Evolution Readiness

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http://www.concord.org/projects/evolution-readiness
The Concord Consortium

- Nonprofit research and development organization
- Dedicated to transforming education through technology
- Pioneers of learning innovations for STEM
- Dedicated to Open Source software
- Primarily funded by NSF since starting in 1994
Introduction

• First step of a planned learning progression
  1. Natural selection as an explanatory model for adaptation
  2. Genetics as an explanatory model for inheritance
  3. Molecular biology as an explanatory model for genetics

• What is evolution “readiness,” anyway?

• What role can computer models play?

• What professional development is required?

• Does learning early steps at one grade level facilitate learning later ones in a higher grade?
Description of the Project

• Target audience:
  Fourth grade classes in MA, MO, and TX
• Materials developed:
  Interactive computer and classroom activities
  Three assessment instruments
• Professional Development:
  Face-to-face workshops
  Online course
• Research and Assessment:
  Comparison to baseline data
  Boston College
Hands-on Activities

- Life on Earth book
- Fast plants and lettuce
- Timeline
- Lego Tree of Life
- Clip Birds
- Food Web
- Science Classroom Environment Survey
The Virtual Greenhouse

Adaptation

- Three kinds of plants, five flowerboxes with differing amounts of light
- Kids experiment to discover which plants live in which flowerbox
The Virtual Field

Inheritance and life cycle: all plants die every winter but healthy plants leave seeds:
- Field with linear light level gradient
- Offspring look exactly like parent plants
Variation: some offspring differ from parents: over many generations small variations build up

- A single variety of plant evolves into nine others
- The different varieties are adapted to different regions of the field; eventually they can grow everywhere
Evolution!

When the environment changes the population of plants may be able to adapt (or not...)

- Kids control the growth of mountains to change the environment on both sides of the mountain range
- If the environment changes too abruptly the plants all die
Finally, a transfer task...

Environment differs in amount of water, not light
Plants all look the same but have different roots
  - Differences between plants are invisible without special tools
The Virtual Ecosystem

Competition for resources (timed)
- Single rabbit eating plant population
- Population of rabbits join your rabbit and compete for the plants
Variations and Adaptations

Plants and animals adapt to survive best in certain environments:
- Different types of grasses grow best with a certain level of water.
- Kids observe which type of grasses the different types of rabbits eat.

![Diagram showing different types of grasses and rabbits with a table indicating which rabbits eat which grasses.](image-url)
Natural Selection

Environment changes so plants and animals adapt in order to survive

- Kids build (and later remove) a dam
- Observe how the population of grasses and rabbits change
Predator and Prey

Introduction of a predator to the rabbit
- Introduction of food chains (and food webs)
- Kids watch as the environment changes (the snow melts)
Nature of Science

Experiment with Ecosystems

- Experiment with the ecosystem
- Kids create and test their hypothesis around the environment
Implementation:
North Kansas City

Linda Lacy – Director of Research, Evaluation and Accountability
Implementation:
North Kansas City

- Philosophical Concerns
  - Consent/Assent
  - Teacher Support

- Integration of ER Curriculum

- Assessment
Implementation: North Kansas City

- Staff: Admin, Teacher, Tech Support
  - Commitment
  - Staffing Changes

- Training
  - Face-to-Face
  - Virtual

- Limited Resources:
  - Time
  - Space
  - Technology
Implementation Results

- Laura O’Dwyer
- Shelagh Peoples
- Katherine Shields
- Caroline Wang
Overview

• Big Ideas and Learning Goals
• Research Design
• Concept Inventory for Evolution Readiness
• Nature of Science Questionnaire
• Science Classroom Environment Survey
Big Ideas

- Big Idea 1: Basic Needs of Organisms
- Big Idea 2: Life Cycle - Birth and Death Cycle
- Big Idea 3: Organisms and Their Environment
- Big Idea 4: Classification of Organisms
- Big Idea 5: Inter-specific Differences
- Big Idea 6: Interactions Between Species
- Big Idea 7: Intra-specific Differences
- Big Idea 8: Adaptation/Evolution
- Big Idea 9: Heritability of Traits
- Big Idea 10: Reproduction
- Big Idea 11: Descent with Modification
Guiding Research Questions

1. Do students come to understand the complex web of models and data, observations and experiments that underpin and validate the theory of evolution?

