Seeds of Science/Roots of Reading

...a curriculum development and research project

www.scienceandliteracy.org

This material is based upon work supported by the National Science Foundation under Grant #s ESI-0242733, 0628272 and 0822119.
## Common Approaches to Teaching Science

<table>
<thead>
<tr>
<th>Inquiry-Only Approaches</th>
<th>Text-Only Approaches</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hands-On Experiences</td>
<td>Reading</td>
</tr>
<tr>
<td>Discussions</td>
<td>Writing</td>
</tr>
</tbody>
</table>
The *Seeds/Roots* Approach to Teaching Science

**Inquiry-Only Approaches**
- Hands-On Experiences
- Discussions

**Text-Only Approaches**
- Do It
- Talk It
- Read It
- Write It

Engage students through multiple learning modalities.
Seeds of Science/Roots of Reading offers an effective approach for enacting Goal 3 of the NRC Report: Successful K-12 STEM Education

Increase STEM literacy for all students, including those who do not pursue STEM-related careers or additional study in the STEM disciplines.
Challenges to address

• The population of school-age English language learners in US schools is growing
• And yet, most instructional materials are written for use with English speakers, leaving the teacher to make necessary accommodations for English learners
ELL/Non-ELL Growth ‘95-’ 05
## Achievement Gap

### 4th Grade Reading Performance (NAEP 2011)

<table>
<thead>
<tr>
<th></th>
<th>Average Scale Score</th>
<th>At or above Basic</th>
<th>At or above Proficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>ELL</td>
<td>191</td>
<td>31%</td>
<td>7%</td>
</tr>
<tr>
<td>Non ELL</td>
<td>227</td>
<td>72%</td>
<td>37%</td>
</tr>
</tbody>
</table>

### 4th Grade Science Performance (NAEP 2009)

<table>
<thead>
<tr>
<th></th>
<th>Average Scale Score</th>
<th>At or above Basic</th>
<th>At or above Proficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>ELL</td>
<td>116</td>
<td>33%</td>
<td>5%</td>
</tr>
<tr>
<td>Non ELL</td>
<td>156</td>
<td>76%</td>
<td>37%</td>
</tr>
</tbody>
</table>
We drew from the research base

• Review of existing research and literature on effective practices for ELLs, found at http://www.scienceandliteracy.org/research/english_language_learners

• Used the results to inform the development of:
  – the instruction for students
  – notes to the teacher about how to accommodate
Four Principles that Make Science Accessible for ELLs

<table>
<thead>
<tr>
<th>1. Provide Additional Scaffolds for Language</th>
<th>2. Make Connections to Students’ Linguistic Resources</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Making abstract concepts more concrete</td>
<td>- Leveraging students’ native language</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Provide Additional Opportunities for Practice</td>
<td>4. Support the Development of Strategic Behavior</td>
</tr>
<tr>
<td>- Repeated access to science concepts through multiple modalities</td>
<td>- Build self-monitoring language abilities</td>
</tr>
</tbody>
</table>
Goals for Today’s Workshop

- Engage you in our multi-modal approach to science instruction, using activities from one unit, *Light Energy*
- Provide evidence from a study focused on the impact of the educative features of the Seeds/Roots curriculum on teacher practices as related to providing ELLs with access to science
- Provide evidence from efficacy studies focused on the Seeds/Roots multi-modal approach, including how ELL students perform
Shared Listening
Partner A listens, while Partner B talks.

What challenges are there for English language learners in your district in learning science?
Partner A summarizes what they heard.

Partner B listens, while Partner A talks.

What are the ways that you have provided, or supported others in providing, English language learners with access to science?
Partner B summarizes what they heard.
# 2nd-5th Grade Scope and Sequence

## Focus for Today

<table>
<thead>
<tr>
<th>Life Science</th>
<th>Earth Science</th>
<th>Physical Science</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Grades 2–3</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soil Habitats</td>
<td>Shoreline Science</td>
<td>Designing Mixtures</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Gravity and Magnetism</td>
</tr>
<tr>
<td><strong>Grades 3–4</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Digestion and Body Systems</td>
<td>Weather and Water</td>
<td>Light Energy</td>
</tr>
<tr>
<td>Variation and Adaptation</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Grades 4–5</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aquatic Ecosystems</td>
<td>Planets and Moons</td>
<td>Models of Matter</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Chemical Changes</td>
</tr>
</tbody>
</table>
Unit Components
Teacher’s Guide
Teaching Support and Considerations

