Literacy Learning in the Context of Inquiry-Based Science

22nd World Congress on Reading:
Reading in a Diverse World
San José, Costa Rica July 29, 2008

Context of Our Work

- Curriculum development and research project focused on exploring the interface of science and literacy
- Partnership between
  - Lawrence Hall of Science and
  - UC Berkeley Graduate School of Education
- Funded mainly through National Science Foundation and IES grants
- Currently developing 12 integrated science-literacy units for grades 2-5

Our Team

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Session Overview

Science & Literacy Integration:

1. Existing Research and Theoretical Base
2. A Curricular Model for Integrating in the Elementary grade Classrooms
3. Some Research results
4. Directions of our Future Research

Existing Research and Theoretical Base on Literacy and Science Integration

WEE (Wondering, Exploring, Explaining)
Anderson, West, Beck, MacDonnell, and Frisbie (1997)

Approach	*Method*	*Findings*
Integrated Non-fiction reading & writing with science	5th grade Students involved in: –Pose wonderment –Explore/gather information –Explain/ summarize what they found out	high levels of student excitement, involvement & learning

Roles of Authentic Experience Purcell-Gates, Duke & Martineau (2007)		
Approach	*Method*	*Findings*
authenticity of literacy activities & learning to read and write science informational text genres	infused 2nd/ 3rd grade classrooms with target informational science text genres and monitored, degree of authenticity of literacy activities	Degree of authenticity related to student growth in reading comprehension and writing of the genres

GIsML (Guided Inquiry Supporting Multiple Literacies) Palincsar and Magnusson (2000)		
Approach	*Method*	*Findings*
Use secondhand experiences in science to prepare students for firsthand investigations and provide common inquiry	compare learning outcomes of 4th grade students studying light in classrooms using GIsML, including the scientist's notebook with students using other texts.	secondhand investigations helped learn more science, make better inferences, and engage in richer scientific conversations

CORI (Concept-Oriented Reading Instruction) Guthrie, Anderson, Alao, and Rinehart (1999)		
Approach	*Method*	*Findings*
embeds literacy instruction in content-area instruction to promote sustained reading engagement	3rd and 5th grade CORI classrooms, compared to those in traditionally organized classrooms	CORI increased conceptual learning, strategy use, and text comprehension

In-depth Expanded Applications of Science (IDEAS) Romance & Vitale (1992)		
Approach	*Method*	*Findings*
Replaces time allocated for ELA instruction with 2-hour science block	concept-focused science instruction & involved firsthand experiences, attention to science process skills, discussion, reading, concept mapping, and journal writing.	IDEAS students outpace students receiving traditional instruction on standardized measures of science and reading

Dialogically-Oriented Read Alouds Pappas, Varelas, Barry, & Rife (2002)		
Approach	*Method*	*Findings*
Use collaborative, dialogically-oriented read alouds of science text	Qualitatively examined the dialogues that took place around science information books embedded in 4-6 week units	Found that intertextuality supported students in sense-making about science, developing scientific understandings, and using scientific registers.

Lasers (Language Acquisition through Science Education in Rural Schools) Stoddart, Pinal, Latske & Canaday (2002)		
Approach	*Method*	*Findings*
Utilize CREDE 5 standards of effective pedagogy in science content (emphasis on science vocabulary)	Provided PD work to teachers around science discourse, particularly utilizing and unpacking science vocabulary	ELLs in grades first through fifth posted significant in their use of complex science vocabulary (e.g., species, fossil, habitat) & accuracy of scientific propositions

Why integrate science and literacy?

- Science provides an engaging and meaningful context for reading, writing, and discussion.
- There is evidence that an integrated approach is beneficial for student learning in both domains.
- Can provide exposure to and interaction with genres of text that are authentic to science yet less frequently found in elementary classroom
- Potential for supporting English language learners' development of academic language.
- Reading and writing are important elements of the work of practicing scientists.

