Evolution Readiness

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http://www.concord.org/projects/evolution-readiness

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Evolution Readiness

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- 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?

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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

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Hands-on Activities

- Life on Earth book
- Fast plants and lettuce
- Timeline
- Lego Tree of Life
- Clip Birds
- Food Web

CreativeCommons darwinsbulldog's photostream Flickr.com

- Science Classroom Environment Survey

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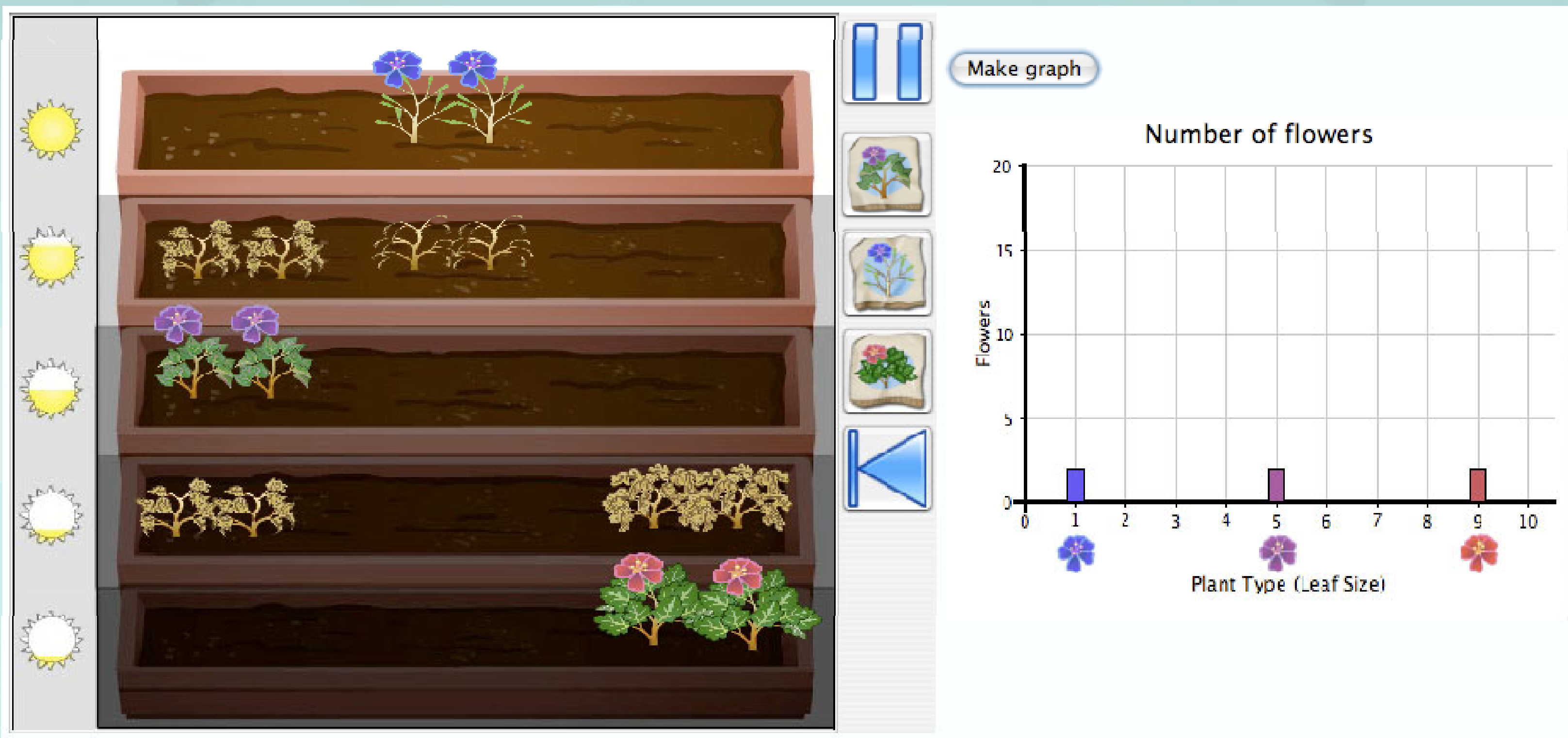
The Virtual Greenhouse

Adaptation

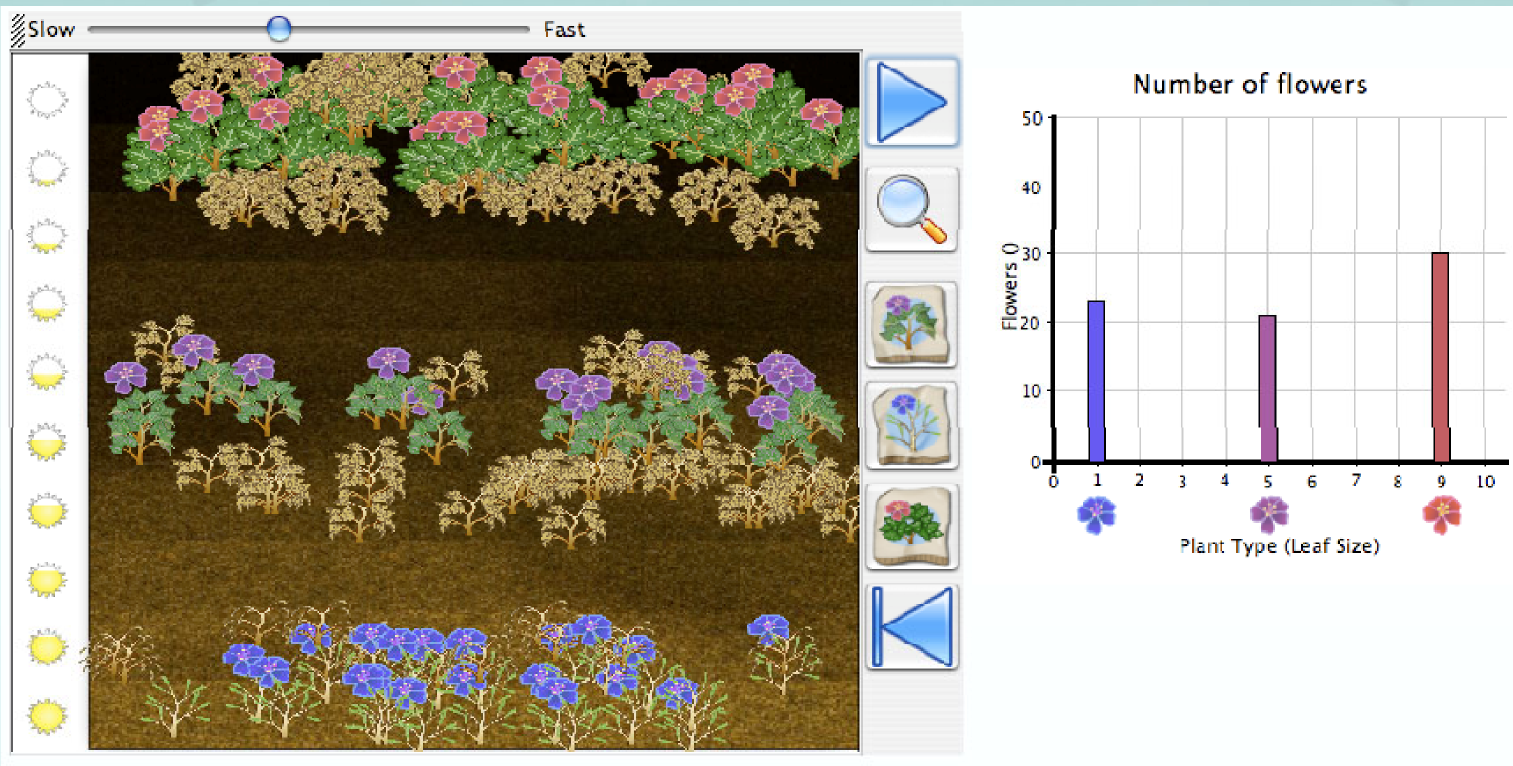
- Three kinds of plants, five flowerboxes with differing amounts of light
- Kids experiment to discover which plants live in which flowerbox



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



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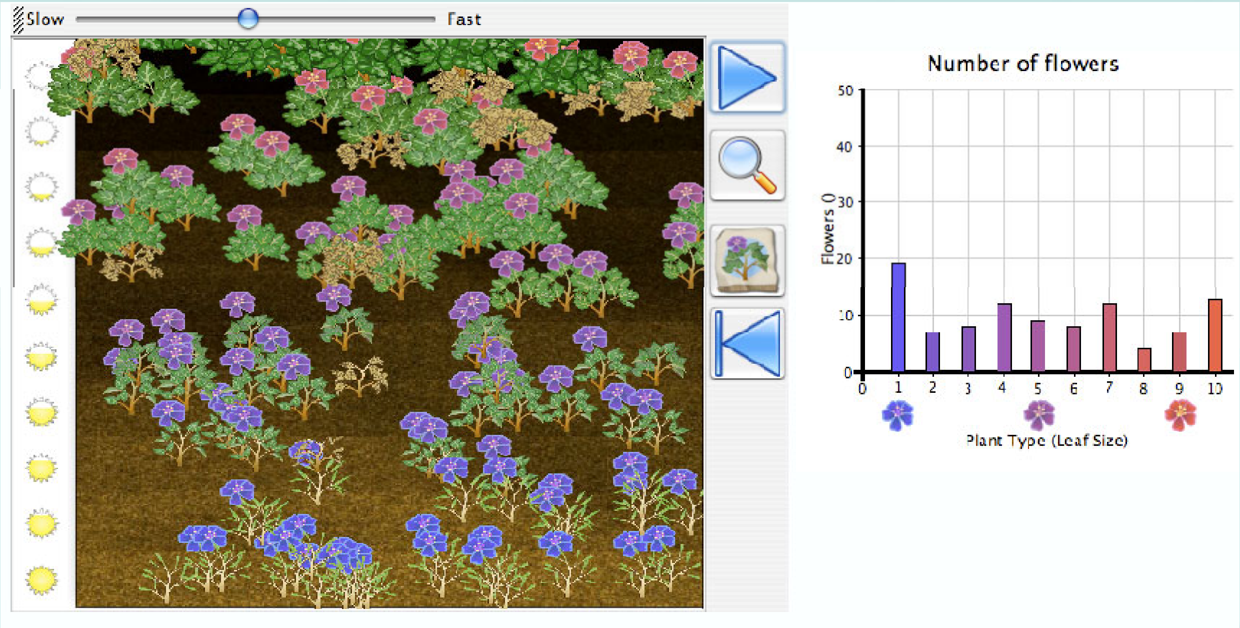
Plants with Variation

