

Supporting Meaning Making in Science:

The role of scientific inquiry, argumentation and the use of evidence in science learning

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Overview of Talk

- Importance of Scientific Explanation & Argumentation
- Study #1 - Synergy between teacher practices and curricular scaffolds to support middle school students in writing arguments to explain phenomena
- Study #2 - Scientific discourse in three urban classrooms: The role of teacher in engaging high school students in argumentation
- Study #3 – Explanations, argumentation and evidence in science, science classrooms and the everyday lives of Elementary Students
- Conclusions Across Studies

Why is this important?

- Science is is about constructing arguments and considering and debating multiple explanations for phenomena (Osborne, Erduran, & Simon, 2004).
- Science education should support students' development toward competent participation in a science infused world (McGinn & Roth, 1999).
- A new vision for proficiency in science - Students should generate and evaluate scientific evidence and explanations (Duschl et al., 2006).
- Engaging students in explanation and argumentation can:
  - Increase student ability to construct explanations and arguments (Yerrick, 2000).
  - Foster deeper understanding of important science concepts (Zohar & Nemet, 2002).
  - Change students' image of science (Bell & Linn, 2000).

Why is this Hard?

- Argumentation is frequently left out of classroom practice (Kuhn, 1993).
- Classroom practices often inhibit student argumentation
  - Students are rarely in positions to substantively engage with one another's ideas (Lemke, 1990; Hogan & Corey, 2001).
  - Authoritative discourse can devalue student thinking (Tabak & Baumgartner, 2004).
- Students have difficulty articulating and justifying their claims (Sadler, 2004).
  - Difficulty using appropriate (Sandoval, 2003) or sufficient (Sandoval & Millwood, 2005) evidence.
  - Difficulty providing backing or reasoning for why evidence supports the claim (Bell & Linn, 2000).

What are Explanation and Argumentation?

- Explanation
  - *make sense* of how or why a phenomenon occurred
  - Examples:
    - Explain why the biodiversity decreased
    - Explain what has happened to the pitch of bird song in cities
- Argumentation:
  - *defend* knowledge claims through persuasive discourse
  - Examples:
    - Argue for your explanation for why the biodiversity decreased
    - Argue for your experimental design to study what is happening to the biodiversity
    - Argue for your management plan to increase the biodiversity

Framework *Adapted from Toulmin (1958)*

- **Claim**
  - a conclusion about a problem
- **Evidence**
  - scientific data that supports the claim
- **Reasoning**
  - a justification that shows why the data counts as evidence to support the claim and includes appropriate scientific principles
- **Rebuttal**
  - describes alternative explanations and provides counter evidence and reasoning for why the alternative is not appropriate.

Chemistry Example

Are any of the liquids the same substance?

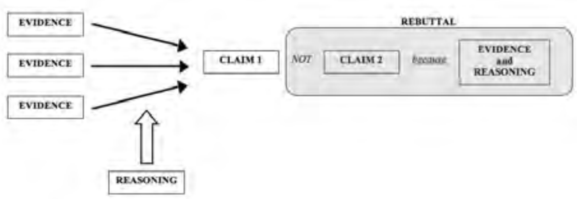
Liquids 1 and 4 are the same substance. (Claim) They both have a density of .93 g/ cm^3, have no color, and start to melt at -98 C. (Evidence) For substances to be the same, they must have the same properties. Since Liquids 1 and 4 have the same properties, they are the same substance. The other 2 liquids are different substances because they have different properties. (Reasoning)

Biology Example

What will happen to the shark population if the phytoplankton populations die out?

The shark population will die out.(Claim) The shark eats other fish such as the ocean fish and the lantern fish. The ocean fish and the lantern fish eat other organisms such as shrimp and copepods. The shrimp and copepods eat the phytoplankton. (Evidence) Phytoplankton are producers and they make their own food from the sun. All of the other organisms in the food web depend on the phytoplankton, even if they do not directly eat them. If the phytoplankton die, primary consumers (shrimp and copepods) will die because they will have no food which will cause the secondary consumers (ocean fish and lantern fish) to die, which will cause the shark to die. (Reasoning) You might think the shark population would not change, because they do not eat the phytoplankton. But they will actually die out because they eat organisms that eat organisms that eat the phytoplankton. (Rebuttal)