A Curricular Model for Integrating Science and Literacy in the Elementary Classroom

Model of Integration: Overview

- Principles of Integration
- Synergies between Science and Literacy
- Enactment in Curriculum Materials

Guiding Principles of Science-Literacy Integration

Employ
multiple learning modalities

Engage students in firsthand and secondhand investigations to make sense of the world

Capitalize on synergies
between science and literacy

Principle: Engage students through multiple learning modalities

Typical Inquiry Science

- Learn from first hand experiences and reflection

Typical Textbook Science

- Learn from reading and writing

Integrated Science-Literacy

- Learn through multiple learning modalities

—Do it
—Talk it
—Read it
—Write it

See the relevance

Read

Students read a book
that connects the unit
to real world examples

Make observations

Do

Students investigate the properties of various ingredients when dry and mixed with water.

Evaluate evidence and make decisions

Talk

Students evaluate what they have learned about ingredients and properties to design a glue that is sticky.

Create procedural texts

Write

Students use procedural writing to record their glue recipes so others can make and test their glues.

Read about other work from "the field"

Read

Students read about a food scientist who designs and tests new jelly beans

Connect to the practices of science

Talk

Students reflect on how their design process is like that used by the jelly bean scientist

Instruction in Multiple Modalities

Investigate **Read** **Investigate** **Write** Talk
Write

Guiding Principles of Science-Literacy Integration

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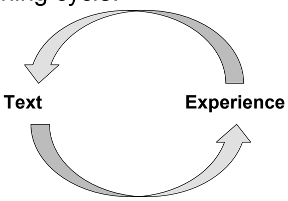
multiple learning modalities

Engage students in firsthand and secondhand investigations to make sense of the world

Capitalize on synergies
between science and literacy

Principle: Engage students in firsthand and secondhand investigations to make sense of the world.

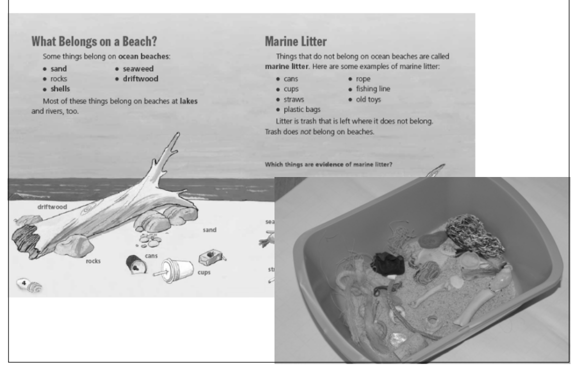
Text and experience can play a set of dynamic roles in the inquiry process and the learning cycle.



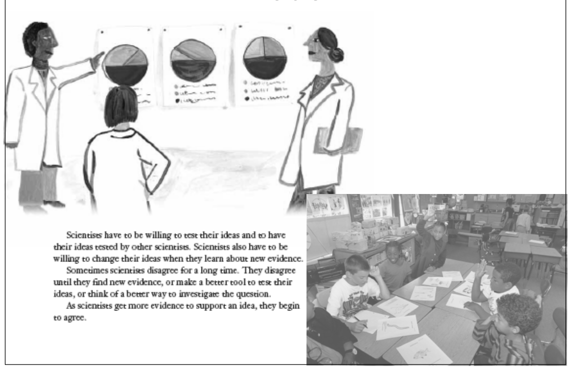
Roles of Text in Inquiry Science

Provide context	Connect to the world outside the classroom
Model	Demonstrate a process or disposition
Support secondhand investigations	Provide data for students to interpret
Support firsthand investigations	Provide information for investigations
Deliver content	Read to learn about science