Variation: some offspring differ from parents: over many generations small variations build up

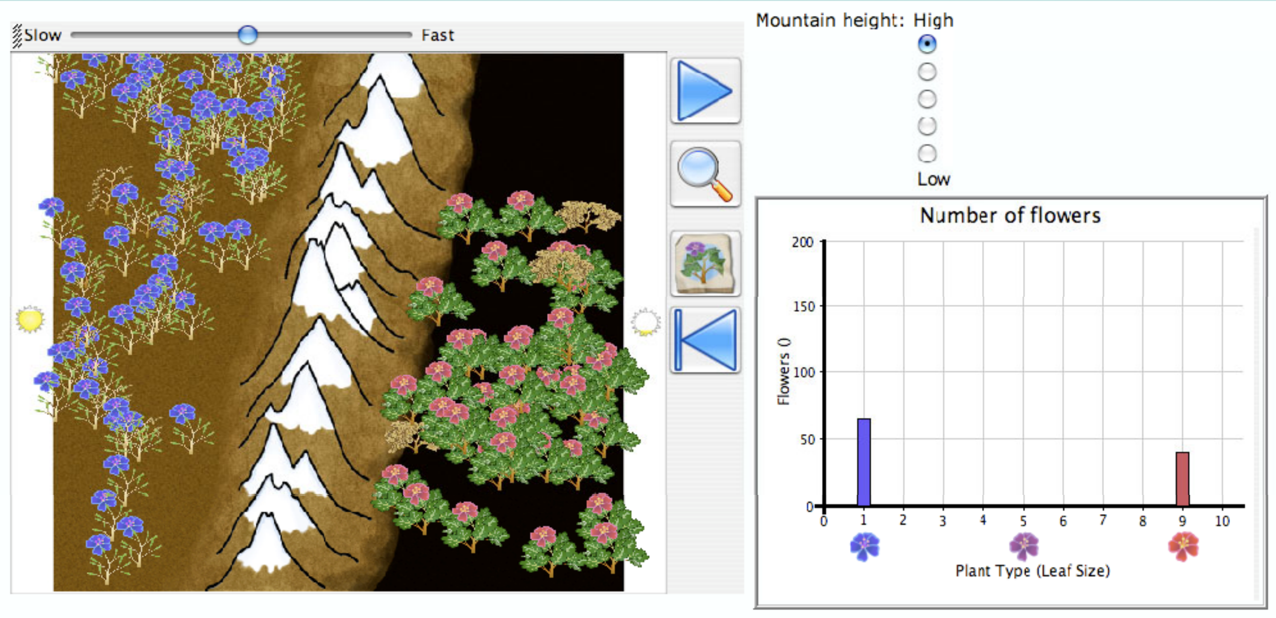
- A single variety of plant evolves into nine others
- The different varieties are adapted to different regions of the field; eventually they can grow everywhere



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

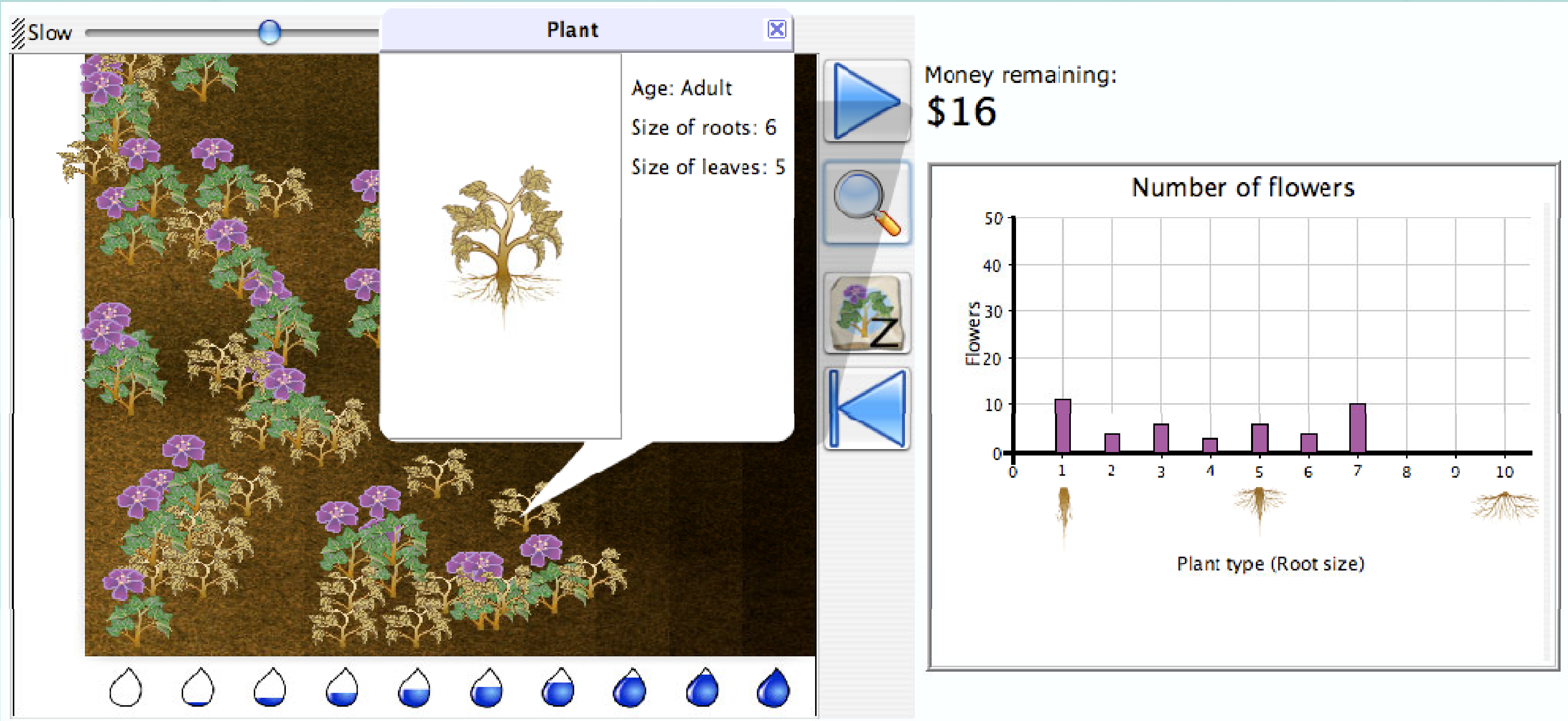


Finally, a transfer task…

Environment differs in amount of water, not light

Plants all look the same but have different roots

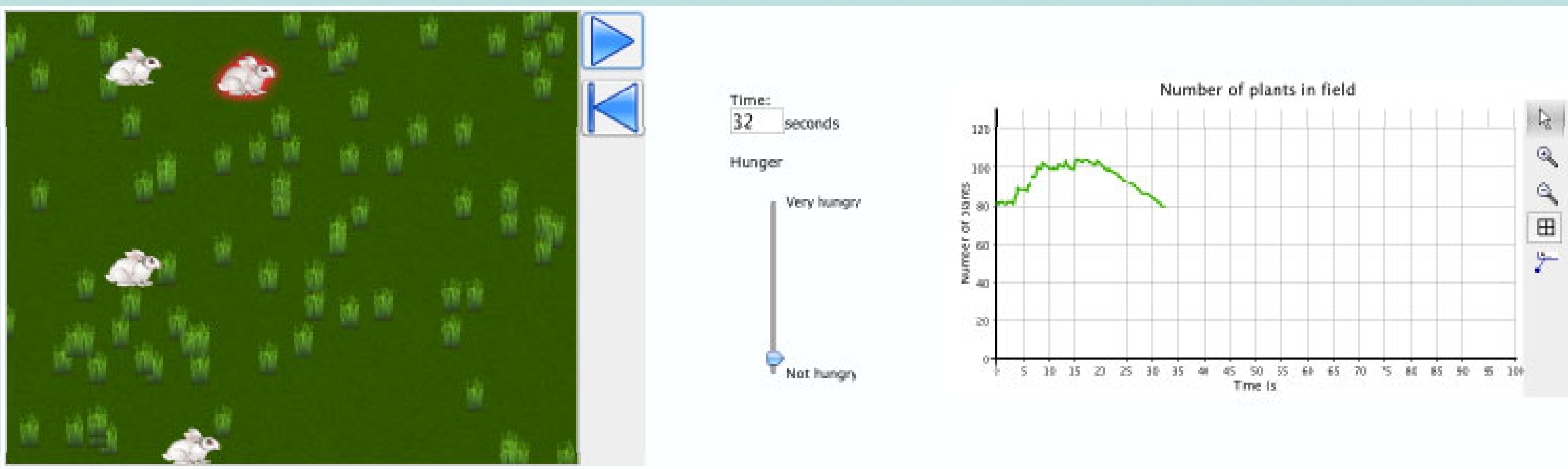
- Differences between plants are invisible without special tools



