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Third-grade students' engagement with systems modeling for plant life

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Abstract for DBER Group Discussion on 2014-09-11

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Title:

Third-grade students' engagement with systems modeling for plant life

Abstract:

Elementary students should have opportunities to engage in the scientific practices of modeling to reason about plant processes (NRC, 2013). However, modeling practices are rarely included within elementary science learning environments and content is provided in discrete pieces that do not highlight the ways in which individual processes work together to form a system. Little research has focused on how elementary students engage with modeling practices to conceptualize and reason about the relationships between plant processes and abiotic and biotic elements that plants need to grow, develop, and survive. Here we provided 3rd-grade students opportunities to model about plant growth in order to develop an empirically-tested learning performances framework integrating science content (i.e., plant systems) and scientific practices (i.e., systems modeling). This study reports findings about the ways in which 3rd-grade students engage with modeling to conceptualize and reason about three core relationships identified within the 3rd-grade science standards: (a) plant structure and function, (b) plant life cycle, and (c) plant dependence on abiotic and biotic elements.

Exploring 3rd-Grade Students' Representations of and Model-Based Explanations about Plant Systems

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Introduction

- Plant growth and development is a foundational topic highlighted throughout K-12 science curriculum (AAAS, 2007; NRC, 2011, 2013)
- Little is known about early elementary students conceptualizations of plant processes and their relationships with abiotic and biotic elements (Assaraf & Orion, 2010; Perkins & Grotzer, 2005; Evagorou et al., 2009; Tunnicliffe & Ueckert, 2011).
- Prior research has focused on early elementary students alternate conceptions about seed and plant growth and development (Barman, Stein, McNair, & Barman, 2006; Canal, 1999; Jewel, 2002; Patrick & Tunnicliffe, 2011)

Elementary Plant Science Curriculum

- Trade books contain errors and omissions about the plant life cycle (Schussler, 2008)
- Widely-available curriculum presents factual information in discrete pieces separated from knowledge-building processes (Metz, 2004, 2008; Patrick & Tunnicliffe, 2011; Zangori & Forbes, 2014)



Look at Those Seeds Grow! (AAAS, 2014)

Elementary students can engage in scientific reasoning about plant processes *when supported to do so* (Manz, 2012; Metz, 2008; Zangori & Forbes, 2014)

Purpose

To explore if 3rd-grade students engage with the practices of modeling to consider and reason about the relationships between plant processes and abiotic and biotic elements that plants need to grow, develop and survive.

Study Rationale

- Modeling supports students' engagement in how and why processes work which leads to conceptual understanding (Chang, 2012; NRC, 2013;)
- Developing conceptual understanding in the elementary grades serves as a foundation for later science learning (NRC, 2007)

However K-3 students are:

- Rarely engaged in the practices of modeling (Assaraf & Orion, 2010; Evagorou, Korfiatis, Nicolaou, & Constantinou, 2009; Groetzer & Basca, 2010)
- Rarely engaged in considering how and why processes work (Metz, 2004, 2008)
- Rarely provided content that connects processes within systems (Evagorou et al., 2009; Grotzer & Basca, 2004; Hogan, 2000).

The Practices of Modeling

What is a model?

An external representation that is an abstraction of a complex system. The representation serves to make hidden and key elements explicit and visible (Harrison & Treagust, 2000; NRC, 2012; Lehere & Schauble, 2010; Schwarz et al., 2009)

How does modeling support learning?

Students use their models as cognitive tools to scientifically reason how and why key system processes work and to propose model-based explanations (NRC, 2013; Schwarz et al., 2009).

Defining Model-Based Explanations

- Using the model to generate an explanation that connects the process to the unseen, underlying cause (i.e., the mechanism) (Forbes, Zangori, & Schwarz, 2014; NRC, 2012; Schwarz et al., 2009; Lehrer & Schauble, 2010)
- The mechanism provides how and why the phenomena behave as it does (Gilbert, Boulter, & Rutherford, 2000)
- The explanation is the verbalization of how and why the representation behaves (Gilbert, Boulter, & Rutherford, 2000)

Model-Based Explanations

(Forbes et al., 2014; Schwarz et al., 2009)