Framework *Adapted from Toulmin (1958)*



Study #1: Synergy (McNeill & Krajcik, 2009) Conceptual Framework

- *Synergistic* supports - multiple co-occurring and interacting supports (Tabak, 2004).
- Curricular Scaffolds
  - Temporary supporting structures provided by people or tools to promote learning of complex problem solving (Bransford et al., 2000).
- Teacher Instructional Practices
  - Teachers draw on their own resources and capacities to adapt curriculum materials (Remillard, 2005).
  - The role of the teacher is important for the successful use of a scaffolded tool (Pea, 2004).

Synergy: Research Questions

- How do the written scaffold treatments (context specific vs. generic) influence student learning of scientific explanations?
- How do teacher instructional practices during the unit influence student learning of scientific explanations?
- Is there an interaction between the written scaffolds and the teacher practices in promoting student learning?

Synergy: Instructional Context

- These study took place during an eight-week standards-based chemistry curriculum designed for seventh grade students.
- The unit includes three key content learning goals:
  - Substances & Properties
  - Chemical Reactions
  - Conservation of Mass

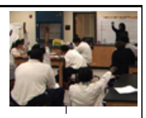
Synergy:
Study Design - Scaffolds

- Two versions of the student books:
  - Context-Specific: provide students with hints about the task and content knowledge
  - Generic: help students understand a general framework for explanation
- Randomly assigned classes to context-specific or generic treatments.

Synergy:
Study Design - Scaffolds

Context Specific Scaffold	Generic Explanation Scaffold
(State whether the stones in Ring #1 and Ring #2 are the same substance. Provide whether properties, such as density, melting point, and color, are the same or different. Do not include measurements that are not properties, such as mass and volume. Tell why properties being the same or different tells you whether two stones are the same substance.)	**Claim** (Write a statement that responds to the original problem.) **Evidence** (Provide scientific data to support your claim. You should only use appropriate data and include enough data. Appropriate data is relevant for the problem and allows you to figure out your claim. Remember that not all data is appropriate. Enough data refers to providing the pieces of data necessary to convince someone of your claim.) **Reasoning** (In your reasoning statement, connect your claim and evidence to show how your data links to your claim. Also, tell why your data count as evidence to support your claim by using scientific principles. Remember reasoning is the process where you apply your science knowledge to solve a problem.)

Synergy:
Participants and Scoring



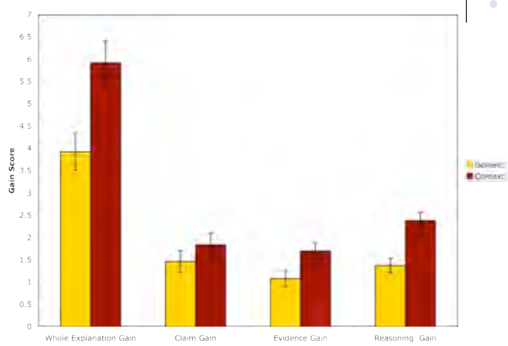
Teacher	Type of School	Number of 7th Grade Classes	Total Number of Students
Ms. Kittle	Urban Public	5	164
Ms. Marshall	Urban Public	5	162
Ms. Hill	Urban Public	2	66
Mr. Kaplan	Urban Public	4	71
Ms. Foster	Urban Charter	2	49
Ms. Nelson	College Town Independent	4	56
Total		22	568

- Identical pre- and posttest measures - three open-ended explanation items. Inter-rater reliability was greater than 98% for claim, 94% for evidence, and 98% for reasoning.

Synergy:
Teacher Instructional Practices

- Videotape the same three lessons for each teacher
  - Substance and properties (focal lesson - 2 days), chemical reactions (2 days), and conservation of mass (1 day)
- Coded for instructional practices
  - Defining or making the framework explicit
  - Modeling scientific explanations
  - Discussing the rationale behind explanation
  - Connecting to everyday
  - Assessing or providing feedback
  - Structure of classroom discourse (IRE vs. Dialogic)
- Independent raters scored the videos. Inter-rater reliability was 88%.