The Virtual Ecosystem

Competition for resources (timed)

- Single rabbit eating plant population
- Population of rabbits join your rabbit and compete for the plants



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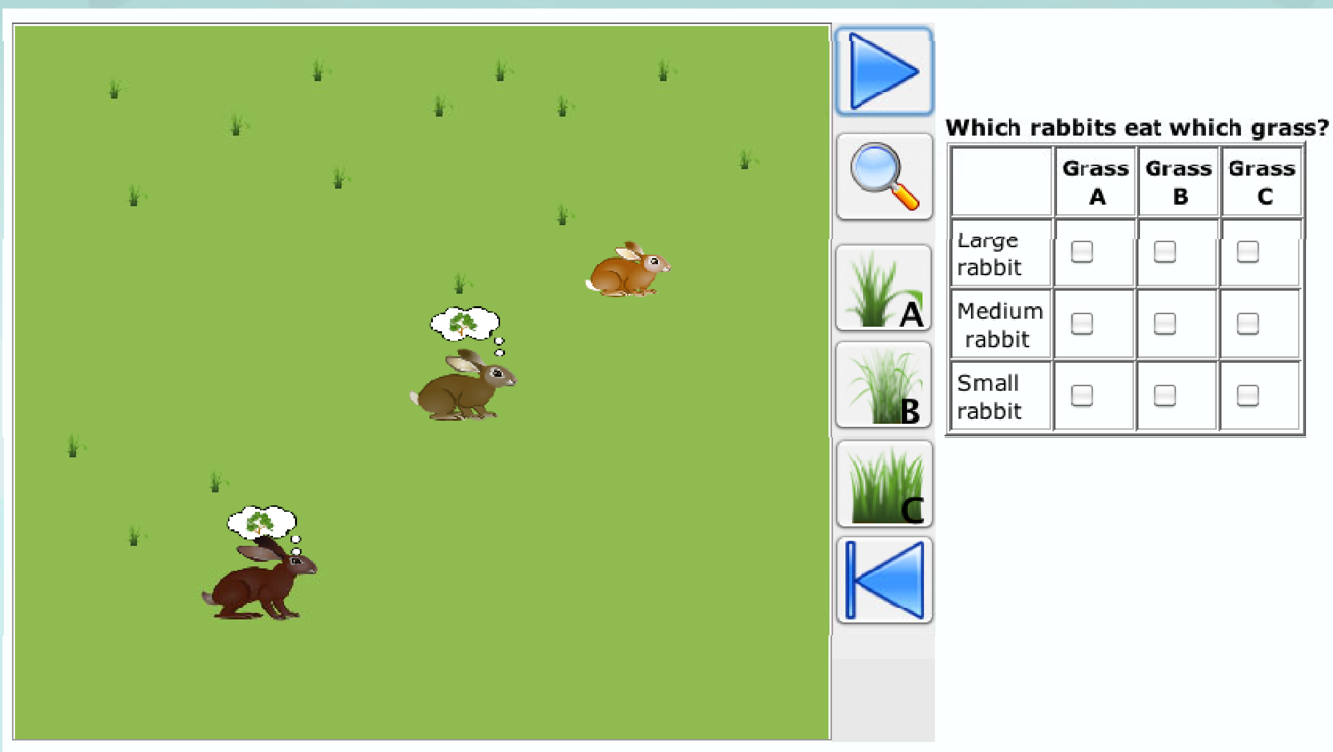
Variations and Adaptations

Plants and animals adapat to survive best in certain environments

- Different types of grasses grow best with a certain levels of water
- Kids observe which type of grasses the different types of rabbits eat



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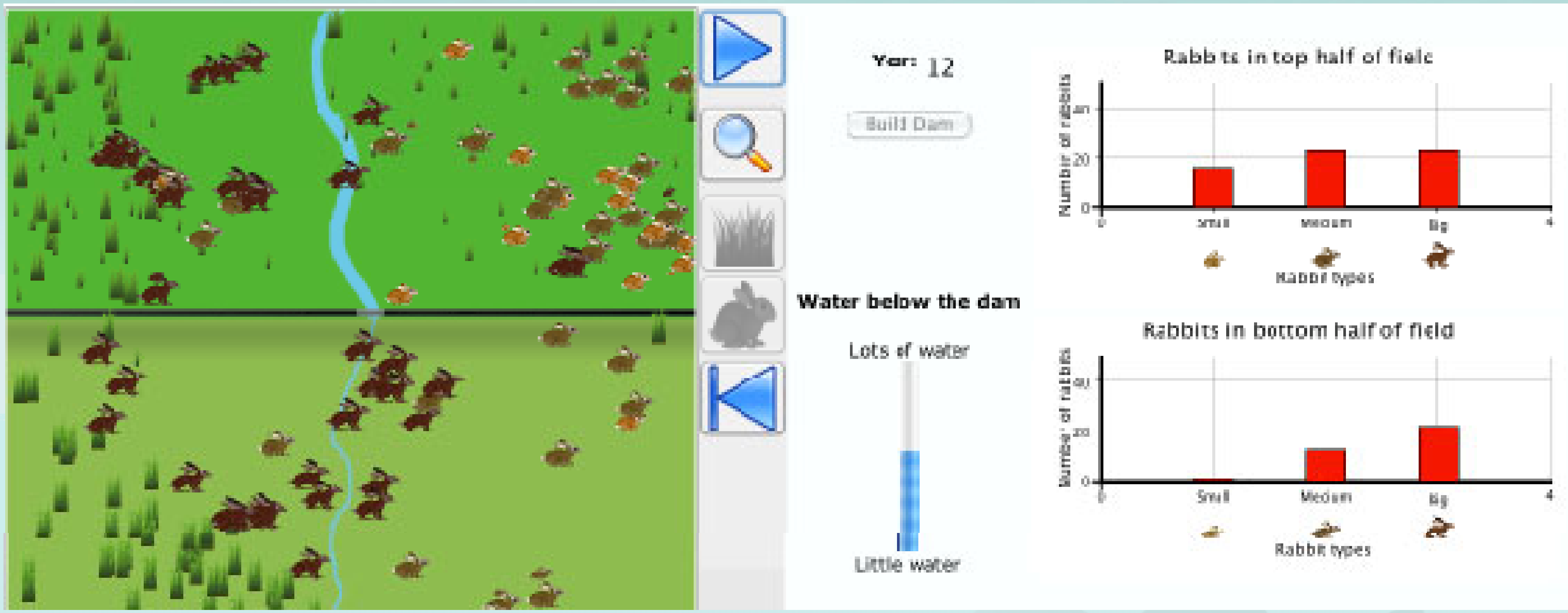
Natural Selection

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



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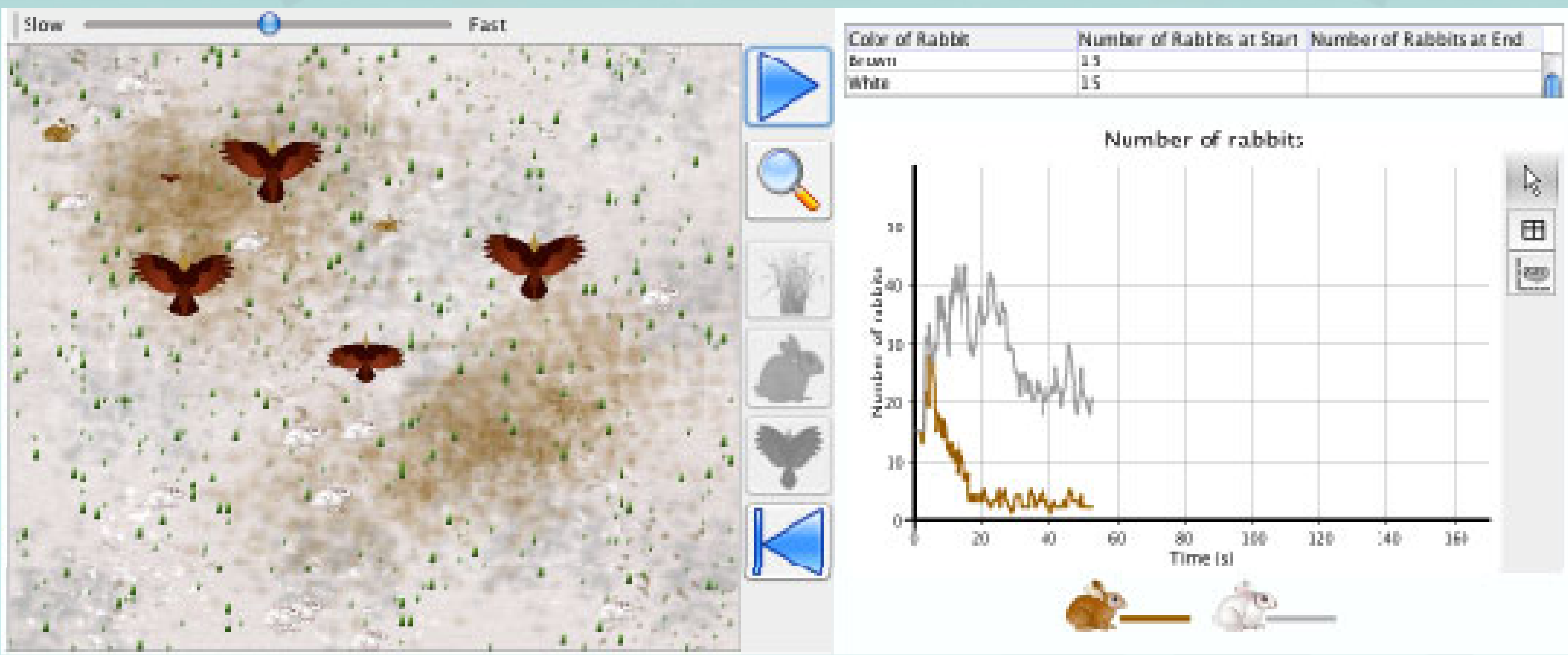
Predator and Prey

