td>102282</td>
</tr>
<tr>
<td>28</td>
<td>314152</td>
<td>499</td>
<td>5</td>
<td>1</td>
<td>2009-12-06</td>
<td>233</td>
<td>4</td>
<td>-5</td>
<td>270</td>
<td>3</td>
<td>1</td>
<td>102282</td>
</tr>
<tr>
<td>29</td>
<td>314152</td>
<td>499</td>
<td>6</td>
<td>1</td>
<td>2009-12-06</td>
<td>236</td>
<td>6</td>
<td>-4</td>
<td>270</td>
<td>2</td>
<td>11</td>
<td>102282</td>
</tr>
<tr>
<td>30</td>
<td>314152</td>
<td>499</td>
<td>7</td>
<td>1</td>
<td>2009-12-06</td>
<td>129</td>
<td>10</td>
<td>125</td>
<td>0</td>
<td>2</td>
<td>10</td>
<td>102282</td>
</tr>
<tr>
<td>31</td>
<td>314152</td>
<td>499</td>
<td>8</td>
<td>4</td>
<td>2009-12-06</td>
<td>124</td>
<td>2</td>
<td>117</td>
<td>100</td>
<td>212</td>
<td>20</td>
<td>102282</td>
</tr>
<tr>
<td>32</td>
<td>314152</td>
<td>499</td>
<td>9</td>
<td>4</td>
<td>2009-12-06</td>
<td>123</td>
<td>0</td>
<td>123</td>
<td>0</td>
<td>107</td>
<td>22</td>
<td>102282</td>
</tr>
<tr>
<td>33</td>
<td>314152</td>
<td>499</td>
<td>10</td>
<td>4</td>
<td>2009-12-06</td>
<td>129</td>
<td>10</td>
<td>118</td>
<td>180</td>
<td>209</td>
<td>22</td>
<td>102282</td>
</tr>
<tr>
<td>34</td>
<td>314152</td>
<td>499</td>
<td>11</td>
<td>4</td>
<td>2009-12-06</td>
<td>137</td>
<td>0</td>
<td>124</td>
<td>37</td>
<td>200</td>
<td>22</td>
<td>102282</td>
</tr>
<tr>
<td>35</td>
<td>314152</td>
<td>499</td>
<td>12</td>
<td>4</td>
<td>2009-12-06</td>
<td>133</td>
<td>0</td>
<td>117</td>
<td>0</td>
<td>111</td>
<td>24</td>
<td>102282</td>
</tr>
<tr>
<td>36</td>
<td>314152</td>
<td>499</td>
<td>13</td>
<td>4</td>
<td>2009-12-06</td>
<td>133</td>
<td>0</td>
<td>117</td>
<td>0</td>
<td>111</td>
<td>25</td>
<td>102282</td>
</tr>
<tr>
<td>37</td>
<td>314152</td>
<td>499</td>
<td>14</td>
<td>4</td>
<td>2009-12-06</td>
<td>103</td>
<td>0</td>
<td>107</td>
<td>37</td>
<td>200</td>
<td>23</td>
<td>102282</td>
</tr>
</tbody>
</table>
Differences from Item-based Tests

Multiple Forms of Complex Measures

Products of Inquiry-
Create conclusions and select evidence

Processes of Inquiry-
Gather data and interview people
Formative/Diagnostic

- Formative, diagnostic assessment provides *more leverage for improvement* than summative measures.
- Formative, diagnostic assessment is *richer and more accurate* than summative measures.
- Potentially, formative, diagnostic assessment *could substitute for* summative measures.
Next Generation Interfaces for “Immersive Learning”

- **Multi-User Virtual Environments:**
  Immersion in virtual contexts with digital artifacts and avatar-based identities

- **Virtual Reality**
  Full sensory immersion via head-mounted displays or CAVES

- **Ubiquitous Computing:**
  Wearable wireless devices coupled to smart objects for “augmented reality”

January 2009 issue of *Science*
“Overlay Devices”

- Wireless mobile devices offer substantial power, at a fraction of the cost for laptops and with greater mobility.
- Entertainment and learning are infused anywhere.
- One-to-one person-to-device ratio becomes affordable in education.

“Augmented Reality” for entertainment and learning.
Collaboration & Interdependence

...Chemist
...FBI Agent
...Computer Expert
...Linguist
U.S. 2010 Educational Tech Plan

1. Learning
2. Assessment
3. Teaching
4. Infrastructure
5. Productivity

http://www.ed.gov/technology/netp-2010
Why Immersive Education?

- allow simulated experiences otherwise impossible to deliver.
- increase engagement in learning by allowing students to immerse themselves in a virtual world.
- support new forms of interaction and collaboration.
- support embedded hints and tutoring delivered via situated, just-in-time processes.
- can increase learner’s knowledge, skills, and self-efficacy.
- may promote transfer to the real world more than other forms of instruction.
Immersive Affordances

- MUVEs and AR can slow down or speed up time.
- MUVEs can zoom in or out to display phenomena at various scales.
- MUVEs and AR can help students understand spatially distributed phenomena by enabling movement through space.
- MUVEs and AR enable collecting data by placing simulated measuring tools into a virtual environment.
- MUVEs can support microworld simulations in which students can make predictions, then change a variable or rule and observe what happens.
Professional Development: Communities of “Unlearning”

- Developing fluency in using emerging interactive media
- Complementing presentational instruction with collaborative inquiry-based learning
- **Unlearning** almost unconscious assumptions and beliefs and values about the nature of teaching, learning, and schooling

**Crucial issue for professional development**
Beyond McLuhan

- Media shape their messages
- Media shape their participants
- Infrastructures shape civilization