Science Notes
About Soil. Soil is an incredibly important earth material that forms the growth medium for much of life. Without soil, trees would not be able to fix carbon dioxide into the air. Soil is a mixture of mineral particles, water, and living and dead organisms. The soil layer that covers the Earth contains billions of plants and animals. Living things interact with the soil by creating tunnels for water and air, recycling nutrients, and eating mineral particles throughout the soil. Organisms such as earthworms, fungi, bacteria, and fungi help to decompose dead plants and animals. Materials from the decomposing materials are left in the soil where they can be reused by plants. The plants in turn provide food for animals and the cycle begins again. Soils come in a variety of colors, textures, and forms. For more information on this and other topics related to this subunit, please see the Unit Overview, under Science Content Background.

Literacy Notes
Page Frame: Please note that on this page and on all the pages of the four main investigations, are lists of words and language constructions that all refer relevant to the investigation.
- Unit-specific Vocabulary. Some words are specific to the context of this unit. They represent the key academic words related to the unit’s main topic.
- Science Inquiry Vocabulary. Some words are essential for doing, writing, and explaining science inquiry.
- Language of Argumentation. These are some of the phrases or other language constructions that are necessary for engaging in scientific discourse.

All of these words and phrases are part of the language of science and should be heard in the classroom repeatedly—often by teachers and students alike. The words that refer most directly to each session, with multiple opportunities for use, appear on the page frames instead. This is to help remind you to use these words often in context and encourage students to use them in talking and writing. Your awareness of these opportunities will enable more intentional use and instruction.

Literacy Standards by Session
- Reading and responding to a text
- Making connections, accessing, and applying your knowledge
- Recognizing and understanding different perspectives
- Listening, speaking, and writing

ENGLISH LANGUAGE LEARNERS
Recognizing Student Linguistic Diversity: You can ask students how they say “fart” in their native languages. Please also see the suggestions related to supporting English learners in reading as outlined on pages 10 and 11.

LANGUAGE OF SCIENCE
Unit-specific vocabulary:
- adsorption
- adaptation
- behavior
- decomposer
- decomposition
- habitat
- soil
- subduction
- survival
- protection
- reproduction
- root
- shelter

LANGUAGE OF SCIENCE
Unit-specific vocabulary:
- adsorption
- adaptation
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- shelter

LITERACY STANDARDS
Daily correlation “snapshots”
Let’s Experience this Firsthand!
Activate prior knowledge
Set norms

Read
Set context for investigations to come

Talk
Build scientific community by developing routines for oral discourse

Guidelines for Partner Reading
1. Sit next to your partner and put the book between you.
2. Take turns reading.
3. Read in a quiet voice.
4. Be respectful and polite to your partner.
5. Ask your partner for help if you need it. Work together to make sure you both understand what you have read.
Search for evidence about the characteristics of light

Do
Explore light rays with various tools

Ray Diagram

Write
Create ray diagrams

Observations About Light
- flashlight made circle of light
- light seen through clear plastic
- foil - shiny in light
- circle of light got smaller when flashlight closer to foil
- light made black felt look silver/yellow
- light circle seen on back of felt
Read and Write Scientific Explanations

Read
Secondhand investigation to gather more evidence about light

Write
Students make sense of the characteristics of light
Learn from the work of others in the scientific community

**Why Do Scientists Disagree?**
by Gina Cervetti
illustrated by Sarah Kessler

Read
Text sets context and models nature and practices of science

Galileo asked questions about space. He wondered: What are stars made of? How do Earth and the Sun, Moon, and planets move in space? What kind of material is the Moon made of?

Galileo decided to investigate the Moon.
Investigate Properties of Light

**Do**
Students predict then measure how much light is
- reflected
- transmitted
- blocked
- absorbed
when they shine light onto 10 different surfaces.
Which materials transmit light?

4 to a group
- Recorder
- Light detector holder
- Material/Flashlight holder
- Extra Pair of Hands
Which materials reflect light?