Introduction of a predator to the rabbit

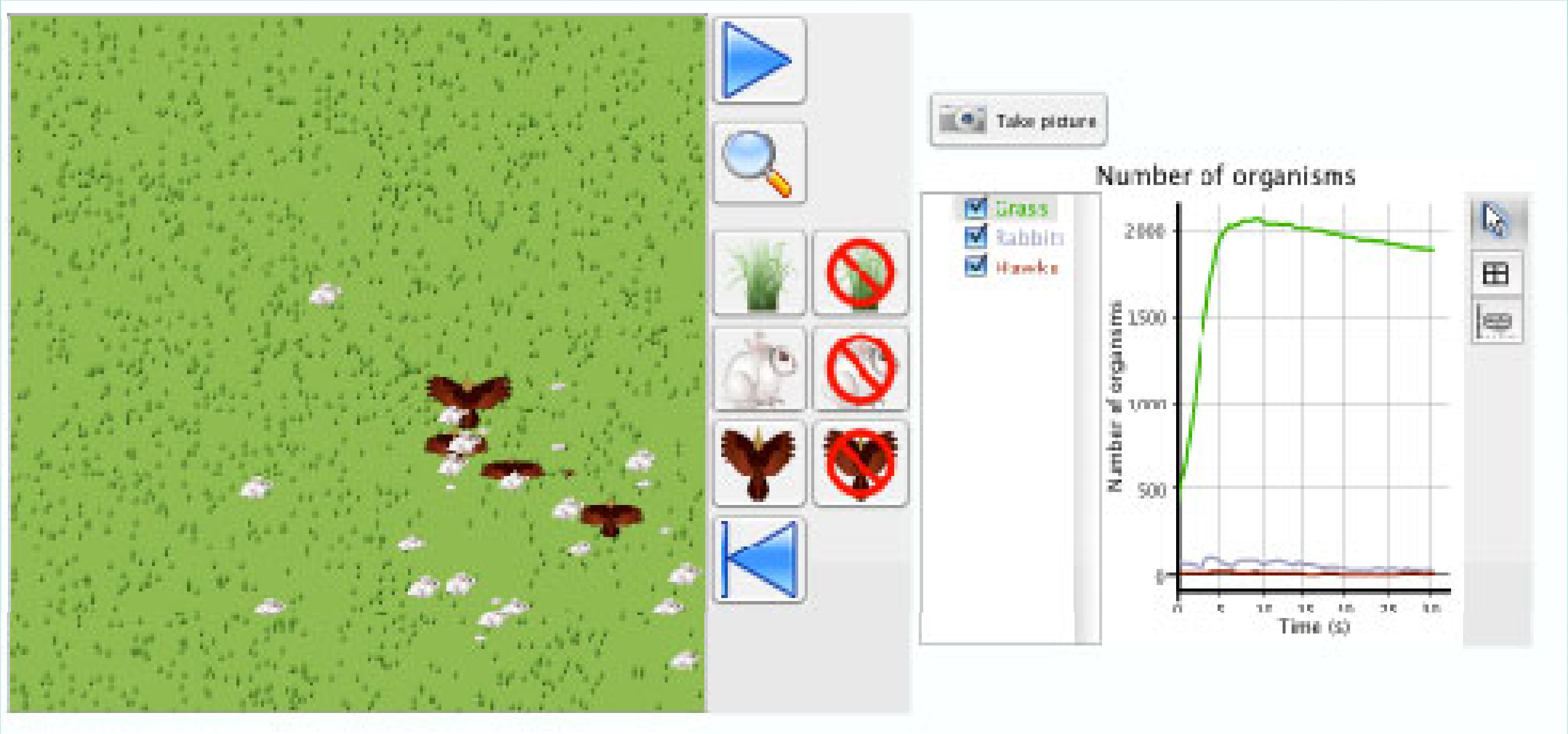
- **Introduction of food chains (and food webs)**
- Kids watch as the environment changes (the snow melts)



Nature of Science

Experiment with Ecosystems

- Experiment with the ecosystem
- Kids create and test their hypothesis around the environment



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Implementation: North Kansas City

Linda Lacy – Director of Research, Evaulation 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

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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

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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?

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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

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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)

Concept Inventory for Evolution Readiness (CIER)

- 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

```
                 Year 1 Results
  More able students   More difficult items
                      |
  800                 |
                      |
                      |
                      |
                  .   |T
                      |  S2Q5f.BI8LG5
                  .   |  S1Q21b.BI11LG2   S2Q3a.BI8LG2 S2Q3c.BI8LG5
  700                 +  S1Q21a.BI11LG2   S2Q2b.BI8LG3
                  #   |  S2Q7b.BI8LG1     S2Q8b.BI8LG2
                  . T |  S2Q1c.BI8LG4     S2Q8c.BI8LG4
                  .   |
                  .   |
               .###   |S
                 .#   |  S2Q2a2.BI8LG6
  600          #### S+  S1Q14.BI9LG2     S1Q17.BI1LG2
               .###   |  S1Q4.BI10LG2
                .##   |  S2Q3b.BI8LG4
            .######   |  S1Q27.BI6LG3     S1Q5b.BI6LG4    S2Q5d.BI8LG2
             .#####   |  S1Q11.BI6LG4     S1Q29b.BI10LG4 S2Q4b.BI6LG4 S2Q5c.BI6LG1 S2Q6d.BI8LG4
             .#### M|  S1Q15.BI9LG1     S1Q30.BI6LG1    S1Q32.BI7LG1 S2Q5e.BI8LG4
               ####   | S1Q7.BI3LG2      S1Q8.BI10IG1    S2Q1b.BI10LG1 S2Q2a.BI8LG6
  500        #######  +M S1Q18.BI6LG4     S1Q28.BI8LG8
              .####   |  S1Q1.BI8LG1      S1Q24.BI11LG1   S1Q3.BI6LG4
                ###   |
              .#### S|  S1Q19.BI7LG2     S1Q20.BI8LG1    S1Q22.BI2LG4 S2Q6b.BI1LG1
                .##   |  S1Q2.BI8LG8      S1Q23.BI6LG4    S1Q5a.BI6LG4 S1Q9.BI9LG2
                  .   |
                  #   |  S1Q10.BI9LG2     S1Q6.BI6LG1    S2Q5b.BI2LG2
  400            ##   +  S1Q13.BI2LG3     S1Q26.BI9LG2
                  . T|  S1Q25.BI3LG1
                  .   |S S1Q29a.BI10LG4   S2Q6a.BI6LG2
                      |  S1Q16.BI8LG7     S2Q4a.BI6LG4   S2Q6c.BI8LG2
                      |  S1Q31.BI3LG1     S2Q1a.BI1LG1
                      |  S2Q8a.BI7LG1
                      |
  300                 +
                      |
                      |
                      |T S1Q12.BI8LG7
                      |  S2Q5a.BI7LG1
                      |
                      |
  200                 +  S2Q7a.BI8LG1
 Less able students    Easier items
  EACH '#' IS 2.
```

Reliability: α=.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

Year 2 Results

```
More able students   More difficult items
800             .  +
                   |
                .  |T
                   |
                # T| S2Q5d.BI8LG2 S2Q5f.BI8LG5 S1Q21b.BI11LG2
700            ##  + S1Q21a.BI11LG2 S2Q8a.BI7LG1
                   | S2Q8b.BI8LG2 S2Q7b.BI8LG1
               ##  | S2Q1c.BI8LG4
           .#####  | S2Q2b.BI8LG3 S2Q3c.BI8LG5 S2Q3a.BI8LG2
            ##### S|
       .#########  |S
600     .   #####  + S1Q14.BI9LG2 S2Q2a2.BI8LG6
              ###  | S2Q2a.BI8LG6
           .####   |
      .########## M| S1Q5b.BI6LG4 S1Q17.BI1LG2
        #########  | S1Q27.BI6LG3 S1Q30.BI6LG1 S1Q4.BI10LG2 S1Q11.BI6LG4 S2Q4b.BI6LG4
          #######  | S2Q6d.BI8LG4 S2Q5e.BI8LG4 S1Q29b.BI10LG3 S1Q32.BI7LG1 S2Q5c.BI6LG1

500       #######  +MS1Q15.BI9LG1 S1Q1.BI8LG1 S2Q8c.BI8LG4  S1Q8.BI10LG1 S1Q7.BI3LG2 S1Q28.BI8LG8 S2Q3b.BI8LG4
      ########## S| S1Q2.BI8IG8 S1Q19.BI7LG2 S1Q18.BI6LG4  S1Q5a.BI6LG4
            .####  | S1Q3.BI6IG4 S2Q6b.BI1LG1  S1Q24.BI11LG1 S2Q1b.BI10LG1 S1Q23.BI6LG4
            .####  | S1Q20.BI8LG1 S2Q5b.BI2LG2 S1Q6.BI6LG1  S1Q9.BI9LG2

                #  |  S1Q22.BI2LG4 S1Q10.BI9LG2
400            .# T+  S1Q25.BI3LG1
                   |S S1Q29a.BI10LG3 S1Q26.BI9LG2 S1Q13.BI2IG3
                   |  S2Q4a.BI6LG4  S1Q16.BI8LG7  S1Q31.BI3IG1

                .  |  S2Q6a.BI6LG2
                   |
300                +  S2Q6c.BI8LG2
                   |
                   |  S1Q12.BI8 LG7S2Q1a.BI1LG1
                   |T
                   |  S2Q7a.BI8LG1
200                +  S2Q5a.BI7LG1
Less able students     Easier items
 EACH '#' IS 2.
```