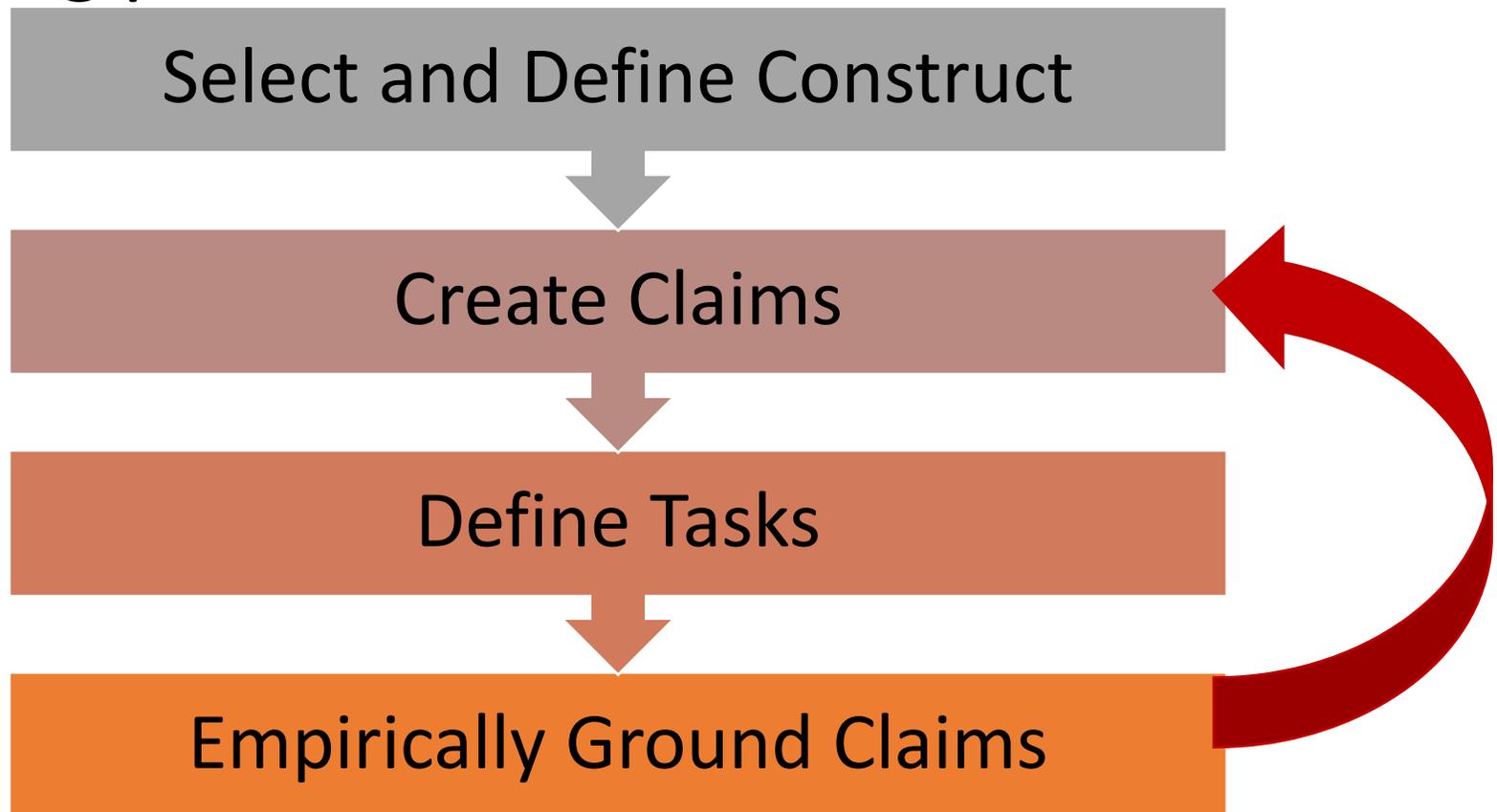
Epistemic Feature	Description
Components	The elements of a process included in the representation
Mapping	Relationship between the model and the physical world
Sequence	Recognizing the connections and relationships within a process
Explanatory Process	Identifying the causal mechanism for the modeled components and sequences
Scientific Principle	A generalization about the phenomena that relates to abstracted components of the model.

Research Questions

1. Do 3rd-grade students' models of plant processes include connections with abiotic and biotic elements?
2. If so, in what ways do 3rd-grade students use their models to form model-based explanations about the relationships between plant processes and abiotic and biotic elements?

Research Design

Construct centered design (CCD) to design a learning performance (Shin, Stevens, & Krajcik, 2010)



CCD Step 1: Select and define a construct

“Big” idea

Plants are complex systems composed of many parts that interact together and with other systems in order to grow, develop, and survive (AAAS, 2007; NRC, 2010, 2013)

Three target concepts

1. Plant structure and function (Concept 1)
2. Plant life cycle (Concept 2)
3. Plant abiotic and biotic relationships for growth and survival (Concept 3)

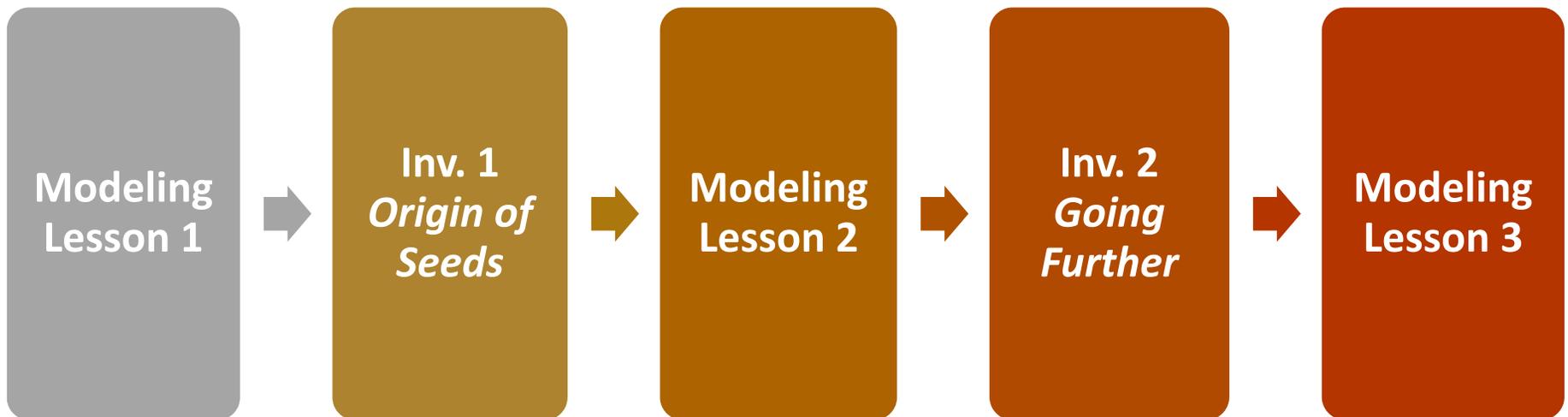
CCD Step 2: Create claims through learning performance design

	Plant Abiotic and Biotic Relationships
Components	Representation includes both visible and nonvisible plant component(s), abiotic and biotic elements necessary for plant growth, development, and survival
Sequence	Sequence describes a relationship that demonstrates a full cycle between plant components and abiotic and biotic elements
Explanatory Process	Students use their models to articulate how and why plant processes require abiotic and biotic elements
Mapping	Statement connects and relates the model to the physical phenomenon
Scientific Principle	Includes all components of the scientific principle that address the relationship between plants and abiotic and biotic elements

CCD Step 3: Define tasks

Modeling lessons embedded in *Structures of Life* (FOSS, 2005).

