Complex Systems and Complex Representational Practices in Early Elementary Classrooms

BeeSign

Prior expectations

- If you ask a typical 7 year old about how honeybees get food, what would you expect as an answer?
- What if you ask them to draw a bee getting food? What would you expect to see?

2

Prior expectations

Two inter-connected topics

1. Young children's science understanding
2. Young children's representational practices

Two guiding research questions

1. Young children's science understanding
2. Young children's representational practices

Two guiding research questions

1. How can we design learning activities which support students in engaging in complex-systems related ideas in intellectually rigorous ways?
2. Young children's representational practices

Two guiding research questions

1. How can we design learning activities which support students in engaging in complex-systems related ideas in intellectually rigorous ways?
2. What are students' representational practices and how can we design activities to support rich engagement with ideas through the creation of representations?

Today's talk

- Draws from 2 studies
  - 1st BeeSign study: Los Angeles, 2008
  - 2nd BeeSign study, Bloomington, 2009
- Collaborations with
  - Kylie Peppler
  - David Phelps
  - DiAnna Washington

Question 1

Young Children's Understanding of Complex Systems

Complex Systems

- Definition: a group of interdependent elements forming a complex whole where the global phenomena emerge from the local interactions of these elements (Wilensky & Stroup, 2000)
- Value
  - Generative ideas (Goldstone & Wilensky, 2008; Jacobson & Wilensky, 2006; Resnick et. al., 1990):
    - Emergence
    - Interdependence
    - Decentralized processes
    - agent-based modeling
    - Etc.
  - Frequently how the world is viewed by scientists and other professionals

Complex Systems

- Challenges
  - Often superficial understanding (Hmelo-Silver, Holton, & Kolodner, 2000; Hmelo-Silver & Pfeffer, 2004; Wilensky & Resnick, 1999)
    - Structure: The bee has a proboscis
    - Behavior: The bee picks up the nectar
    - Function: Bees are efficient in collecting nectar
- Young Children
  - Few studies, often superficial (c.f., Shepardson, 1997)
  - However, young children are capable of far more complex science given the right activities and motivation (c.f., Chi and Koeske, 1983; Metz, 1995)
  - Develop learning progressions (NRC, 2007)

Design

- 10-week design experiment (Brown, 1992; Barab, 2006)
  - 19 sessions replacing the science curriculum
  - 4 mixed-age, mixed-ability, mixed-classroom groups
    - Groups rotated through the 4 main activities
- Data
  - Pre / post interviews about how honeybees collect food
  - 2 video case-studies each day
  - Copies of student work

Participants (1st BeeSign Study)

- Progressive elementary school in Los Angeles
- 2 mixed-age K-1 classrooms (ages 5-7)
  - 3 Experienced teachers (10-25 years of experience each)
- 42 students
  - 22 boys, 20 girls
  - 21 kindergarten, 21 1st grade
    - Mean age: 5 years, 10 months

Pre and Post Interviews

- Structured, open-ended interviews to elicit students ideas about how bees collect food
  - Specific questions to elicit students' awareness of the behaviors and functions
    - i.e., bees dance to collect food more quickly
  - Roughly 10 minutes
  - 2 interviewers
  - Clarifying questions were included as needed

1. When you see bees going to flowers, what are they doing?
2. How do bees get food?
3. Do all of the bees in the hive collect food?
4. How do bees know where to find good food?
5. Does it matter if bees collect food quickly?