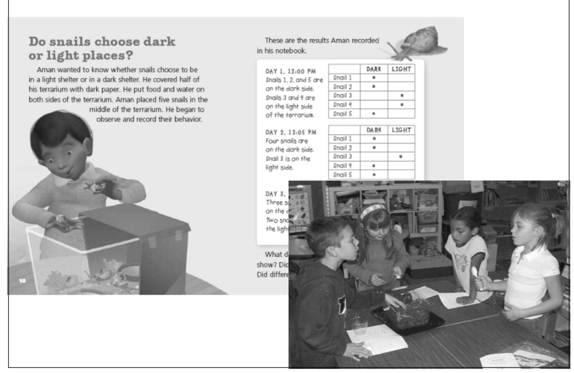
Provide Context



Model

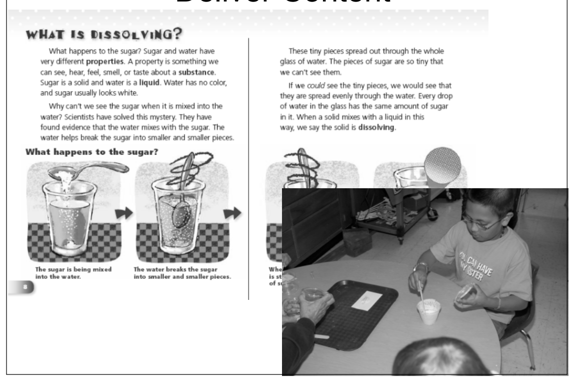


Support Secondhand Investigations



Support Firsthand Investigations

Deliver Content



Guiding Principles of Science-Literacy Integration

Employ multiple learning modalities
Engage students in firsthand and secondhand investigations to make sense of the world
Capitalize on synergies between science and literacy

Capitalize on synergies between science and literacy

↓ ↓ ↓

Synergy A:	Synergy B:	Synergy C:
Words are concepts	**Inquiry strategies are comprehension strategies**	**Science is a Discourse**

Synergy A: *Words are Concepts*

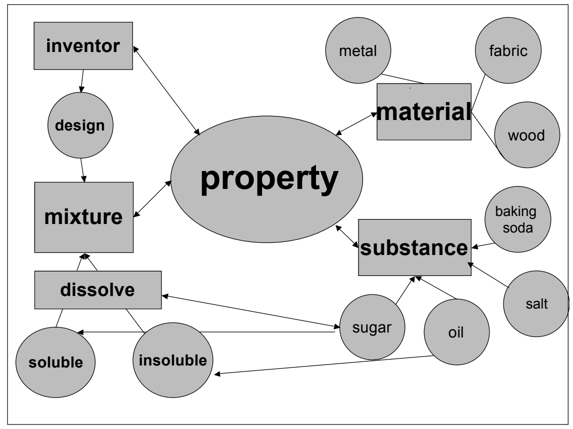
- Words are labels for concepts and ideas
- Excellent vocabulary development is nearly indistinguishable from excellent concept development
- Learning the academic language of science means forming rich conceptual networks of words

What does it mean to know a word?

Recognition Recognizing word when it is heard or read	**Definitional** Knowing what the word means
Relational Understanding how the word is related to other words	**Contextual** Being able to use the the word in various appropriate contexts

Our approach to teaching words as concepts

- Emphasize a few powerful science words
  - interact, transmit, reflect, absorb, emit, travel, source, refract, material, block, ray, lens, shadow, energy, transformation, characteristic
- Provide repeated opportunities for exposure and practice
- Teach words through text, talk, and experience
- Teach words as networks of related concepts



Synergy B: *Inquiry strategies are comprehension strategies*

- Strategies that students learn in order to comprehend text are the same as those they learn to investigate in science
- The cognitive process used in both domains is extremely similar
- Students learn to flexibly apply strategic thinking in both domains

Inquiry or comprehension?

- Making inferences
- Posing questions
- Setting goals
- Making predictions
- Visualizing and using mental models
- Synthesizing information from multiple sources

Our approach to teaching inquiry/comprehension strategies

- Target pairs of inquiry/comprehension strategies in each unit
- Pose questions and use terminology that invokes the use of the strategies when reading *and* when investigating
- Gradual release of responsibility, beginning with explicit instruction and moving towards independent application
- Students reflect on the similarity of these cognitive strategies

Making Predictions

- Students make predictions about which materials will reflect light, then test their predictions by investigating.

Making Inferences

- Students simulate an oil spill and make inferences about the properties and effects of oil in the ocean. They then read about a real oil spill that happened off the coast of Spain, and make inferences about the impact of the spill as they read.