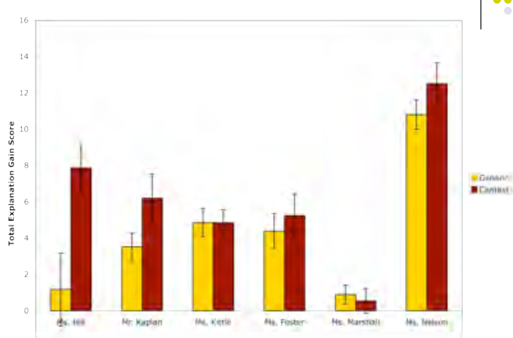
Synergy Results: Effect of Curricular Scaffolds



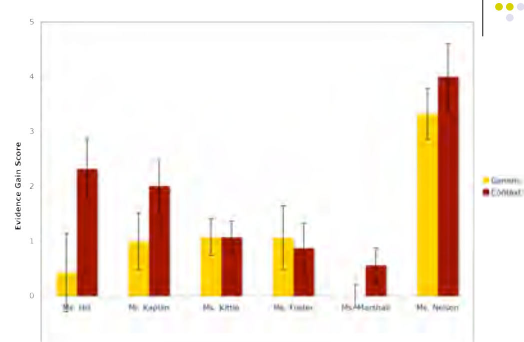
Synergy Results: Teacher Instructional Practices

1. Framework for scientific explanation
   - Framework for scientific explanation influenced other instructional practices (e.g. connecting to everyday, feedback, modeling).
   - Aligned with curriculum materials
     - Mr. Kaplan, Ms. Hill, Ms. Kittle, and Ms. Nelson ⇨
   - Modified definition of scientific explanation - claim, definition, evidence, therefore/conclusion
     - Ms. Marshall and Ms. Foster ⇨
2. Classroom discourse
   - Traditional IRE structure
     - Mr. Kaplan, Ms. Hill, Ms. Kittle, Ms. Marshall and Ms. Foster
   - Dialogic - Greater student interaction, ownership and peer support in the classroom discussion
     - Ms. Nelson ⇨

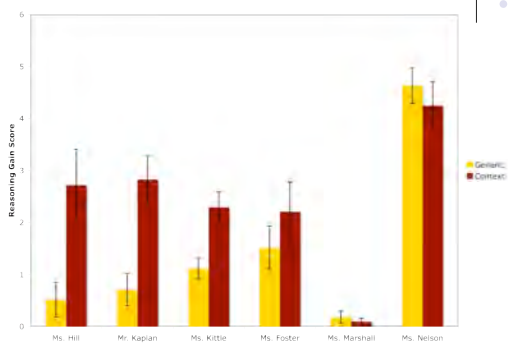
Synergy Results: Relationship between Scaffolds and Teacher - Total



Synergy Results: Relationship between Scaffolds and Teacher - Evidence



Synergy Results: Relationship between Scaffolds and Teacher - Reasoning



Synergy Results: Summary

- Mr. Kaplan, Ms. Hill & Ms. Kittle
  - Context-specific resulted in greater student learning in terms of writing scientific explanations compared to generic scaffolds
- Ms. Marshall, Ms. Foster & Ms. Nelson
  - No significant curricular effect

Synergy: Conclusions

- Mr. Kaplan, Ms. Hill & Ms. Kittle
  - Context-specific curricular scaffolds were more effective only in classrooms where teachers provided the general explanation framework
  - “intimate intermingling of generality and context-specificity in instruction” (Perkins & Salomon, 1989).
- Ms.Marshall and Ms. Foster
  - “…for productive synergy to occur…different materials need to share semiotic features, and these features need to be consistent not only with the designers’ but with the teacher’s conception of the task, goals, and discipline” (Tabak, 2004).
- Ms. Nelson
  - Curricular scaffolds may have been “redundant”

Study #2: Discourse (McNeill & Pimentel, 2010) Conceptual Framework

- Linguistic practices in classrooms define science through the ways that science is spoken and written in different contexts (Kelly, 2005).
- Traditionally, the discourse in science classrooms has been dominated by teacher talk (Crawford, 2005).
- Classroom science also often portrays science as a static set of facts than than the social construction of knowledge (Lemke, 1990).