Pre and Post Interviews

Structure:

[*Bees get nectar*] *With their proboscis. And it goes to its honey stomach.*

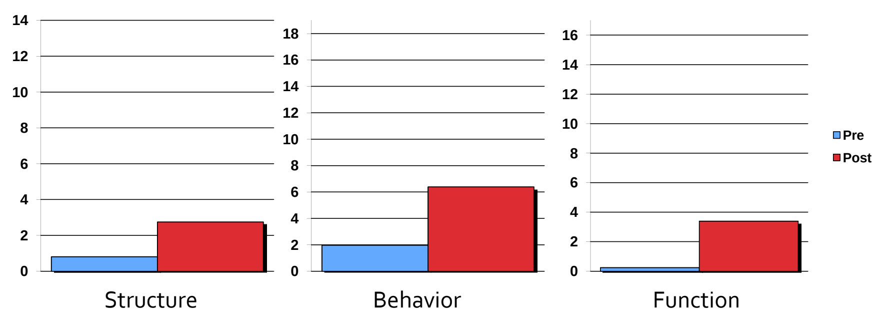
Behavior:

Because they will do the dance. One bee goes to a flower and then the bee does the dance and then all the bees look carefully at the dance and they may go to the flower that the dancers tell them to go to.

Function:

The dance makes it faster [to collect food].

Science Gains



- Students' scores, when controlling for grade, improved significantly (N=36)
  - Structure: 0.81 to 2.75, $F(1,34) = 45.87$, $p < .003$
  - Behavior: 1.97 to 6.39, $F(1,34) = 112.60$, $p < .003$
  - Function: 0.25 to 3.39, $F(1,34) = 92.03$, $p < .003$

* SBF framework based on the work of Hmelo-Silver et. al., 2004

Activity Structure and Complexity

Activity	Description	SBF
Individual creation of representations	Students create individual drawings of honeybees, and honeybees collecting nectar.	Structure
Participatory modeling	Students work together to develop and enact a skit of how honeybees collect food.	Structure and local behavior
Participatory simulations	Students play a hide-and-seek like game where they hide "nectar" in the yard and have to communicate its location to their peers.	Some local behavior and function
Inquiry with BeeSign	Students engage in guided inquiry using the BeeSign simulation tool.	Aggregate behavior, function

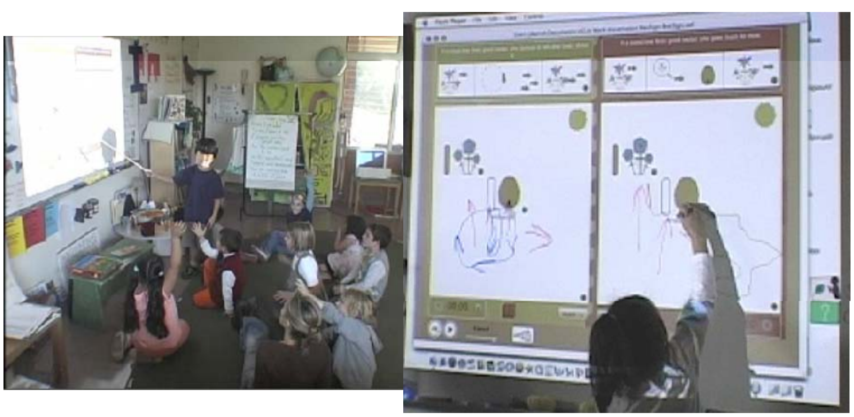
Participatory Modeling: Linking Structures to Behavior

S1: Why did he touch his shoes?
T: Good question. Why did you touch your shoes?
S2: I was… I was rubbing it into the pollen sack?
T: Oh! Rubbing what into the pollen sack?
S2: Rubbing he pollen into the pollen sack.

Participatory Modeling: Thinking through sequence and causal chains

T: All right, well there isn't any [nectar] at that flower. So, if you were a bee would you stay at that flower?
Ss: No.
T : What would you do Chris?
C: I would go back.
T: You would go back?
C: And not do a dance. Because you don't know.