- Does not include the practices of modeling
- Does not include scientific explanation construction
(Metz, 2004; Zangori & Forbes, 2014)

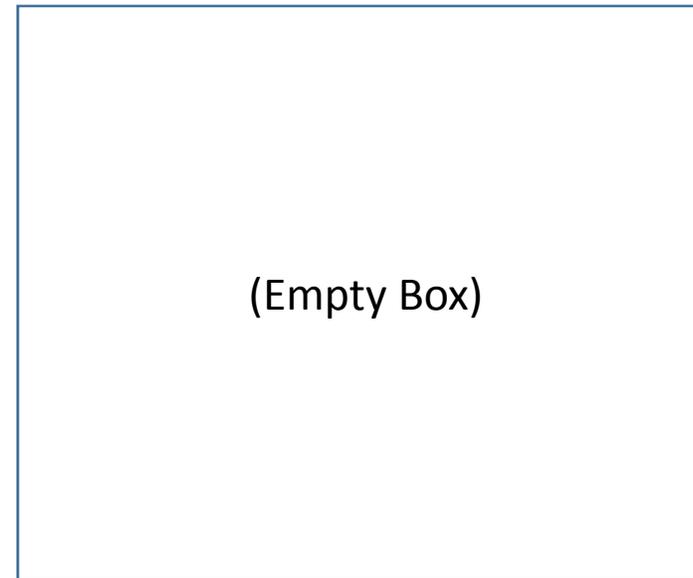


Modeling Task

Four reflective questions about the model

1. What does your model show happening to a seed as it grows?
2. Why do you think this happens to a seed as it grows?
3. What have you seen that makes you think this happens to a seed as it grows?
4. How would your model help you convince others that this is how a seed grows?

How does a seed grow?



(Empty Box)

Participants

Four different schools

Five 3rd-grade classrooms

Demographics

- Urban (2), suburban (1) , rural (2)
- SES range: 5.4 – 75%
- Class size range: 11 – 22 students
- Teacher experience: 11 – 23 years
- Teacher modeling experience: 2 years
- Teacher experience with plant science curriculum: > 2 years

Data Collection

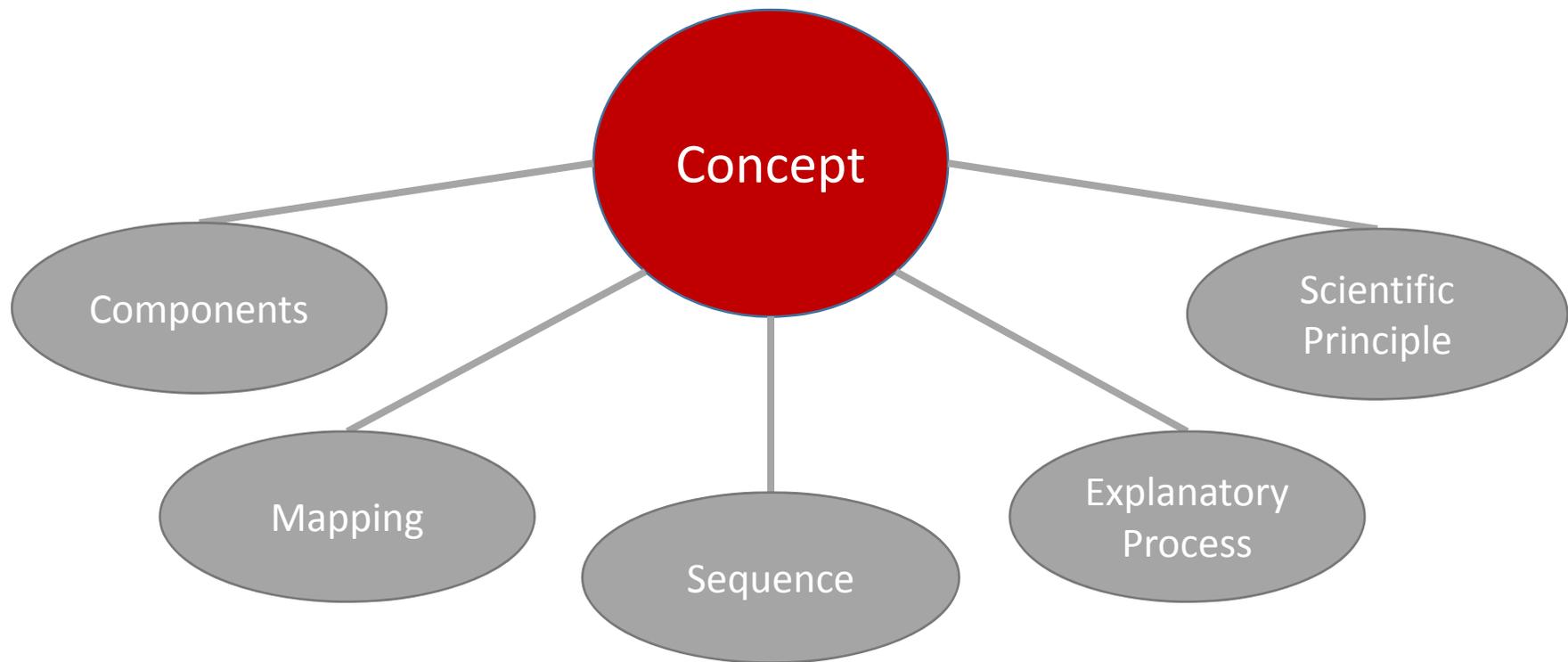
Models with associated writings from each modeling lesson: $n = 73 * 3 = 219$