Discourse: Research Questions

- What are the patterns in classroom discourse in three urban science classrooms?
- What is the role of the teacher in promoting argumentation in terms of both the argument structure and dialogic interactions in classroom discourse?

Discourse: Instructional Context

- This study took place during a high school urban ecology curriculum, *How do we develop healthy and sustainable cities?*
  - Developed as a capstone course for high school students (i.e. 11th and 12th graders).
  - Consisted of eight modules each of which is designed to last between two and four weeks.
- The study occurred during Module 2, which focused on global climate change.

Instructional Context

- During Lesson 1 of Module 2, students observed two short video clips
  - Videoclip #1 - Argued Climate is Changing
  - Videoclip #2 - Argued Climate is Not Changing
- Students wrote scientific arguments.
  - "Write an argument for whether or not the earth's climate is changing. Is global warming occurring? Provide evidence for your claim and provide your reasoning for why that evidence supports the claim."
- Class discussed their different views on climate change.

Discourse: Participants

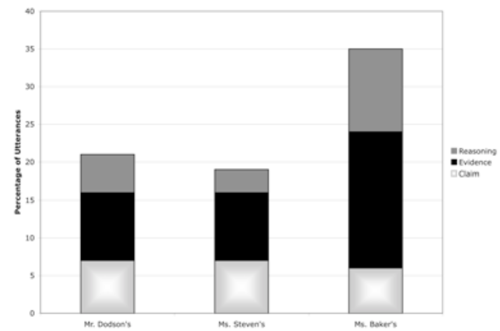
- Three teachers and their high school students, all from the same large urban area.

Teacher	# students in focus class	# students in school	Student Ethnicity	School Statistics
Mr. Dodson	26	261	61.7% Black 32.6 % Hispanic 2.7% White 2.3% Asian 0.8% Native American	4.9% student mobility 7.1% annual student dropout rate 57.6% graduate in 4 years
Ms. Baker	14	289	46.7% Black 33.9% Hispanic 15.9% White 3.1% Asian 0.3% Native American	21.2% mobility 4.6% annual student dropout rate 44.4% graduate in 4 years
Ms. Stevens	30	305	60.7% Black 33.8% Hispanic 3.9% White 0.3% Asian 1.3% Native American	32.5% student mobility 15.2% annual dropout rate 26.8% graduate in 4 years

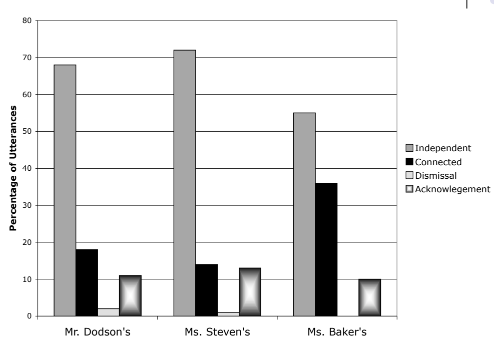
Discourse: Methods

- Lesson 1 was videotaped and the classroom discussions were transcribed.
- Each transcription was broken into utterances
  - An utterance represented a unique idea or contribution to the discussion.
- Each utterance was identified as teacher or student and coded using 3 coding schemes.
  - Argument Structure
  - Dialogic Interactions
  - Teachers' Questions
- Two independent raters coded the transcripts.
  - Percent agreement was 78% for structure codes, 78% for dialogic codes and 75% for teachers' questions.

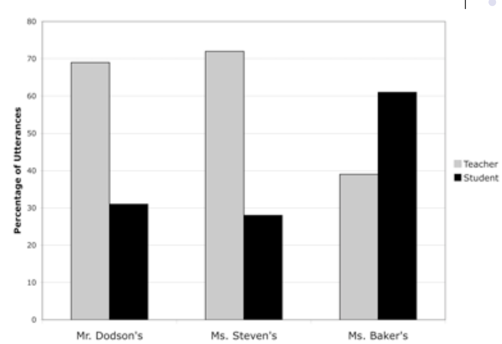
Results: Argument Structure



Results: Dialogic Interactions



Results: Teacher-Student Discourse



Results: Teacher-Student Discourse

	Mr. Dodson	Ms. Stevens	Ms. Baker
TS (1)	62	23	38
TSS (2)	4	1	14
TSSS (3)		2	3
TSSSS (4)		1	4
TSSSSS (5)			5
TSSSSSSS (7)			2
TSSSSSSSSSSS (11)			1