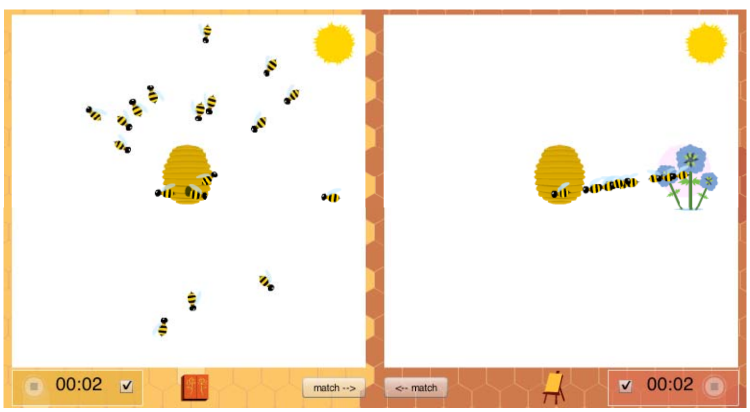
Inquiry with BeeSign



R: If we have a race between these two hives which one do you think is going to get more nectar?

S: The one that's not dancing because it wastes the other one's time?

S: To get more nectar easily.. Because then they get more nectar for the winter.

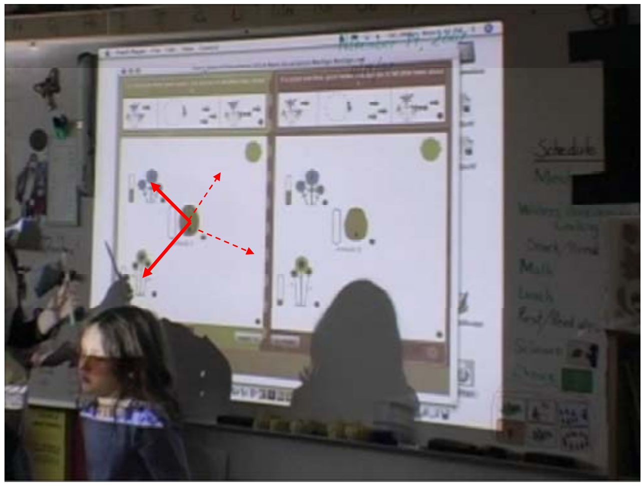


R: What does it do for the bees to dance?

S: It makes them get more nectar. Because if they don't dance, all the bees would still be looking for it. And when one of them finds it, it won't dance so it will just go back.

And that one (*pointing at the dancing side of the board*) tells [bees] so that more [bees] will go.

A typical BeeSign session



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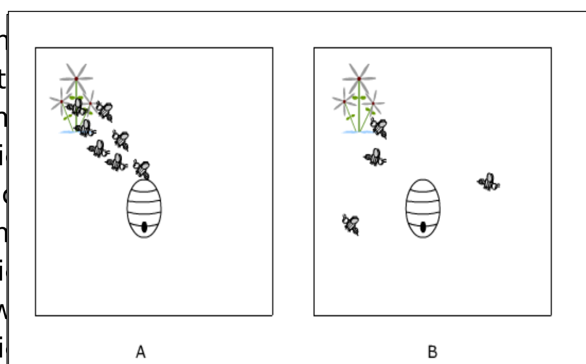
Follow-up study

- Participants (2nd BeeSign study)
  - Public Elementary School in Bloomington Indiana
  - 1 mixed-age 1st and 2nd grade (ages 6-9) classroom (N=40)
  - Changes
    - More refined / focused interviews to tease out aggregate undersatndings
    - Examine the role of teacher in supporting students' inquiry
    - Replicate the findings in a public school
    - Extend features of BeeSign and other activities
    - More extensive examination of representational practices

Interview subscale: Aggregate behavior of honeybees



1. Usin e bees that they were flyin
2. Whi the dan] How com
3. Whi
4. How ancing?
5. Whi
6. Is it important for the hive to collect nectar quickly [and if so] how come?