Synergy C: *Science is a discourse*

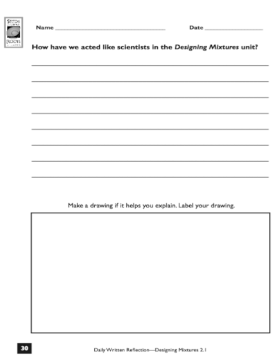
- Science is all about language…but language is more than words. Science is a discourse involving ways of communicating; that is, talking, writing, and being.
- Learning science includes learning the ways that scientists describe, explain, predict, synthesize, and argue
- Ways of communicating in science are different from those of everyday life

Our approach to teaching science as a discourse

- Scaffold students' oral and written language development
- Contrast the language of science with everyday language
- Increase the frequency of student-student talk
- Explicitly teach genres of science writing (including visual representations of information)
- Reflect on what scientists do and how scientists work

Science-Everyday Words

Scientific Language	Everyday Language
conclude	figure out
classify	group
predict	guess
investigate	find out about
observe	look
demonstrate	show
report	tell what
explain	tell how or why
record	write down
analyze	think about
evidence	clues


Name ____________ Date ____________

How have we acted like scientists in the *Designing Mixtures* unit?

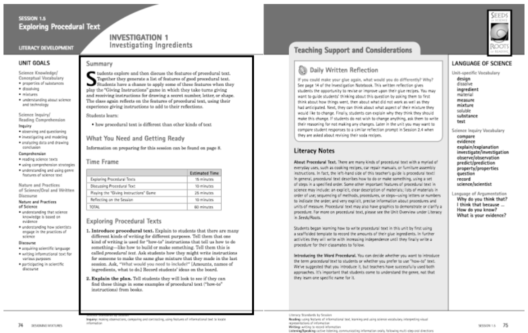
Make a drawing if it helps you explain. Label your drawing.

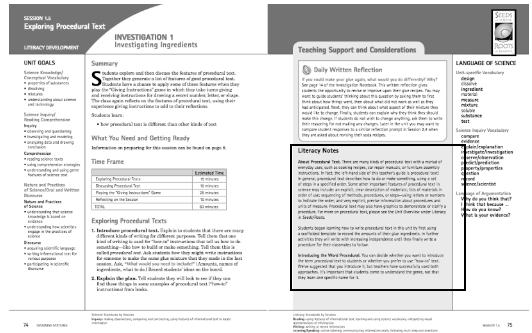
30 Daily Written Reflection—Designing Mixtures 2.1

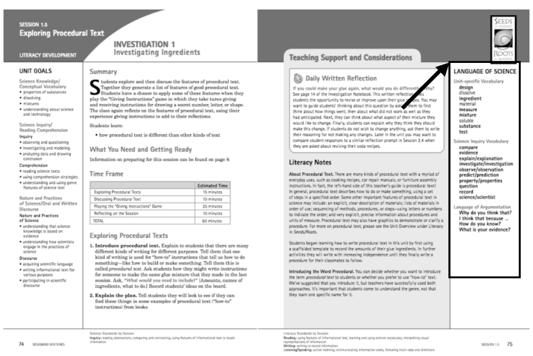
Reflecting on "How We Were Like Scientists"

Curricular Goals

- Communicate model of integration primarily through instructional materials
- Design materials that support teacher learning about science content, literacy strategies, and integrating science and literacy
- Provide materials that are tested by teachers in a variety of classroom settings to ensure feasibility







Science-Literacy Integration

- Is multimodal
- Provides opportunities to work iteratively between text and experience
- Capitalizes on parallel strategies and processes in both domains
- Balanced attention to both domains
- Is integrative, not additive

Science & Literacy Integration: Evidence from Research

Research Studies

- Efficacy Study
- Science Attitudes
- Science Vocabulary
- Science Text Genre

Efficacy Study

Efficacy Study

- **Research Question:** How do students who receive a combined science/literacy curriculum compare in literacy & science outcomes to students that just receive science, just literacy and those that get no treatment?
- 89 teachers from 21 states each involved in one or more trials (randomly assigned to experimental or comparison conditions)
  - 2nd grade, 3rd grade & mixed grade classrooms
  - 1/3 30%+ English learners
  - Mix of urban, rural, and suburban settings

Comparison conditions

- Science-Only Comparison Groups: Implement original science-only unit on which the revision is based
- Literacy-Only Comparison Group: Implement a literacy program using the integrated books
- No-Treatment Comparison Group: Administer assessments, but do not implement any of the interventions