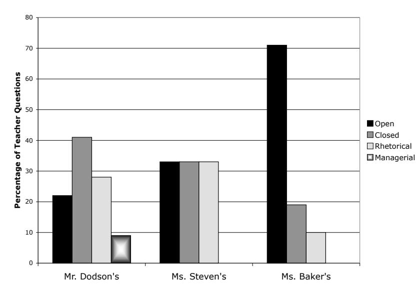
Results: Ms. Baker

	Classroom Transcript	Structure	Dialogic	Question
Jamar:	Maybe the sun is too old.	*Reasoning*	*Connected*	
Ms. Baker:	Maybe the sun is too old?/You think that has to do with global climate change?	*Question* *Question*	*Connected* *Connected*	*Open* *Open*
Jamar:	It's like dying out.	*Reasoning*	*Independent*	
Ms. Baker:	But Sam is saying that in places it's actually not warm it's colder. Or in other in some places too warm in other places it's too cold.	*Evidence*	*Connected*	
Jamar:	It's colder cuz it's dying out.	*Reasoning*	*Connected*	
Maria:	It's probably, it's probably the way it's tilting.	*Reasoning*	*Connected*	
Alesha:	Yeah, that's why it's tilting like it's in different places.	*Reasoning*	*Connected*	
Maria:	Or maybe because it's more um environmentally friendly. That, like that part. Like they say that they get holes in the atmosphere/ so maybe where the holes are is above cities.	*Reasoning*	*Independent*	

Results: Mr. Dodson

	Classroom Transcript	Structure	Dialogic	Question
Mr. Dodson:	What was the evidence that was presented in the video? / Let's. For ah Donna, / What was some of the evidence presented?	*Question* *Other* *Question*	*Dismissal* *Independent* *Independent*	*Rhetorical* *Closed*
Donna:	It had examples of areas that was	*Other*	*Independent*	
Mr. Dodson:	Sorry. Which, which video are you talking about?	*Question*	*Connected*	*Closed*
Donna:	The first video. / It had examples of areas that were like all ice. At one point, like um they were gone. The ice was gone. And then on, and then it showed the after picture and it was either all gone or all (inaudible).	*Other* *Evidence*	*Independent* *Independent*	
Mr. Dodson:	Right. / It was showing all these, uh, glaciers and, and uh, so ice melting. / They showed that in the first video. / Right? / They showed uh, uh, Kilimanjaro. / Marcus.	Other Evidence O/Question Evidence/O		*Rhetorical*
Marcus:	Yeah, uh, I found the first video like kind of hard to like understand.	Other	*Independent*	

Results: Role of the Teacher



- Teacher connects to previous student comment
  - Mr. Dodson - 1, Ms. Steven's - 0, Ms. Baker - 5

Discourse: Conclusion

- Ms. Baker's use of *open questions* may have encouraged more student participation and reflective discourse.
- Ms. Baker's explicit *connections to previous students' contributions* may have encouraged students to consider multiple views.
- Developing a classroom culture of "reflective discourse" (Van Zee & Minstrell, 1997) may be essential for supporting scientific argumentation in k-12 classrooms.

Study #3: Everyday (McNeill, in review) Conceptual Framework

- Success in school is impacted by students' ability to acquire academic social language, which can have different norms compared to their "lifeworld" or everyday discourse (Gee, 2005).
- Classroom instruction should be informed by students' everyday ways of knowing (Warren et al., 2001).
- Research around students' everyday discourse suggests the use of evidence may have a similar meaning (Bricker & Bell, 2007), while argumentation may have both similarities and differences (Bricker & Bell, 2007; Hudicourt-Barnes, 2003).

Research Questions

- What are students' ideas about the terms explanation, argument and evidence in the context of science, science class and their everyday lives and how do they change over the school year?
- How do students' abilities to write scientific arguments change over the school year?

Participants

- One teacher, Mr. Cardone, and his two classes of 5th grade students from a large urban district.