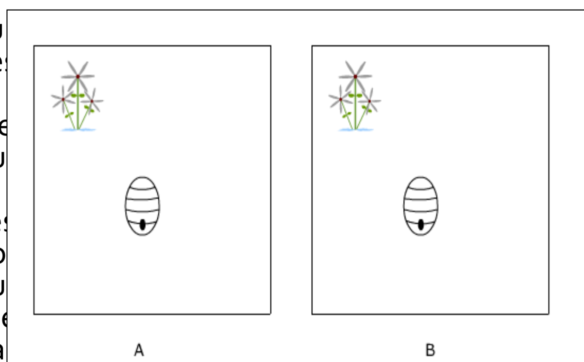
Significant improvement

- Pre-test average: 25% (SD = 0.19)
- Post-test average: 70% (SD = 0.28)

- $t(36) = 2.03$, $p < 0.000$ (two-tailed)

Example question

Can you … which one does …



Pre: We … ut the bu…

Post: Yes … probably go … *ight line*] bu… ut to see if the… non-da… ey would just go scattering out like so [*gesturing in all different directions*]. [Like] if you dropped some marbles they would just go all in different directions.

Role of teacher prompt in scaffolding inquiry

Cycles of inquiry
1. Predict
2. Observe
3. Explain
4. Design

Role of teacher prompt in scaffolding inquiry

		Teacher prompt			
		Notice	Predict	Describe	Explain
Student response	Notice	**75/86**	1/142	0/142	0/158
	Predict	2/86	**135/143**	0/142	25/158
	Describe	1/86	2/142	**134/142**	18/158
	Explain	0/86	31/142	22/142	**139/158**

Proportion of teacher prompts leading to a description of the mechanism

Notice	Predict	Describe	Explain
1/64	11/64	13/64	48/64

Summary

- Young students (k-2) can learn about complex systems related concepts in the context of honeybees
  - Students had lively discussion about the function of bee behaviors
  - Students engaged in description, prediction, and interpretation of emergent patterns in bee behavior (e.g., how the bee dance supports nectar collection)
  - Traditional representational contexts (i.e., drawing) appear to highlight discussion of structure
  - Participatory modeling helped to link structure to behavior
  - BeeSign, as a simulation tool, supported discussions of emergence and function
  - Teacher role in scaffolding inquiry was crucial
  - Some intuitions persisted (the angry queen)

Question 2

Young Children's Representational Practices

Representations in Science

- As students learn science, representations help students with
  - collection
  - movement
  - refinement
  - labeling
  - layering
  - mathematization
  - simplification
  - comparison
  - etc.

  - DiSessa, 2004; Latour, 1998, Lehrer and Schauble, 2006, Roth and McGinn, 1998

Focus on Representational Practices

Practices: The patterned way of acting that people develop over time (c.f. Lave & Wenger, 1991)

- Focus on "doing" instead of disembodied knowledge

Benefits of the Practice Approach

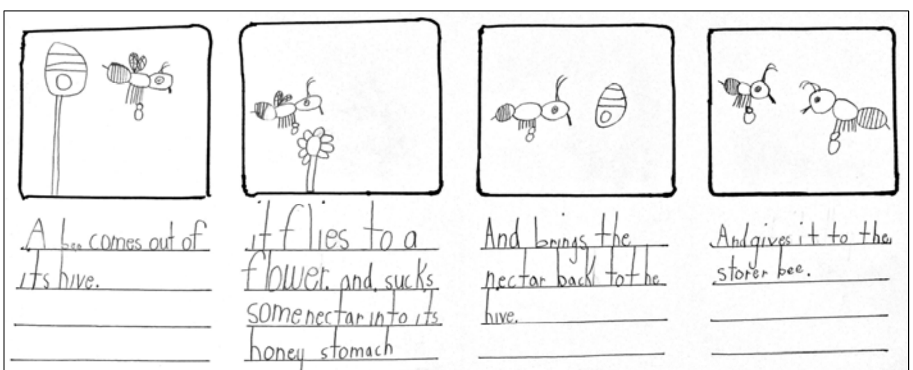
- Practice approach highlights
  1. Unspoken assumptions about representations (Hall, 1996; Roth & McGinn, 1998)
  2. The *differences* between creating, reading, and critiquing representations (diSessa, 2004) *
  3. The *commonalities* between creating, reading, and critiquing representations (Danish & Enyedy, 2007)
  4. The relationship between conceptual understanding and representing (Hall, 1996; Roth & McGinn, 1998)
  5. Inseparability of individual and social components of cognition (Cobb, Stephan, McClain, & Gravemeijer, 2001)