Reliability: α=.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)

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CIER - Difficult Concepts

<u>Most difficult</u> 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)

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CIER: Easy Concepts

<u>Easier concepts</u> 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)

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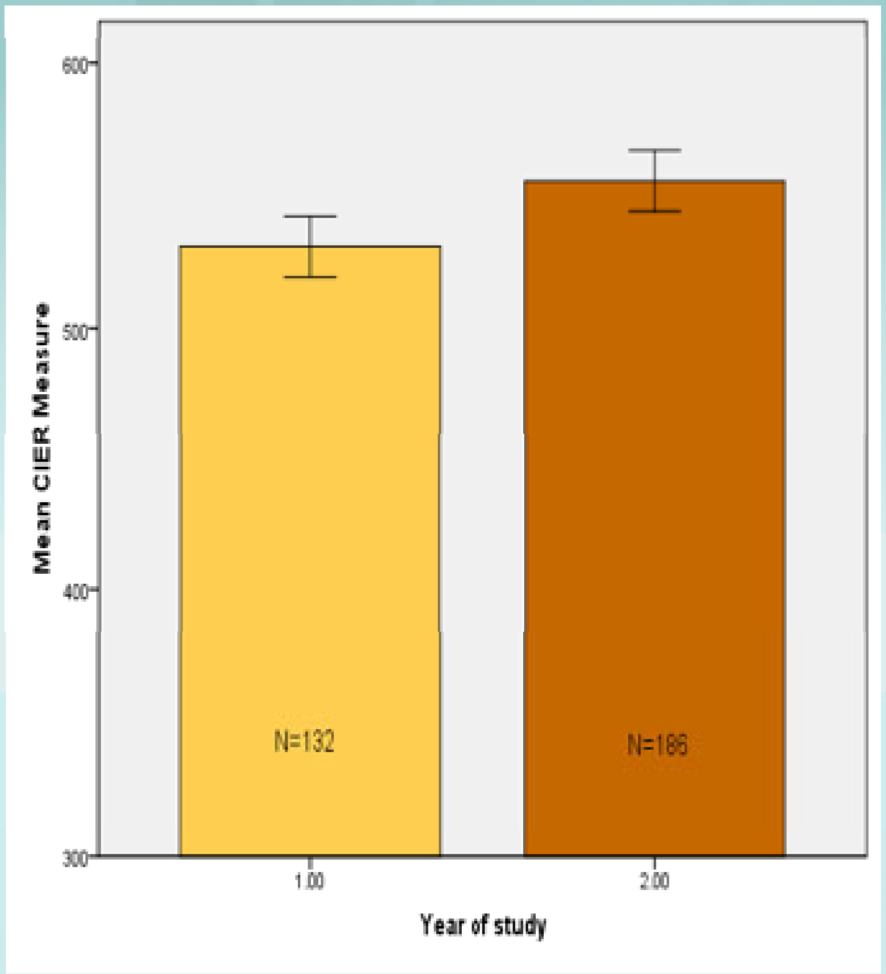
CIER Year 1 - Year 2 Comparisons



Overall Results

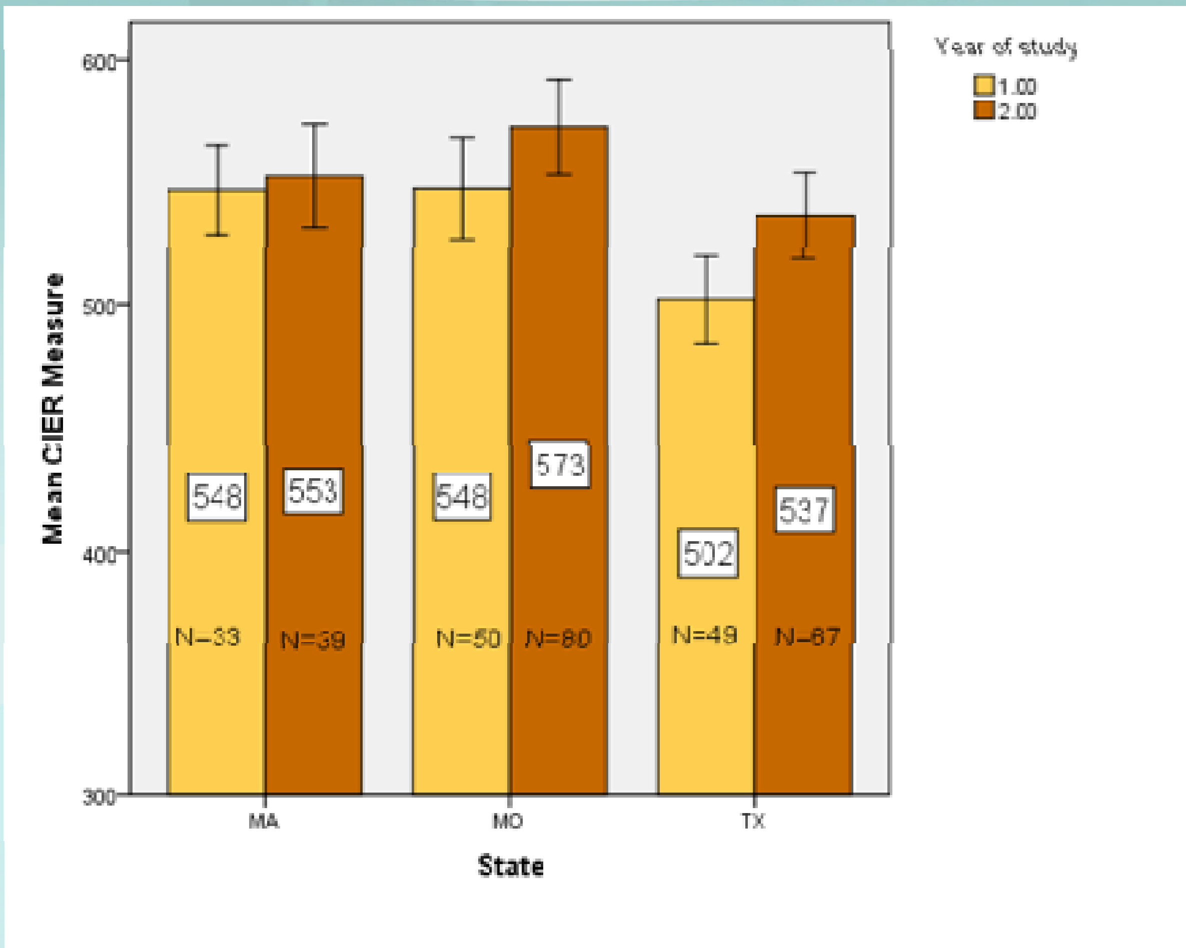
Year 1 Mean =530.87

Year 2 Mean =555.71

Significant difference ($p<.005$)

Effect size d = .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.

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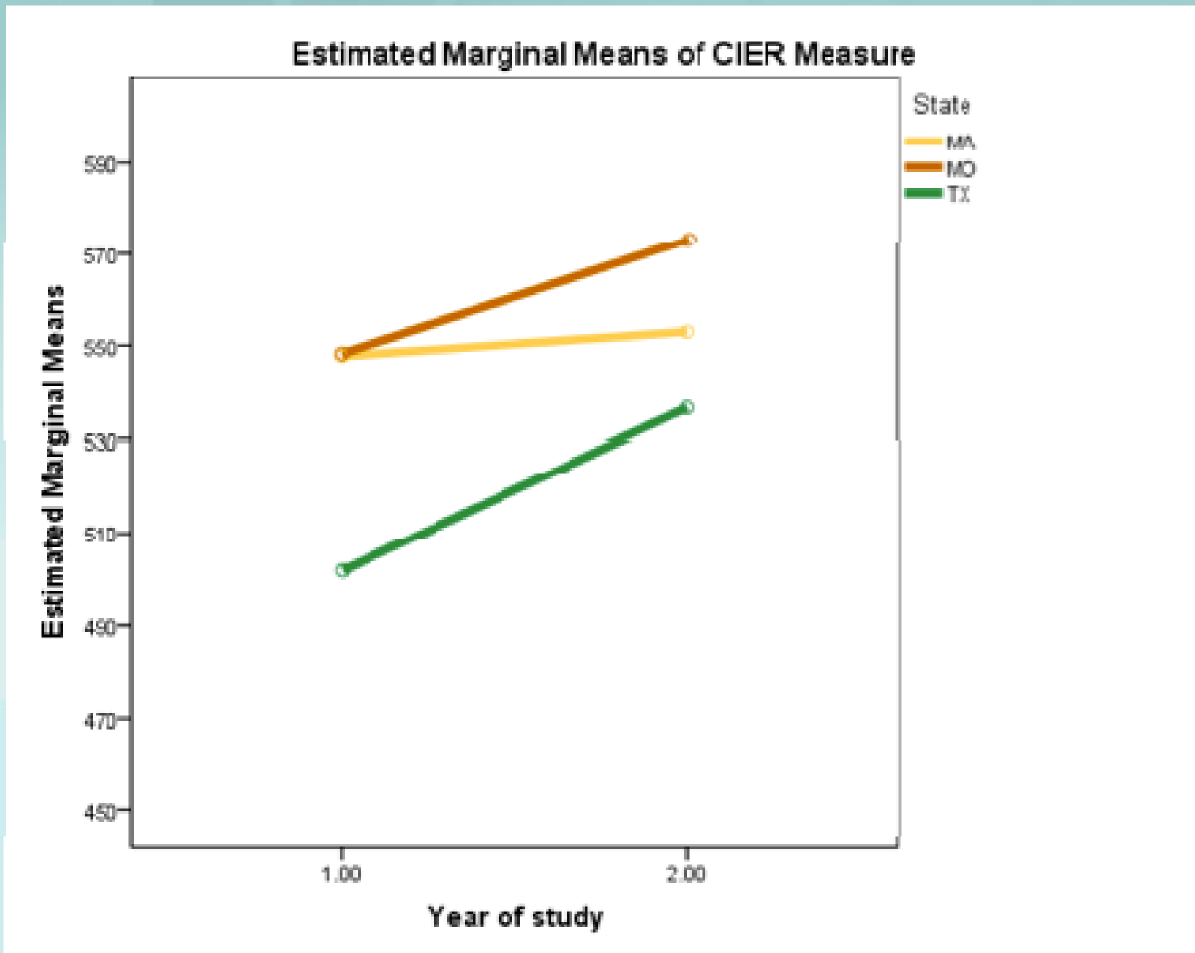
CIER State Comparisons