Purposeful, maximum variation sampling within each classroom for student interviews $n = 21 * 3 = 63$

- Teacher input
- Range of academic interest
- Same students interviewed throughout study
- Situated in modeling artifacts

CCD Step 4: Empirically ground claims in the learning performance design

Qualitative pattern matching (Patton, 2001)



Components Learning Performance Design Claims for Plant Abiotic and Biotic Relationships

Level	Components
0	No abiotic or biotic elements represented
1	Visible plant, abiotic and/or biotic components
2	Visible plant, abiotic and/or biotic; non-visible plant and abiotic or biotic components
3	Visible and nonvisible plant, biotic and abiotic elements

Example of Empirically Grounding the *Component* Learning Performance Claims for Plant Abiotic and Biotic Relationships

Level	Components
1	Visible plant, abiotic and/or biotic “...bees pollinate so that the flowers can grow or so the leaves and stuff can grow. “
2	Visible plant, abiotic and/or biotic; non-visible plant and abiotic or biotic “The roots absorb the water using the root hairs on the plant...multiple root hairs can grab into the water and suck it up from different places”
3	Visible and nonvisible plant, biotic and abiotic elements “This is the rain coming down and the plants growing and there are inchworms all over the place [above and below ground]. These are the clouds and there's a plant popping out [of the ground]. These are roots and water [underground] ”

Data Analysis

Quantitative analysis

Multi-level repeated-measures mixed model

ANOVA

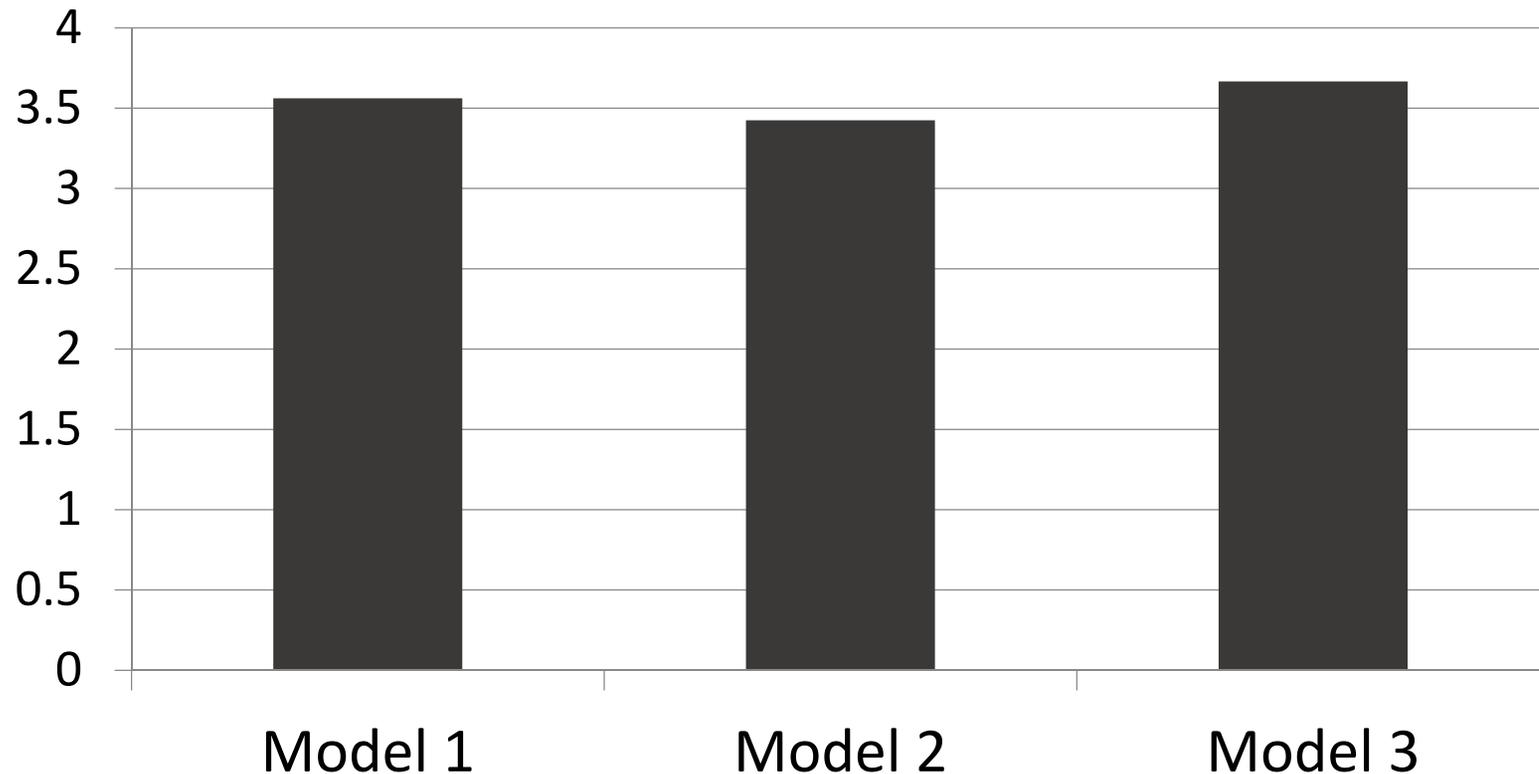
- Modeling lessons
- Concept
- Epistemic features