	Science-Literacy	Science-Only	Literacy-Only	No-Treatment
Shoreline ecosystem	24	10		
Forest floor habitats	20	13	12	10

Data Sources

- Pre-post Assessments of Science
- Pre-post Assessments of Literacy
- Magazine Assessment of Comprehension and Science Understanding*
- Instructional Surveys
- Embedded Student Work (writing)*
- Information About the Students, School Setting, and Teachers
- Teacher Interviews
- Student Interviews

Sample Science Assessment items

1. Besides rocks, what are two other things that sand can be made of?________________________________

2. How can a rock become sand?____________________

3. Some of the sand grains on the beach are black. Where do you think the sand comes from?
   a. California
   b. A dark place
   c. The desert
   d. Volcano

Sample Literacy Assessment items

The Beach

The place where land meets water is called a shoreline. Many shorelines are beaches. Beaches are (have, places, ball) where people can walk some of (the, have, hold) time. Beaches can be covered with (how, mud, draw) or rocks. However, many beaches are (covered, go, the) with sand. All sand is not (dog, alike, after). Some sand grains are large and (down, look, the) like pieces of shell. Others are (small, its, by) and look like glass.

1. **helpful behavior or structure**
   a. prediction
   b. adaptation
   c. habitat
   d. statement

2. **wearing away**
   a. reproduce
   b. erosion
   c. inference
   d. danger

Science Results

- Students in integrated groups outperformed students in all other comparison groups on measures of science knowledge
  - Shoreline Science: science-only (p<0.5; std. effect size=.40).
  - Terrarium Investigations: science-only (p<.01, std. effect size .64); no-treatment (p<.05; std. effect size .40), literacy-only group (p<.05; std effect size=.30).

Literacy Results

- Experimental students outperformed students in all other comparison groups on measures of science vocabulary except LO for TI.
  - Shoreline Science: science-only (p < .01, std. effect size =.34)
  - Terrarium Investigations: science-only (p<.05; effect size .06); no-treatment groups (p<.01, effect size .8).
- Experimental students outperformed students in the SO and NT groups on assessments of science text comprehension. In the Terrarium Investigations trial, Seeds/Roots students performed similarly to students in the LO group.
  - Shoreline Science: science-only (p<.01, std. effect size = .58)
  - Terrarium Investigations: science-only (p< .01, effect size of .51, SD: 1.14)

Science Attitudes

Science Attitudes

- Research Question:
  - Does science/literacy integrated instruction effect students' attitudes toward science, students' efficacy beliefs about themselves as science learners?
- Girod (2005) examined student attitudes in three units on Soil:
  - an integrated science-literacy unit;
  - an inquiry-only unit developed at LHS;
  - and mainly textbook unit from one of the major educational publishers.

Exemplar for the Feelings toward Science Inventory

Factor	***Exemplar***
Affect	"I have a good feeling toward science" and "Science is fun"
Interest	I enjoy learning science" and "Science is interesting to me"
Efficacy	"I believe I will do well in science" and " I think I am capable of learning science"
Identity	"I can imagine myself as a scientist"

Findings

- Found significant effects in favor of the integrated classrooms on measures of:
  - conceptual understanding
  - affect
  - interest
  - efficacy
  - identity

Science Vocabulary

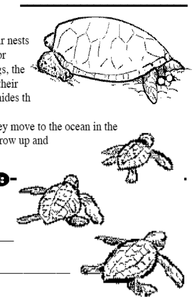
Science Vocabulary

- Research Questions
  - Do students make gains in their use of science vocabulary as taught in a science-literacy integrated curriculum?
    - **Core unit conceptual vocabulary**
      (e.g. **shelter, habitat, moisture**)
    - Cross-unit inquiry words
      (e.g. evidence, investigate, predict)

Assessment Magazines

- Literacy section and science section
- Integrated with curriculum
- Includes open-ended reading comprehension and science knowledge questions
- Administered by the teachers near the beginning and near the end of the unit

Sea Turtle Parents



Sea turtles live in the ocean, but they make their nests on beaches. They are good swimmers, but it is hard for them to move on the beach. When it is time to lay eggs, the turtles climb onto the beach. They dig a hole and lay their eggs. Then, they cover the eggs with sand. The sand hides th animals and people.