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.

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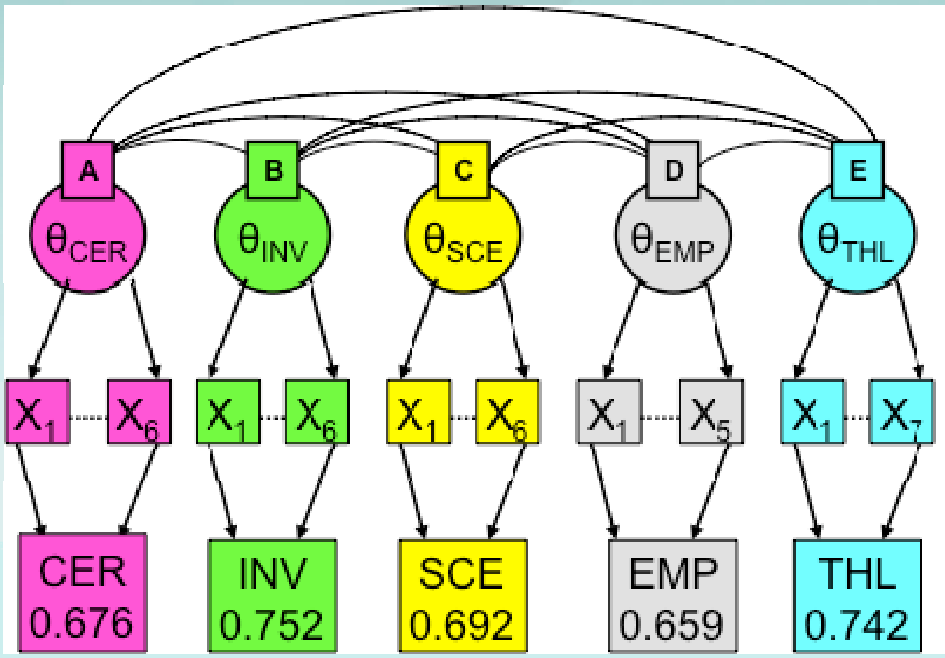
Nature of Science (NOS)

- **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.



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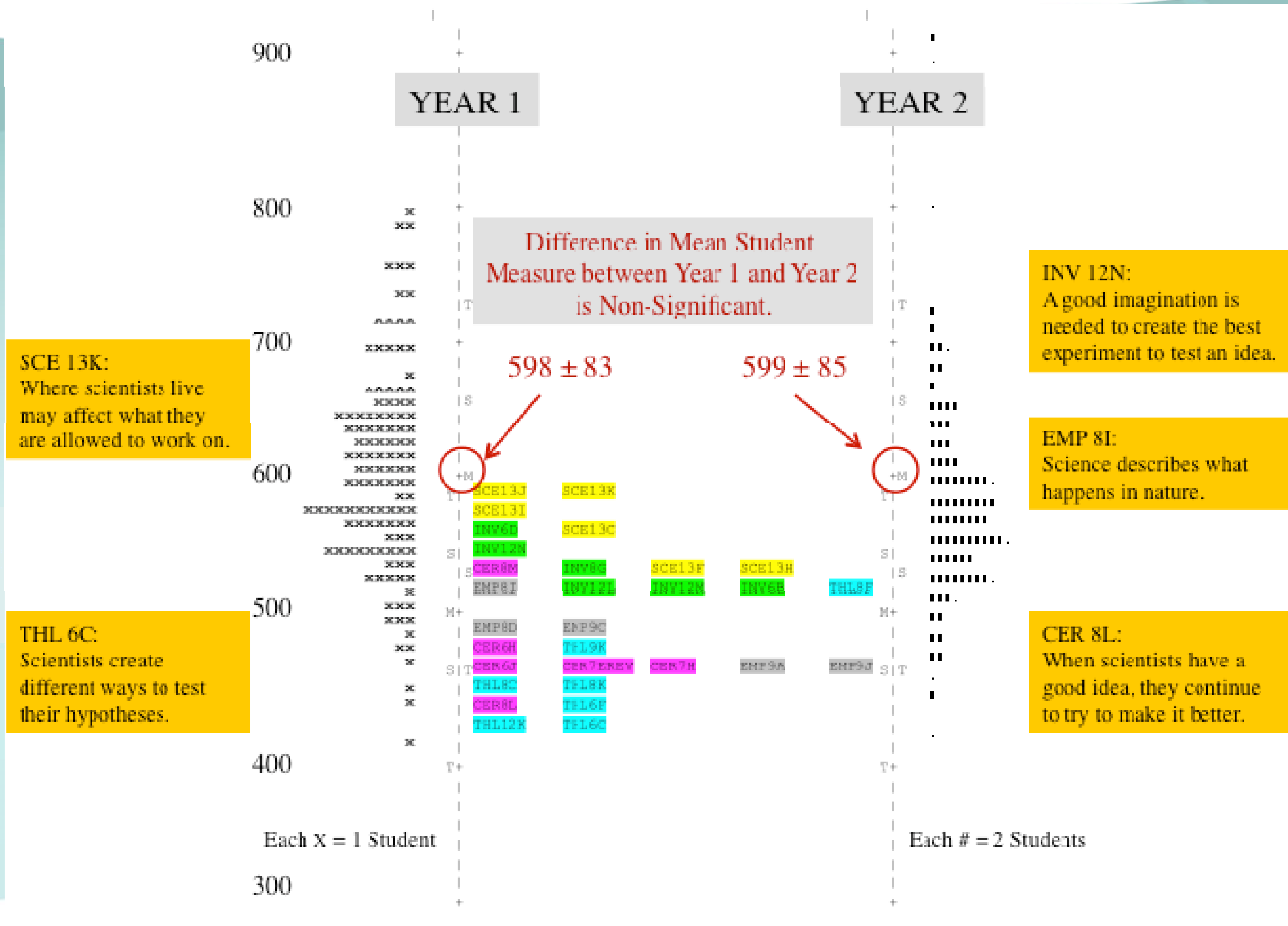
NOS Rasch Variable Maps: Year 1 vs. Year 2



Sub-Scale Comparison: Year 1 to Year 2 Mean* (Std. Dev.)

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

*All differences are Non-Significant.