Table 1: Student Backgrounds (N= 33)

Gender	Race	Birth Country	Speak Another Language	What language
Male – 15	Black – 3	USA – 22	English only – 6	Bangia – 1
Female - 18	Asian – 7	Aruda/Bonire - 1	Other language - 27	Cambodian - 2
	White – 3	Colombia - 1		Creole – 1
	Latino/Latina – 17	Dominican Republic – 2		Portuguese – 2
	Multiracial - 3	El Salvador - 3		Spanish – 20
		Guatemala – 3		Vietnamese - 1
		Haiti- 1		

Methods

- Engaged in design-based research (Brown, 1992) during the 2008-2009 school year to investigate how to best support Mr. Cardone's students in these scientific practices.
- Data sources included:
  - Student pre and post interviews
  - Student writing for the lessons focused on argumentation
  - Student writing from a district wide common writing assignment
  - Student writing from end of the year assessment
  - Videos tapes of the seven lessons focused on argumentation.

Methods -Student Interview

- 23 students interviewed during the second week of school and the last month of the school year
- The interviews focused on the three terms - explanation, argument and evidence in three different contexts:
  - What scientists do
  - What happens in science classrooms
  - What happens in everyday life
- Interviews were transcribed. Coding scheme developed from theoretical framework and iterative analyses of the data (Miles & Huberman, 1994).
- Two independent raters coded the interviews and interrater reliability was 84%.

Results:
Students' Ideas about Explanation

	Scientist		Science Class		Everyday	
	Pre	**Post**	**Pre**	**Post**	**Pre**	**Post**
Link to argument	0%	0%	0%	0%	0%	4%
Link to evidence	4%	22%	0%	9%	0%	9%
Writing	4%	9%	13%	4%	0%	0%
Observation	48%	26%	39%	13%	35%	9%
Exchange between people	**57%**	17%	17%	30%	**74%**	**83%**
How or why a person does something	4%	9%	0%	13%	30%	70%
How or why phenomenon occurs	26%	**70%**	13%	**52%**	4%	4%
Other	4%	4%	9%	4%	4%	0%
Don't know	0%	4%	**43%**	17%	13%	4%

Science Class - How or why phenomenon occurs
"My explanation was that, like there was a lot, a lot of bees going around the flowers because they have pollen and that's why." Mariela (post-interview)

Results:
Students' Ideas about Argument

	Scientists		Science Class		Everyday	
	Pre	**Post**	**Pre**	**Post**	**Pr e**	**Post**
Link to explanation	13%	9%	0%	9%	9%	9%
Link to evidence	4%	17%	0%	9%	4%	9%
Writing	4%	9%	4%	4%	9%	0%
Observation	13%	9%	13%	9%	4%	0%
Exchange between people	**83%**	**83%**	44%	**70%**	**87%**	**91%**
Persuade or convince	*13%*	*17%*	*4%*	***57%***	13%	*13%*
Disagreement	***57%***	***65%***	*22%*	***57%***	***39%***	***70%***
Emotional or angry fighting	*22%*	*9%*	*13%*	*9%*	*35%*	*22%*
One individual thinking through an idea	4%	4%	0%	0%	*4%*	0%
Other	9%	0%	4%	0%	9%	0%
Don't know	0%	9%	**48%**	22%	0%	9%

Science Class - Exchange Between People (Convince & Disagreement)
"You're trying to convince someone to agree with you. Like arguing, argument. Argument when like someone disagrees with you or something, in the claim or something." Carlos (post-interview)

Results:
Students' Ideas about Evidence

	Scientists		Science Class		Everyday	
	Pre	Post	Pre	Post	Pre	Post
Link to explanation	9%	4%	4%	4%	0%	9%
Link to argument	9%	13%	4%	0%	9%	9%
Writing	9%	0%	9%	22%	0%	0%
Observation	22%	9%	35%	4%	9%	0%
Exchange between people	48%	30%	**43%**	26%	**70%**	**70%**
Data	43%	43%	26%	48%	57%	65%
Results from an experiment	17%	13%	9%	39%	0%	0%
Support an answer to a question	**52%**	**52%**	13%	**57%**	9%	22%
Other	13%	9%	4%	0%	9%	4%
Don't know	0%	0%	22%	0%	4%	4%