The babies dig their way out of the sand. As they move to the ocean in the dark, birds try to eat them. If they survive they may grow up and lay eggs on beaches too.

Questions:

What do sea turtle parents do to keep their eggs safe?

____

____

Why do baby sea turtles move to the ocean?

____

____

Results: Vocabulary

Unit	N	Mean gain	Pooled S.D.	Effect Size
Terrarium Investiga-tions	251	2.9	5.13	.6**
Designing Mixtures	204	1.02	2.34	.4**

**p<.01

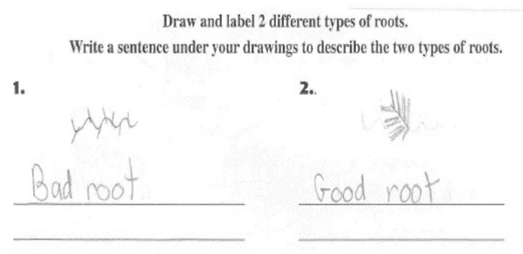
Sample Student Response: Science Vocabulary

Write two questions you have about meadows/forests.	
Pretest Response	**Posttest Response**
Why are meadows beautiful?	What kind of shelter is there in forests? I wonder how spiders survive in the winter?

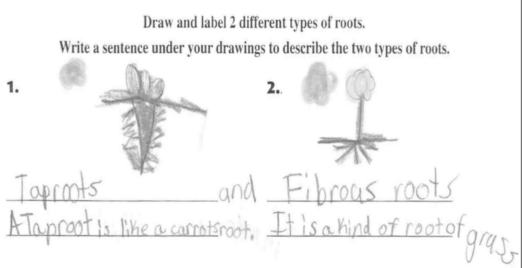
Sample Student Response: Science Vocabulary

What is a habitat?	
Pretest Response	**Posttest Response**
A place where animals live.	A place where an animal lives, finds food, gets moisture, gets protection, and gets shelter.

Sample Student Response: Science (Pretest)



Sample Student Response: Science (Posttest)



Summary of Results

- At posttest, students:
  - Gained control over comprehension strategies
  - Demonstrated a higher level of science conceptual understanding
  - **Used more science vocabulary**
    - Inquiry Words (predict, evidence)
    - Conceptually core words (shelter, habitat)

Science Text Genre Study

Science Text Genre

- Research Questions?

  -How does the genre of science texts influence text comprehension?

  (*Is the understanding and acquisition of new information hindered or helped by embedding that information in a familiar narrative frame*?)

  -Do students show preference toward one text type over another?

Participants

- Seventy-four students in the summer before fourth grade (n=28) or the first month of fourth (n=46) across 5 schools in California's East Bay and Santa Cruz areas participated in the study.
  - 45 girls and 29 boys
  - 25 were English Learners, 3 were redesignated, and 44 EO kids (2 unknown)
  - 30 (42%) are Hispanic; 16 (23%) Asian; 15 (21%) White; 10 (14%) African American (3 unknown)

G

Procedures

- One 45-minute one-on-one interview. Students:
  - Read a set of hf words from the TOWRE
  - Answered attitudinal questions about book topics
  - Read two of the science texts --one narrative and one informational (100 words aloud)
    - Oral retelling
    - Respond to a series of comprehension questions
  - Indicated preference for one text

G

The Texts

	Topic: Snails	Topic: Sand
Genre: Narrative	Gail's Snail Tale	Sandy's Journey to the Sea
Genre: Informational	Snail Tales	From Rocks to Sand

Snail Texts

Snail Tales

Snails begin their lives as eggs hidden under the soil. After a few weeks, the eggshells break open and tiny snails crawl out. Little snails begin eating as soon as they come out of their shells. They start by eating the empty eggshells. Then they dig their way to the surface of the soil and look for plants to eat.