** $p < 0.052$

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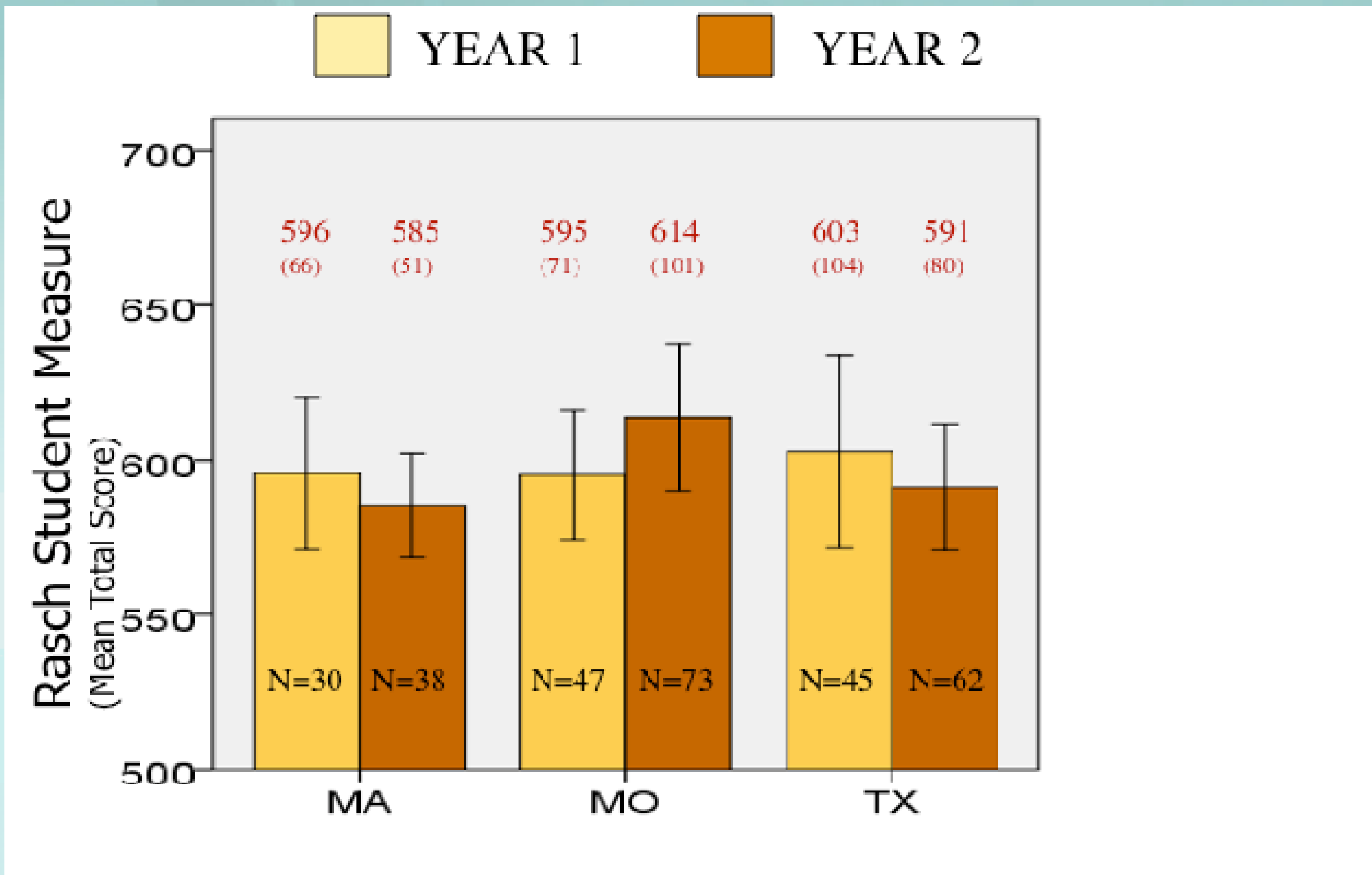
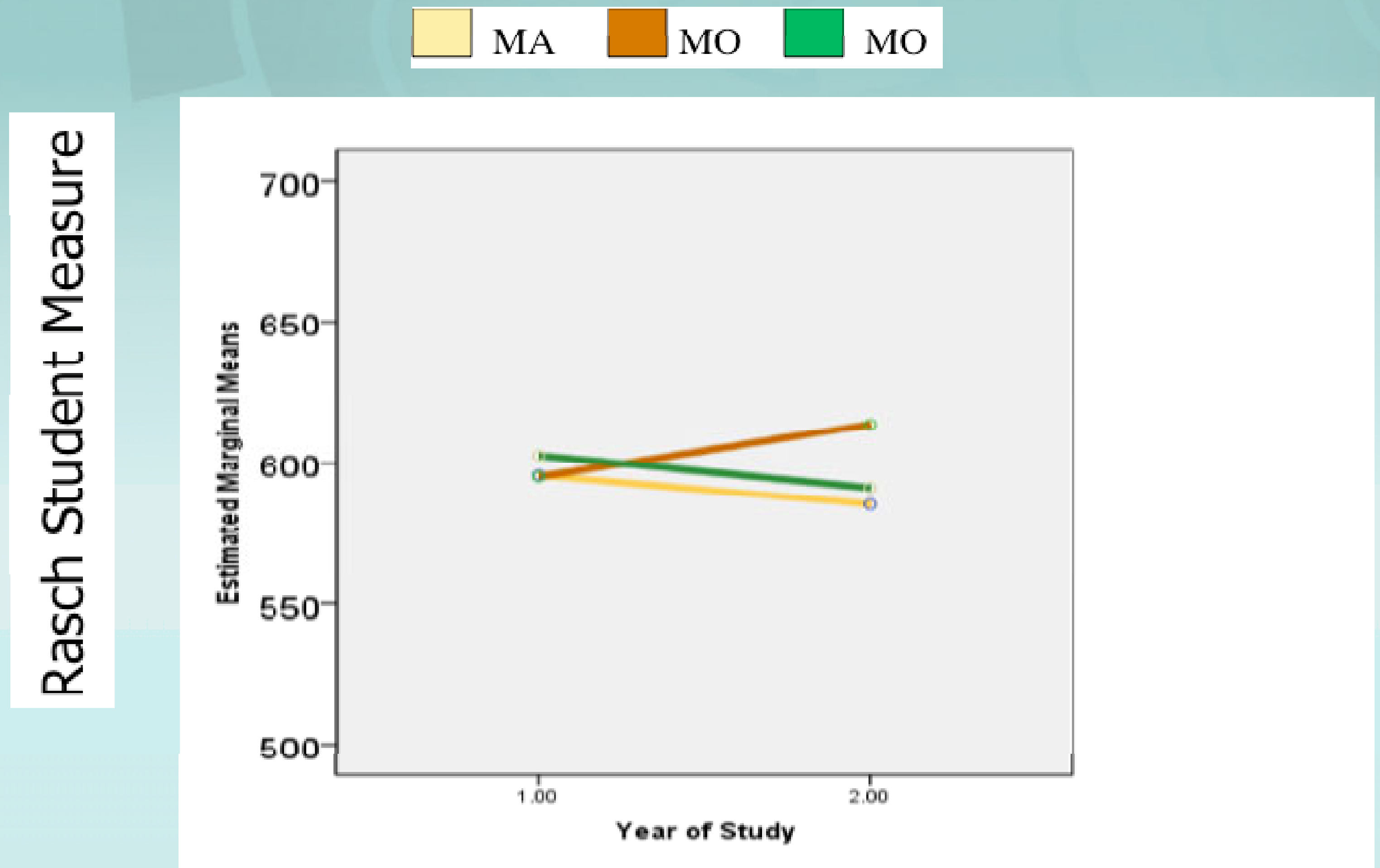
NOS: Across State Comparison Mean Total Rasch Score (Std. Dev.)



- 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

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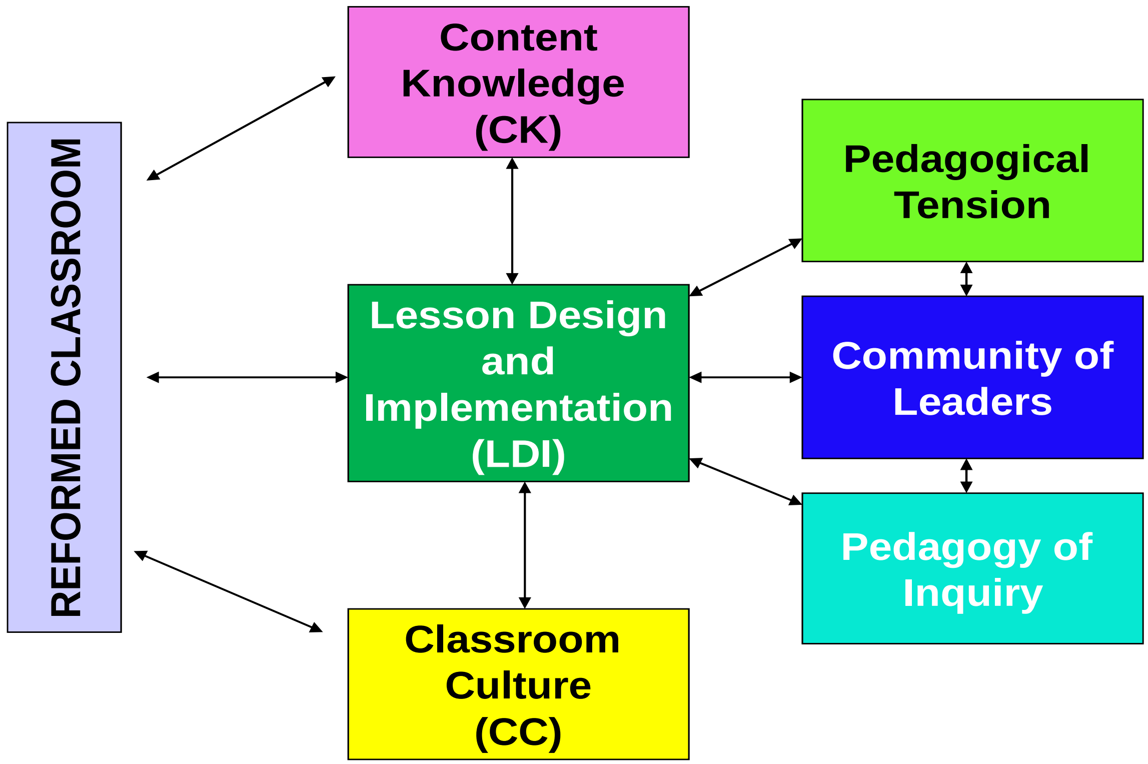
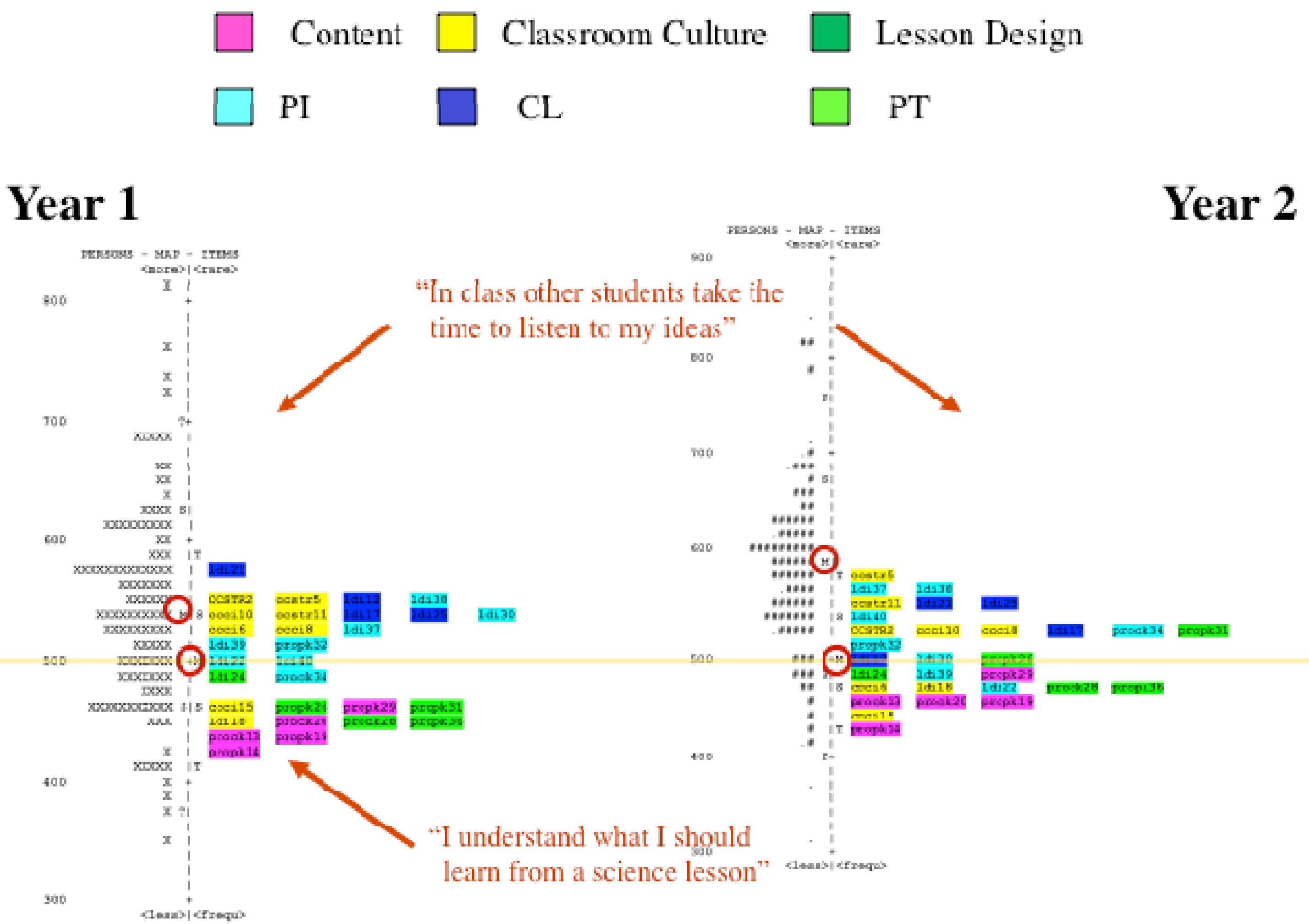
SCES Subscales Relationships