Science Class - Support an answer to a question

"To support our ideas we have to use evidence from like the text or everything else like we use it to like help us, to always help you when you need to use it, when you need to support it you have to have evidence or it's just going to be a statement." Sanjay (post-interview)

Conclusion: Students' Ideas

- Pre - Students responded "I don't know" suggesting they were unclear of the discourse norms in the science classroom.
- Pre & Post - The fifth grade students were aware that language could have different meanings in different contexts.
- Students' views for scientists and for science class changed over the course of the school year, while their everyday meanings remained more constant.
  - Explanation - focused on how or why phenomena occur
  - Argument - focused more on the dialogic meaning as the interaction between multiple people (not structure).
  - Evidence - focused on supporting an answer to a question in science (not data).

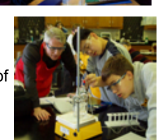
Conclusions Across Studies

- Even elementary students are aware that words can have different meanings in science, science classrooms, and everyday.
  - Need explicit support around evidence, explanation and argument.
- Both curricular scaffolds and teacher instructional practices can support students' written arguments.
  - Different supports need to be synergistic
  - More effective when they provide both general and context specific support.
- Creating a classroom culture of reflective discourse through teacher moves may promote argumentation.
  - Teacher's use of open questions
  - Teacher modeling connections to previous students' ideas.

More Information

- Kate's Contact information
  - kmcneill@bc.edu
- Powerpoint presentation
  - www.katherinelmcneill.com
    - Presentations --> Invited Presentations

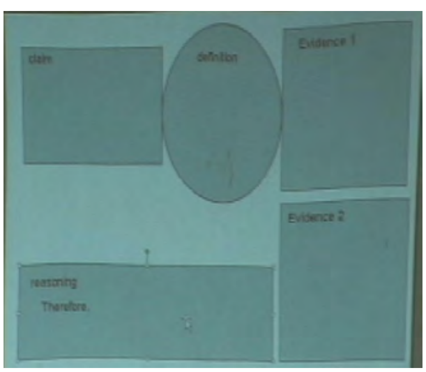
- Thanks to Many
  - Numerous teachers and students
  - Colleagues from Boston College, the University of Michigan and Northwestern University
  - National Science Foundation
    - Investigating and Questioning our World through Science and Technology (IQWST) (ESI-0101780)
    - Center for Curriculum Materials in Science (CCMS) (ESI-0227557)
    - Urban EcoLab (*ESI-0607010).*
    - Supporting Grade 5-8 Students in Writing Scientific Explanations project (DRL 0836099)



Hyperlinked Slides

Providing Students With Feedback

Modified Definition of Scientific Explanation



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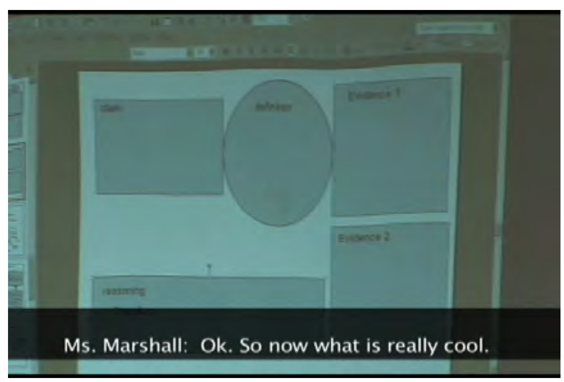

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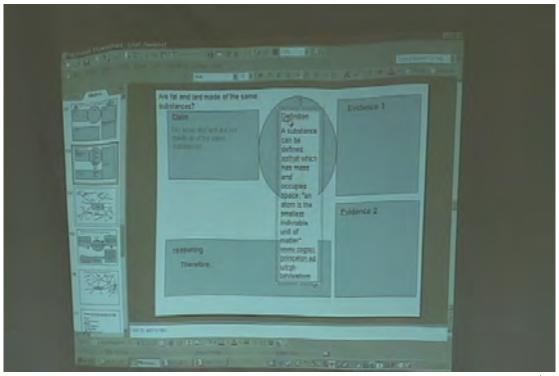

Ms. Nelson - Dialogic Classroom Discourse