2. Do students develop a better understanding of the nature of science? Does knowledge about the nature of science play a role in students’ success in understanding and applying the concepts of evolution?

3. Does the Science Classroom Environment change as a result of program implementation?
Research Design: Cohort Design

• Year 1
  Developed and piloted instruments - Spring 2009
  Collected baseline data from the students of participating teachers using the traditional curriculum - Spring 2009

• Year 2
  Project implementation began in September 2009
  Collected data in Randolph, MA in Oct/Nov 2009
  Collected data in TX, MO in February – April 2010

• Year 3
  Collecting data this year from classes taught by the same Teachers using our treatment
Data Sources

**Student Data**
- Content assessment data:
  - Concept Inventory for Evolution Readiness (CIER)
- Survey instrument data:
  - Nature of Science (NOS)
  - Science Classroom Environment Scale (SCES)
• Items developed after we had finalized the learning progression and the curriculum/model goals.

• Pilot tested in North Kansas City, MO in spring 2009

• Developed CIER to be administered in two sessions
  - 61 sub-prompts, MC, SA, OR questions, scored 0-1, 0-2, or 0-3

• Data Collection (spring 2009)
  - Year 1 – 132 students in three states
  - Year 2 – 186 students in three states
CIER Year 1 Results

Reliability: $\alpha = .88$
Overall Mean = 530.87
S.D. = 67.78

MA Mean = 547.60 (51.86)
MO Mean = 548.15 (73.13)
TX Mean = 501.98 (62.68)
CIER Year 2 Results

Reliability: $\alpha = .90$
Overall Mean = 555.71
S.D. = 78.97
MA Mean = 552.95 (64.92)
MO Mean = 573.04 (86.87)
TX Mean = 536.65 (72.68)
Most difficult concepts for students to understand:

- Selection pressure could lead to a change in the characteristics of a population (Big Idea 8, Learning Goal 5)

- Different species could arise from one species if different groups had different selection pressures (Big Idea 11, Learning Goal 2)

- Species adapt to changes in their environment (Big Idea 8, Learning Goal 3)
CIER: Easy Concepts

Easier concepts for students to understand:

- Particular physical traits help an organism to survive in a given environment (Big Idea 8, Learning Goal 7)

- Individuals of the same species may differ (Big Idea 7, Learning Goal 1)

- Plants and animals need air and water; plants also need light and nutrients; animals also need food and shelter (Big Idea 1, Learning Goal 1)

- An organism thrives in specific environments that match its specific needs (Big Idea 3, Learning Goal 1)
Comparisons

Overall Results

Year 1 Mean = 530.87

Year 2 Mean = 555.71

Significant difference (p < 0.005)

Effect size d = 0.35 s.d.
CIER Year 1 - Year 2
Comparisons

Results by State

MA: NS, d=.09 s.d.

MO: p<.1, d=.31 s.d.

TX: p<.01, d=.52 s.d.
There are three statistically significant differences:

In Year 1 MA and MO means are higher than the TX mean.

In Year 2 the MO mean is higher than the TX mean.
Nature of Science (NOS)

- **Certainty**: Scientific knowledge is durable but subject to change.

- **Inventive**: Imagination & creativity are needed in science.

- **Socially & Culturally Embedded**: Science is socio-culturally embedded.

- **Empirical**: Science is based on observations of the natural world.

- **Theory-laden**: Science is guided by theory & inference.
NOS Rasch Variable Maps: Year 1 vs. Year 2

Difference in Mean Student Measure between Year 1 and Year 2 is Non-Significant.

SCE 13K: Where scientists live may affect what they are allowed to work on.

THL 6C: Scientists create different ways to test their hypotheses.

INV 12N: A good imagination is needed to create the best experiment to test an idea.

EMP 8I: Science describes what happens in nature.