* While diSessa's notion of MRC is not explicitly aligned with the practice orientation, and is more focused on the individual, the importance that is placed on tasks and context is well-matched to our current discussion.

The present analysis

- Aims to extend the literature
  - Focus on young children's practices (K-1)
  - Hold the task constant
  - Couple qualitative narrative with fine-grained quantification
- General research questions:
  - What are k-1 students' representational practices?
    - What the students are saying and doing as they represent?
    - How do these practices change over time?
    - How are they related to the content being studied?

Methods



- individual representations
- 6 groups of 3-6 students
- 10 groups analyzed (5 pre-, 5 post-)

Participants (1^{st} BeeSign study)

- Progressive elementary school in Los Angeles
- 2 mixed-age K-1 (5-7 years old) classrooms
- 3 Experienced teachers (10-25 years of experience each)
- 42 students
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Analysis

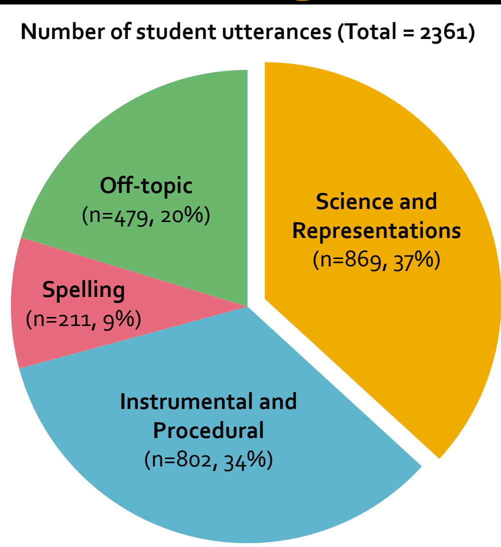
- Storyboards
  - Coding scheme documenting features of students' storyboards (based on interview codes)
- Video of representational practices
  - Grounded, iterative analysis of the video data (Erickson, 2006)
    - Topics of students' talk
      - Details of science and representations the students addressed
    - Role of context in shaping interactions
      - Audience
      - Timing (pre- v. post-intervention) as students' conceptual understanding (measured via interviews) also changed
    - Interactional role of their discussions

Q1: Did the students' storyboards improve?

	Pre-Storyboard	Post-Storyboard
Example		
Example score	0	6
Mean score	1.2	5.55

* This increase was statistically significant: $t(34) = 11.115$, $p < .01$, two tailed.

Q2: What do students talk about when creating their storyboards?



- Coded using transcript and video for clarification
- Inter-rater reliability:
  - High-level categories: 84.7%
  - Science and Representations: 93.5%

Q3: What aspects of the science content do students discuss?