Gail's Snail Tale

Deep in the soil, the shell of an egg broke open. Out came a brand-new snail named Gail. Gail quickly ate the eggshell but she was still hungry. Slowly, she dug out of the soil. Gail could not see well. However, she had a good sense of small. Gail smelled plants nearby. Gail used her short tentacles to find the good-smelling plants. Then she began doing what would keep her busy for the coming months--eat, eat, eat!

Oral Retelling

- Task: Tell "everything you remember about the book."

Oral Retelling Results

- Analysis: Extent to which cross-text concepts appear in retellings.
- Retellings of narrative texts are longer than those for informational texts.
- Sand Passages: 8/10 concepts were more often recalled by readers of the informational text.
- Snail Passages: 10/14 concepts were more often recalled by readers of the informational text.
- On the sand passages, the dif. is statistically significant, but not on the snail passages.

Retelling Length

Unit	Average Number of Words
Gail's Snail Tale (N)	83.3
Snail Tales (I)	69.8
Sandy's Journey to the Sea (N)	82.9
Rocks to Sand (I)	57.8
Informational Texts	63.5
Narrative Texts	82.9

Comprehension

- Task: Respond to 10 comprehension questions for each passage.
  - Where does sand come from?
  - What causes rocks to break apart?
  - How do the rocks from the mountain reach the seashore?
  - Why might pieces of the same rock end up in different places?
  - What role do waves play in the formation of sand?

Comprehension Results

- Analysis of Variance revealed an overall effect for topic, but not genre.
- Irrespective of genre, students performed better on comprehension questions related to the snail topic (*M*=10.65, *SD*=3.91) than the sand topic (*M*=8.22; *SD*=4.04, *F*=37.176; *p*=.000).
- Overall, the effect of topic is significant irrespective of genre, but the effect of genre is only significant for the sand/rock topic. When the topic is snails, the influence of genre is not significant, but when the topic is sand, the influence of genre is significant (F=10.57; *p*=.002). (See Tables 7 and 8.)

Preferences

- Task: Select book of the two that "you would choose to read."

Preferences Results

- One group preferred narrative; The other preferred informational
  - SJ-ST preferred SJ; GST-RTS preferred RTS
- There were no significant differences by gender.
- Informational preference: "new information"; Narrative preference: "more interesting"

	Girls	Boys
N	24	13
I	21	16

Discussion

- Extreme exemplars of the genre
- Informational texts may better support science learning
- Assumptions about engagement

D

Directions of our Future Research

Efficacy Studies: Grades 4 & 5

- Design
  - 100 classrooms
  - Experimental: Seeds/Roots unit
  - Control: “business-as-usual” science teaching of same content
- Measures
  - Reading comprehension
  - Science vocabulary
  - Science content knowledge
  - Inquiry
  - Writing
  - Attitudes towards science

Semilla

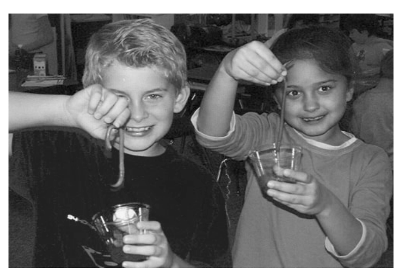
- Design
  - 20 classroom teachers
    - 10 ELL Experience---10 No/Little ELL Experience
- Research Questions
  - Can curriculum materials that are designed to support teacher learning, as well as student learning, have positive impacts on teacher knowledge, attitudes, and instructional practices?
  - To what degree do educative curriculum materials help teachers who have more and less experience teaching English language learners and how does level of ELL teaching experience relate to teacher knowledge, attitudes, and instructional practices?
- Measures
  - *Student*: language proficiency, vocabulary, science knowledge, attitudes (toward science & language),
  - *Teacher*: pedagogical content knowledge, efficacy-beliefs questionnaire, classroom observation,

Pilot: Vocabulary Measure Development

- Design
  - Preliminary validation during Seeds/Roots field test
  - 30 classrooms
  - Fourth grade

Construct Development

- Which of these is an example of precipitation?
- Which of these sentences uses the word precipitation correctly?
- Can precipitation start a fire?
- Which two words are most closely related to precipitation? (Choose two.)
  - Wind
  - Snow
  - Cloud
  - Temperature
  - Phase Change



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