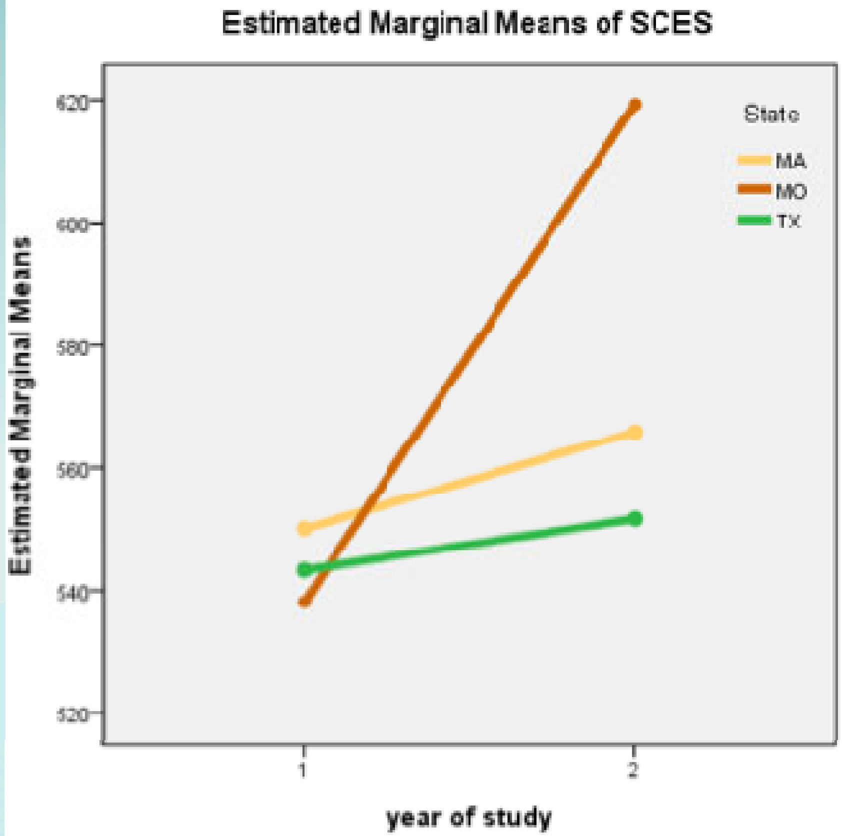
SCES Item Map



SCES Overall Score

	Year 1 (n=124)	Year 2 (n=170)	*p* value	Effect Size d
Mean (s.d.)	543 (82)	583 (94)	< .01	0.49
By State				
Massachusetts	550 (64)	566 (70)	.35	0.25
Missouri**	538 (69)	619 (106)	< .01	1.17
Texas	543 (102)	552 (80)	.63	0.08

SCES Two-Way ANOVA



Source	F	Sig.	Partial η^2
Year	11.109	.001	.037
State	3.665	.027	.025
Year* State	5.590	.004	.037

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SCES Subscale Scores

	Year 1	Year 2	*p* value	Effect Size d
Content	3.11 (0.58)	3.20 (0.58)	.148	0.17
Classroom Culture**	2.63 (0.56)	2.95 (0.62)	< .01	0.57
Lesson Design & Implementation**	2.72 (0.64)	2.97 (0.57)	< .01	0.39
- Pedagogy of Inquiry**	2.69 (0.69)	2.91 (0.61)	< .01	0.32
- Community of Learners**	2.41 (0.79)	2.89 (0.71)	< .01	0.60
- Pedagogical Tension	3.01 (0.65)	3.12 (0.67)	.156	0.17

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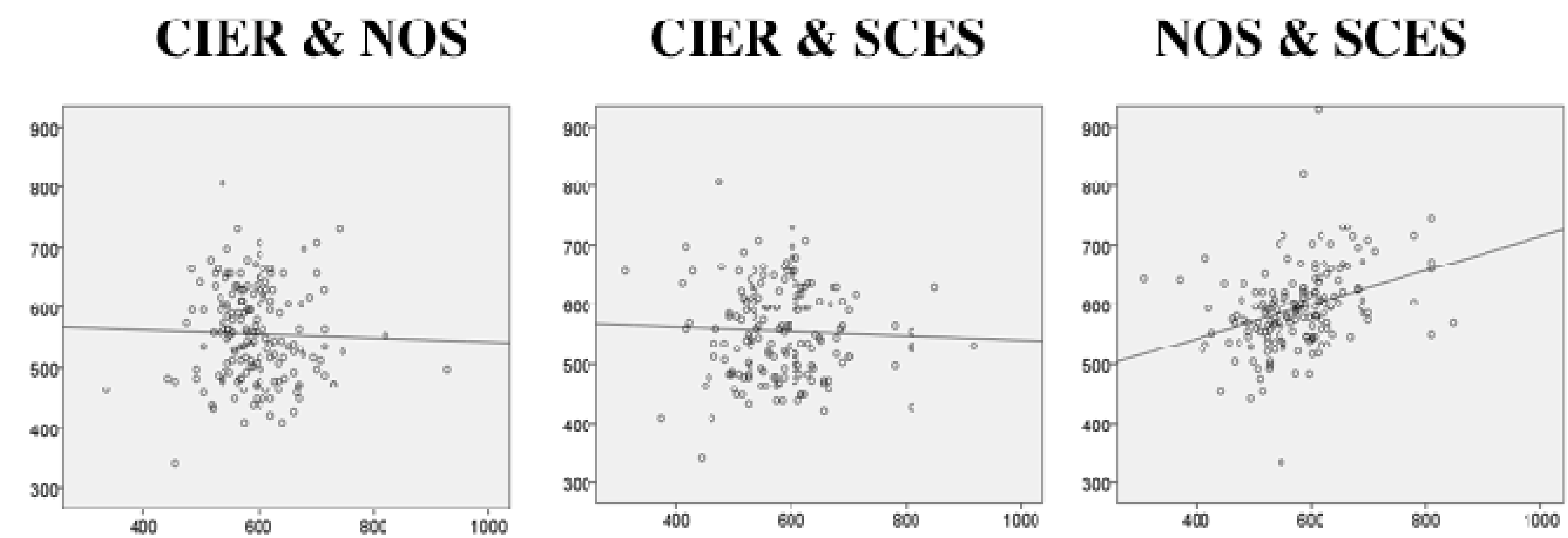
Big Picture: How are these constructs related? (Year 2)



$r = -0.033$ $r = -0.036$ $r = 0.517^{**}$

** $p < 0.01$

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Next Steps

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

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