Qualitative Analysis

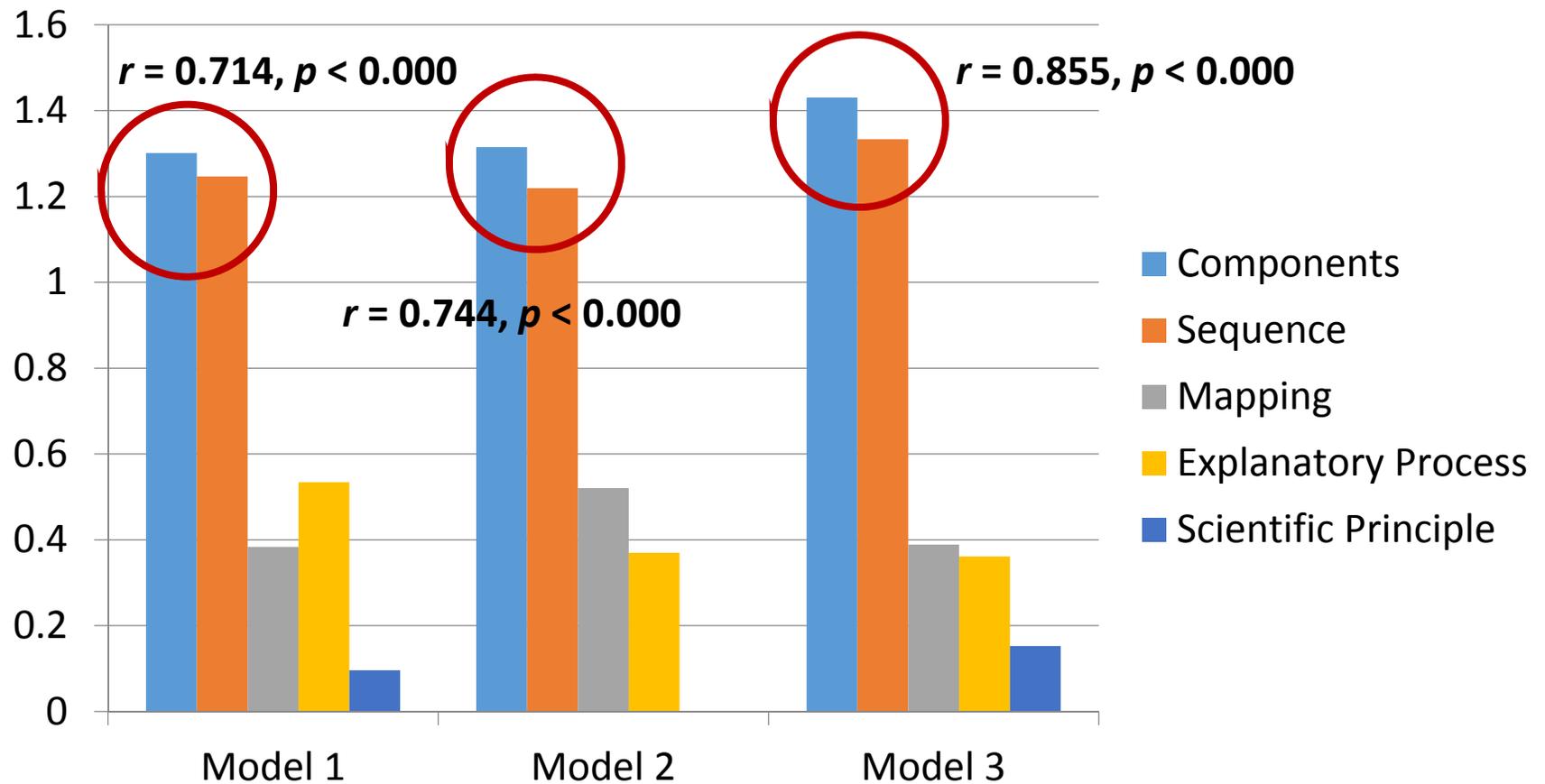
Qualitative pattern matching (Patton, 2001)

- Target conceptions
- Epistemic features

RQ1: Do 3rd-grade students' models of plant processes include connections with abiotic and biotic elements?



Epistemic Features



RQ2: How do students use their models to form model-based explanations about the relationships between plant processes and abiotic and biotic elements?

Qualitative Themes

1. Alternate conceptions used for model-based explanations
2. Above ground model-based explanations
3. Below ground model-based explanations