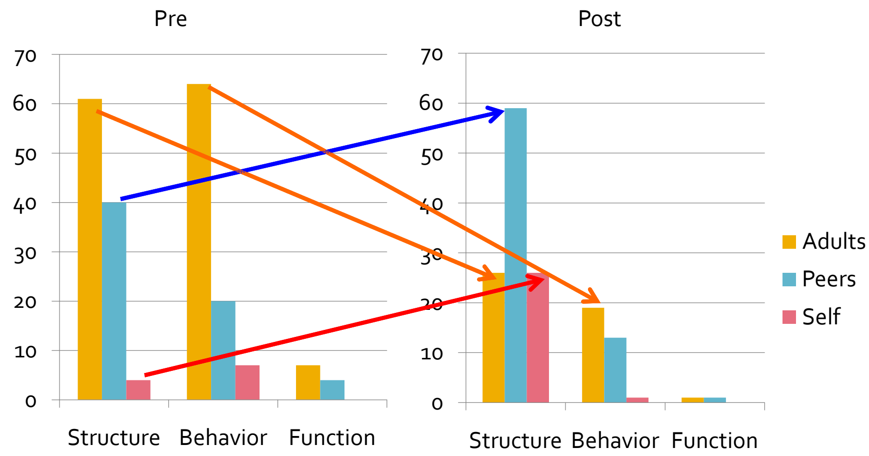
	Structure	Behavior	Function
Examples	Bee; hive; proboscis	Searching for flower; dancing; returning to hive	Survive the winter; collect nectar more quickly
Utterance Examples	"This is a bee hive"	"They're going to drink nectar from the flower"	"They do a dance to tell others where the honey is"

Quality of Student Science Talk

	Inaccurate	Detailed	Extraneous
Examples	Flowers that contain honey, hives with a King Bee	Head, Thorax, Abdomen, Proboscis, Pollen Basket	House, Trash Can, Jetpack, Chairs, and fictional events
Pre N=367	11 (3%)	0 (0%)	19 (5.2%)
Post N=502	1 (0.2%)	24 (4.8%)	8 (1.6%)
$X^2(1, N = 869)=$	12.18, $p < .001$	18.04, $p < .001$	9.04, $p = .003$

Students' references to science were significantly more accurate, more detailed, and less extraneous over time.

Students' science talk across audiences



Q4: What aspects of representing are students discussing?

	What	How	Why
Description	The features that are included in the representation.	How they are represented.	Why the different representational choices are made.

Example:

Victoria: Are you gonna make the proboscis?

Joseph: I already made the proboscis.

Victoria: That does not look like a proboscis. It's not in there it's the curly thing like [shows her storyboard to Joseph]

Victoria: They don't have mouths like us.

Students' representational talk across time

	What	How	Why
Description	The features that are included in the representation.	How they are represented.	Why the different representational choices are made.
Pre N=367	232 (63.2%)	27 (7.3%)	13 (4.3%)
Post N=502	199 (39.6%)	98 (19.5%)	73 (14.5%)

Interactional role of students' science and representational talk

- How their talk shaped interaction
- In particular, a focus on assessments because of how they influence the conversation and the product (representation)

1	Victoria:	I made the pollen basket.	Assessment of peer's representation
2	Victoria:	You didn't make the pollen basket.	
3	Joseph:	Yes I did.	
4	Victoria:	The pollen basket is not on the front leg.	Resulting discussion of content nuances

Q5: The interactional role of students' talk -- assessments

	Assessment-Seeking	Assessment-Giving	Assessment-Warranting	Assessment-Responding
Description	Directly requests evaluation of storyboard	Explicitly appraises their storyboard or their peer's	Augments their appraisal with a reason or example	Replies to the given feedback

Shifts in Representational Practices

Construct	Measure	Change
Knowledge	Interviews	Increase (prior study)
Knowledge represented	Storyboards	More, accurate, details
Representational practices		
-- discussion of science	Video data	Shift from less to more accurate, detailed, relevant
-- discussion of representations	Video data	Shift from "What" to "How" and "Why"
-- interactional moves (assessments)	Video data	Shift to assessment-seeking, -giving, -warranting, -responding

Conclusions

- Representational Practices with K-1 Students
  - Focus on same task
    - Reveals shifts that co-occur with conceptual understanding
  - Use of quantification
    - Led to some important surprises
- Specifically…
  - Increase in "constructive" interactions
    - More accurate
    - Focus on "how"
    - Critical assessments
  - Shift from Adults to Peers

What about differences across activities?