CER 8L: When scientists have a good idea, they continue to try to make it better.
Sub-Scale Comparison: Year 1 to Year 2 Mean* (Std. Dev.)

<table>
<thead>
<tr>
<th>NOS Sub-Scale</th>
<th>Year 1 (N = 121)</th>
<th>Year 2 (N = 173)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Certainty</td>
<td>3.43 (0.55)</td>
<td>3.36 (0.50)</td>
</tr>
<tr>
<td>Empirical</td>
<td>3.32 (0.53)</td>
<td>3.33 (0.52)</td>
</tr>
<tr>
<td>Inventive</td>
<td>3.02 (0.77)</td>
<td>3.02 (0.64)</td>
</tr>
<tr>
<td>Soc. &amp; Cult. Embedded</td>
<td>2.78 (0.69)</td>
<td>2.77 (0.63)</td>
</tr>
<tr>
<td>Theory Laden**</td>
<td>3.41 (0.52)</td>
<td>3.47 (0.46)</td>
</tr>
<tr>
<td>Total NOS</td>
<td>3.17 (0.41)</td>
<td>3.20 (0.39)</td>
</tr>
</tbody>
</table>

*All differences are Non-Significant.

** p < 0.052
NOS: Across State Comparison
Mean Total Rasch Score (Std. Dev.)

- All differences are Non-Significant
NOS: Across State Comparison
Mean Total Rasch Score (Std. Dev.)

* All differences are Non-Significant
Science Classroom Environmental Scale (SCES)

Based on the Reformed Teaching Observation Protocol (RTOP):

- CK: Content Knowledge
- CC: Classroom Culture
- LDI: Lesson Design & Implementation
  - Pedagogy of Inquiry
  - Community of Learners
  - Pedagogical Tension
SCES Subscales Relationships

- Content Knowledge (CK)
- Pedagogical Tension
- Community of Leaders
- Pedagogy of Inquiry

- Lesson Design and Implementation (LDI)
- Classroom Culture (CC)

- REFORMED CLASSROOM
SCES Item Map

“In class other students take the time to listen to my ideas”

“I understand what I should learn from a science lesson”
### SCES Overall Score

<table>
<thead>
<tr>
<th></th>
<th>Year 1 (n=124)</th>
<th>Year 2 (n=170)</th>
<th>p value</th>
<th>Effect Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean (s.d.)</td>
<td>543 (82)</td>
<td>583 (94)</td>
<td>&lt; .01</td>
<td>0.49</td>
</tr>
</tbody>
</table>

#### By State

<table>
<thead>
<tr>
<th>State</th>
<th>Year 1 (n)</th>
<th>Year 2 (n)</th>
<th>p value</th>
<th>Effect Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Massachusetts</td>
<td>550 (64)</td>
<td>566 (70)</td>
<td>.35</td>
<td>0.25</td>
</tr>
<tr>
<td>Missouri**</td>
<td>538 (69)</td>
<td>619 (106)</td>
<td>&lt; .01</td>
<td>1.17</td>
</tr>
<tr>
<td>Texas</td>
<td>543 (102)</td>
<td>552 (80)</td>
<td>.63</td>
<td>0.08</td>
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</tbody>
</table>
SCES Two-Way ANOVA
<table>
<thead>
<tr>
<th>SCES Subscale Scores</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Content</strong></td>
</tr>
<tr>
<td>Content</td>
</tr>
<tr>
<td><strong>Classroom Culture</strong></td>
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<tr>
<td>Lesson Design &amp; Implementation</td>
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<tr>
<td>- Pedagogy of Inquiry</td>
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</tr>
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<td>- Pedagogical Tension</td>
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</tbody>
</table>
Big Picture: How are these constructs related? (Year 2)

- CIER & NOS: $r = -0.033$
- CIER & SCES: $r = -0.036$
- NOS & SCES: $r = 0.517^{**}$

**p < 0.01**
Next Steps

- Spring implementation in TX and MO
- Scoring after combining all tests
- Proposals for ongoing funding submitted
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