Theme 1: Alternate Conceptions

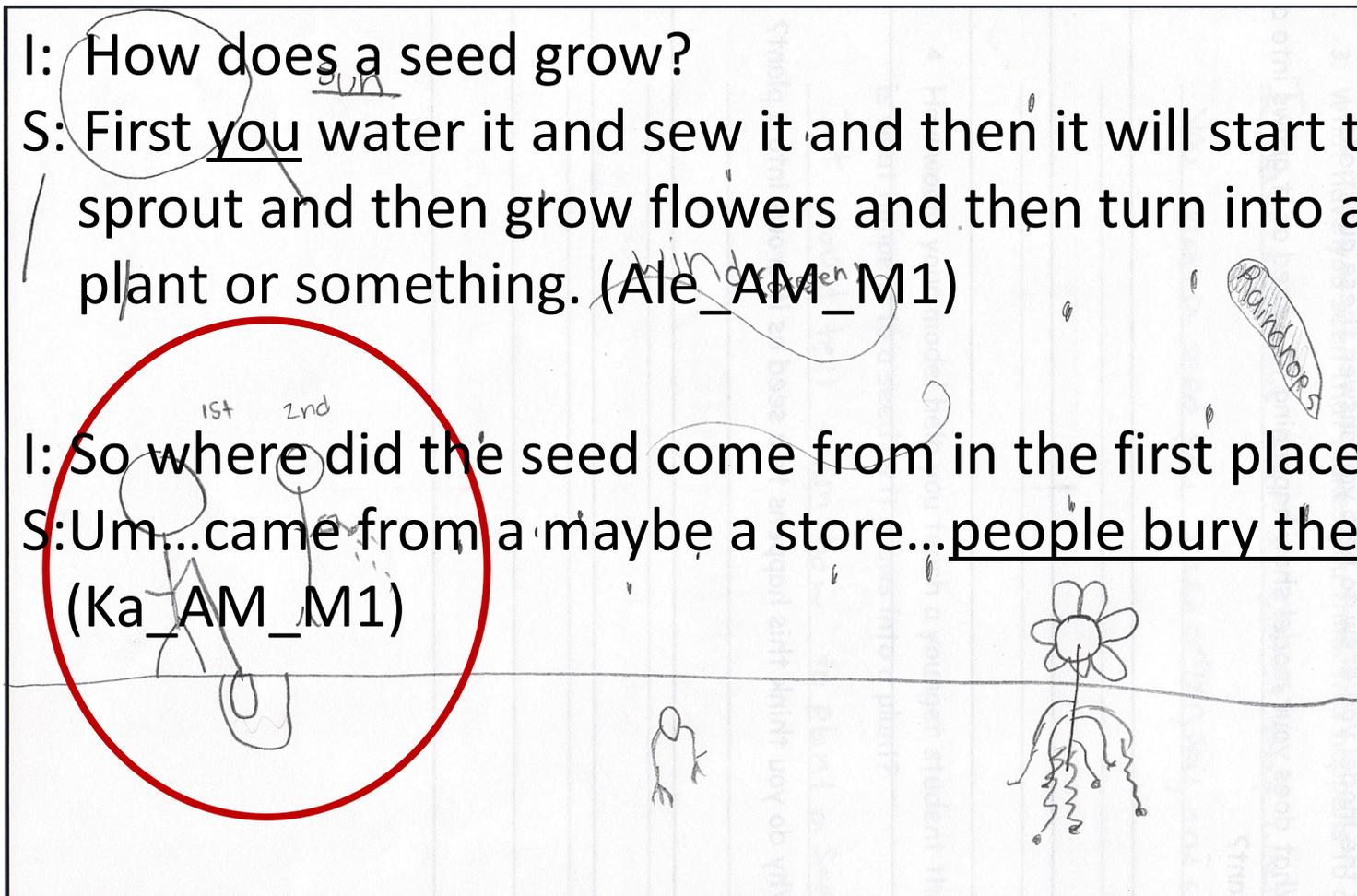
Model 1 - Sherry

I: How does a seed grow?

S: First you water it and sew it and then it will start to sprout and then grow flowers and then turn into a big plant or something. (Ale_AM_M1)

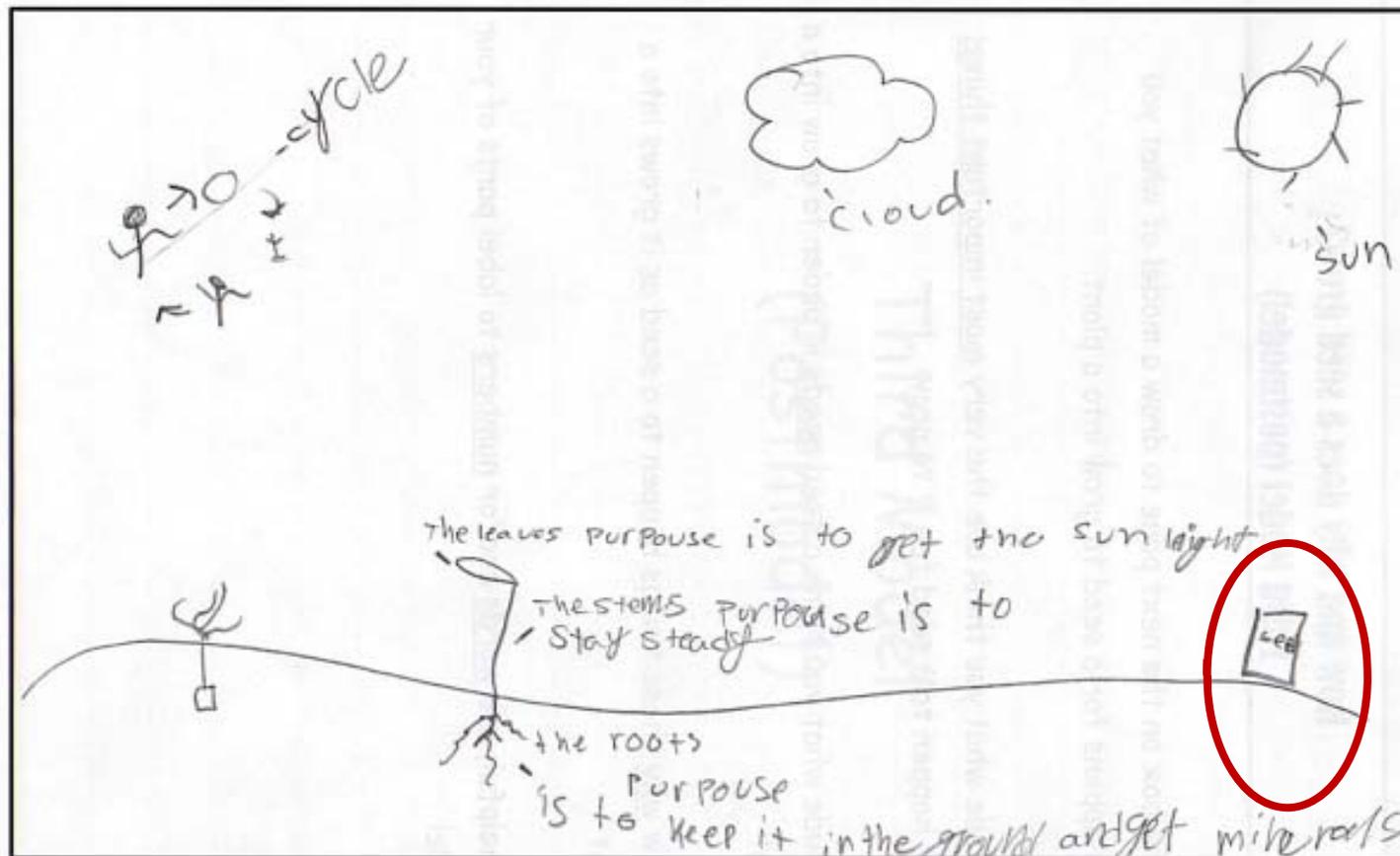
I: So where did the seed come from in the first place?