Activity	Resources	SBF	Representational
Individual creation of representations	Familiarity with drawing, peers	Structure	What
Participatory modeling	Interaction, communicative focus, teacher structuring	Structure and local behavior	What, How, Why
Participatory simulations	Interaction, communicative focus, game rules	Some local behavior and function	What, How, Why

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Object: Satisfy the class rules for a science drawing

G: Is this the 3 parts?
B: [that's] the stinger.
G: I know, but there's only 2 parts!
B: Oh yeah, I forgot.

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Activity	Re
Individual creation of representations	Far pee
Participatory modeling	Int cor tea
Participatory simulations	Int cor gar

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What about differences across activities?

Activity	R
Individual creation of representations	F p
Participatory modeling	Ir c te
Participatory simulations	Ir c g

S1: But then they'll have no idea where it is.

S2: No, that's OK Ajay, we don't want them to find it.

R: You gonna tell them it's by the red rake?

S2: No, we're gonna tell them it's behind the green structure- it's behind, by it near the green gate. Let's go!

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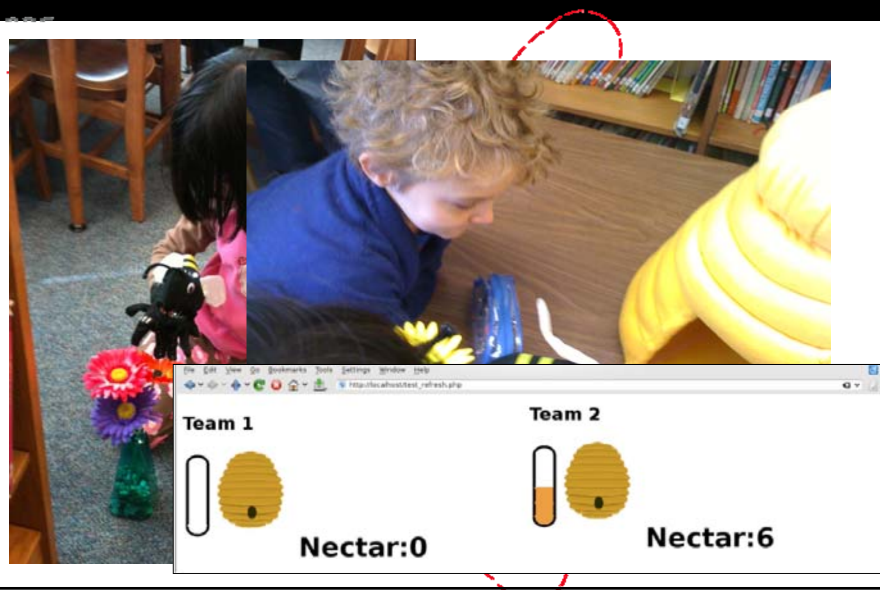
Conclusions

- The organization of activity shapes the way students engage with representations
  - Traditional organization (drawing alone at tables) promotes a focus on the what
  - Including the community in the process via Participatory Modeling and Participatory Simulations promotes discussion of how and why
  - Audience awareness is very present in Participatory Simulations, less so elsewhere

Sneak Peek

Next steps

BeeSim



Representational Practices Intervention

Science Drawings

1: Plan

- Think
- Research
- Conversations
  - Questions
- Who are we drawing for?
- Write down goals

2: Draw

- Details → color
- How does it look?
- Is there anything I should add?
- Does it make sense?
- Labeling

3: Explain

- More detail?
- Giving more ideas
  - Really specific suggestions
- Editing
- Labeling
- Ask for help
- Does it make sense?

A quick pitch: If you are interested in these design issues

- Computational Technologies in Educational Ecosystems
  - Education P574 / f401, Spring 2011
  - Online and face-to-face
  - Survey of technologies in education and the theories used to describe them
  - Focus on the relationship between technology and context of use

Thank you!

- Questions, comments or suggestions?
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