S: Um...came from a maybe a store...people bury them
(Ka_AM_M1)



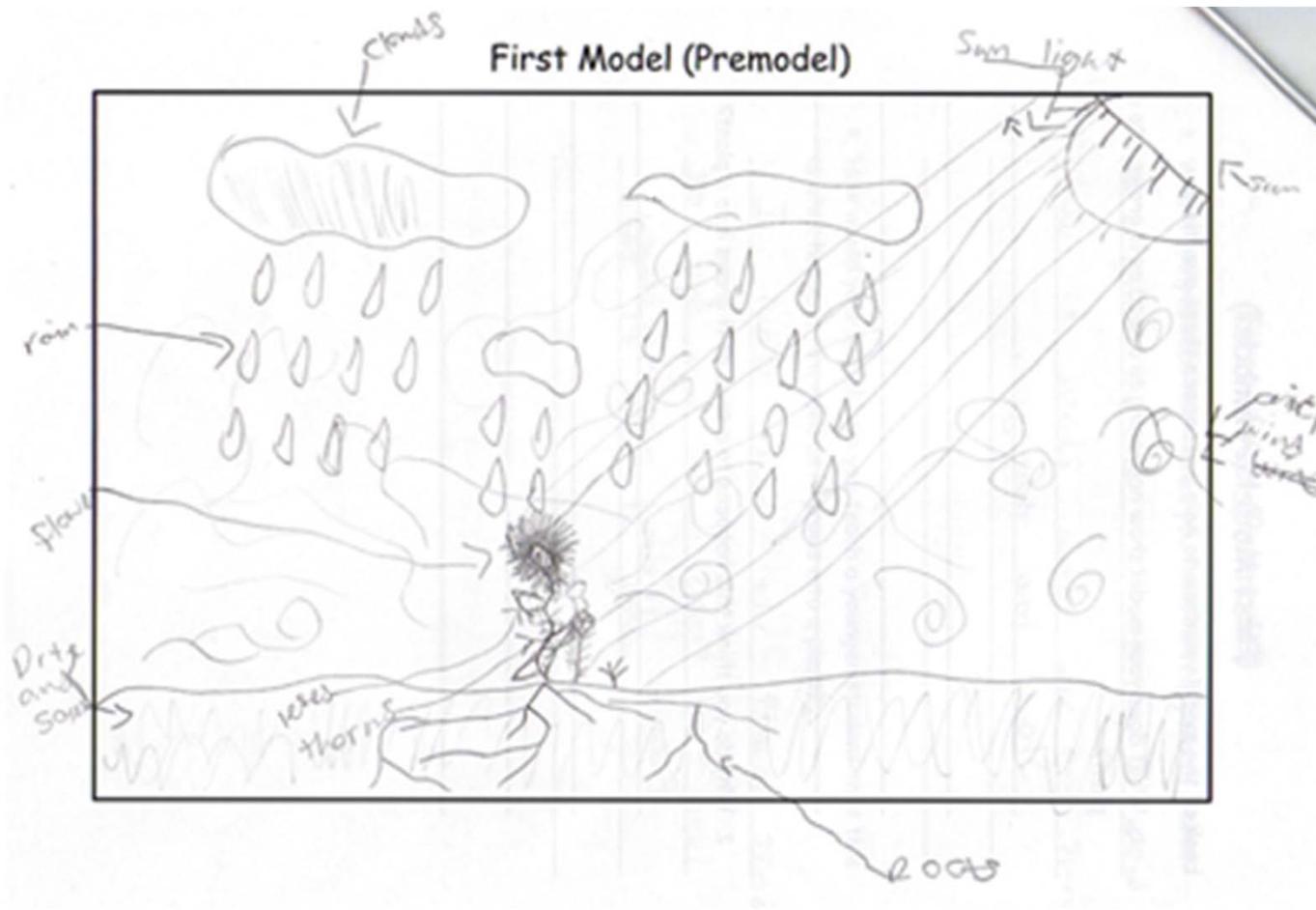
Model 3 - Sherry

Third Model (Postmodel)



Theme 1 Summary: How and why initial seed growth occurs is human intervention.

Theme 2: Above Ground Interactions



“water is
the most
important
thing”
(N.S2M2)

Above Ground Theme

Theme 2 Summary: Students articulation of their models focused on *what* happens to the plant not *how* and *why* plant processes interact

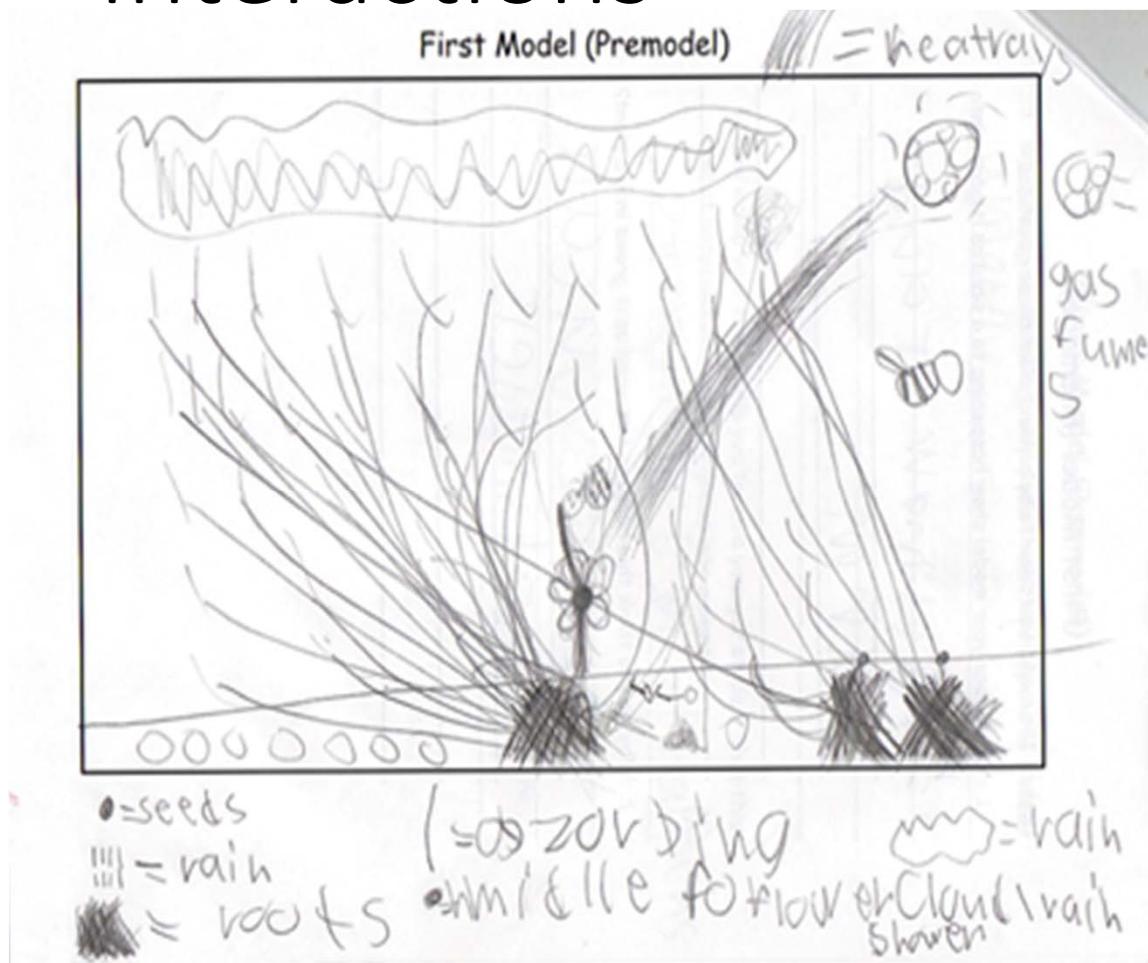
I: What's the most important part of your model?

S: Rain and sun. Because it helps the plant get bigger.
(Av.W.M1)

Other examples:

- “sunlight also has nutrients that it needs” (A.W.M1)
- Water “starts the whole [life cycle] process” through “wak[ing] up the embryo” (H.SHM2)

RQ2: Above and Below Ground Interactions



When it rains the water goes underground and goes to roots. The water is like a food... otherwise the plant can't grow(L.HM1)

Above and Below Ground Theme

Theme 3 Summary: Considered how and why interactions occur between plant processes

Examples:

- Water is absorbed by the plants through “the fuzzy stuff...the hair on the roots will suck ‘em [the water] up” (A.AM3)
- The stem works like a “vacuum” (H.VM2) for the water to be distributed to other plant parts
- There are “little holes” in leaves to “drop it [water] back out [of the plant]” to return it to the atmosphere for “the water to be reused” (A.CKM2)

Synthesis & Discussion

The practices of modeling support students in making their thinking visible (Assaraf & Orion, 2010; Perkins & Grotzer, 2005; Evagorou et al., 2009; Tunnicliffe & Ueckert, 2011)

- Sophisticated conceptions for model-based explanations
- Alternate conceptions for model-based explanations

Curriculum and instruction did not build on their prior knowledge (Metz, 2004; 2008)

- Relationships between plant processes, abiotic, and biotic (i.e., seed origin)
- How and why these relationships are interdependent

Implications

- Modeling should be embedded throughout the curriculum to provide multiple opportunities for students to engage in explanation construction (Metz, 2004, 2008; Patrick & Tunnicliffe, 2011; Schwarz et al., 2009; Zangori & Forbes, 2014)
- Within lessons, the underlying cause and effect *and* hidden processes should be explicit (Groetzer & Basca, 2010; Lehere & Schauble, 2010; Schwarz et al., 2009; Schussler, 2008)
- Curriculum materials should include a systems perspective providing students opportunities to examine relationships between processes (Assaraf & Orion, 2010, 2005)

Thank You!

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