4 to a group

• Recorder
• Light detector holder
• Material/Flashlight holder
• Extra Pair of Hands
Light Interactions Concept Map

How does light interact with materials?

- Light is transmitted: goes through
- Light is blocked: does not go through
- Light is refracted: bends
- Light is reflected: bounces off
- Light is absorbed: stays in
Search for additional evidence in text

Read

Students read a book that shares the results of someone else’s investigation and search for evidence in the text about the interaction of light on various materials.

**Fabric**

Fabric is the same as cloth. Fabric is made of thin fibers that are usually woven together. The fibers may be natural or made by people. Fabric is soft and easy to bend. These characteristics mean that fabric is good for making clothes, bags, bed sheets, and lots of other things. Different kinds of fabric can be smooth, bumpy, or even furry, and fabric comes in all different colors.

<table>
<thead>
<tr>
<th>Material</th>
<th>Measurements</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Brightness of light source</td>
</tr>
<tr>
<td>fake fur (yellow)</td>
<td>1,000 lux</td>
</tr>
<tr>
<td>felt (black)</td>
<td>1,000 lux</td>
</tr>
<tr>
<td>felt (red)</td>
<td>1,000 lux</td>
</tr>
<tr>
<td>felt (white)</td>
<td>1,000 lux</td>
</tr>
</tbody>
</table>
Make sense of data

Read and Talk
Students work together to make sense of the data gathered during their investigation.

Write
Students create a visual representation that helps them make sense of the phenomenon.

Summary of Light Investigations

<table>
<thead>
<tr>
<th>Material</th>
<th>Transmits light?</th>
<th>Blocks light?</th>
<th>Reflects light?</th>
</tr>
</thead>
<tbody>
<tr>
<td>clear plastic</td>
<td>yes</td>
<td>-not sure-</td>
<td>not sure</td>
</tr>
<tr>
<td>foil</td>
<td>no</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>black felt</td>
<td>-not sure-</td>
<td>yes</td>
<td>not sure</td>
</tr>
<tr>
<td>red felt</td>
<td>-not sure-</td>
<td>yes</td>
<td>not sure</td>
</tr>
<tr>
<td>white felt</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>waxed paper</td>
<td>yes</td>
<td>-not sure-</td>
<td>yes</td>
</tr>
<tr>
<td>wood</td>
<td>no</td>
<td>yes</td>
<td>not sure</td>
</tr>
</tbody>
</table>

Light Interactions Concept Map

How does light interact with materials?

- goes through: Light is transmitted.
- does NOT go through: Light is blocked.
  - bends: Light is refracted.
  - bounces off: Light is reflected.
  - stays in: Light is absorbed.
Discuss Results and Make Claims

Talk
Students participate in a discourse circle responding to the claim, “Materials of the same color absorb similar amounts of light”.

Write
Students work together to make claims about the reflection of light and support their claims with evidence.

---

**Do Non-shiny Things Reflect Light?**

Write an explanation that answers the question “Do non-shiny things reflect light?” Include a claim and support it with evidence. Make an illustration that supports your thinking.

Non-shiny things reflect light. For instance, when we did our investigation, we saw that wood reflected light. In addition, the reflected light shone on the table. Similarly, the moon reflects the light from the Sun. Therefore, we can see it from Earth. We can conclude that non-shiny things reflect light.
Revisit Nature of Science

Write
Students connect their experience to the nature and practices of science.
Reminding us of
Goal 3 of the NRC Report:
Successful K-12 STEM Education

Increase STEM literacy for all students, including those who do not pursue STEM-related careers or additional study in the STEM disciplines.
## Language Demands of English Language Learners

### Language Demands of Science

<table>
<thead>
<tr>
<th>Listening</th>
<th>Reading</th>
<th>Speaking</th>
<th>Writing</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Follow multi-step directions for an investigation</td>
<td>• Navigate reference books</td>
<td>• Participate in discussions in appropriate ways</td>
<td>• Write procedural and descriptive texts in appropriate genre</td>
</tr>
<tr>
<td>• Understand explanations without concrete examples</td>
<td>• Read to comprehend and interpret science texts</td>
<td>• Explain and/or present a process or findings</td>
<td>• Record extensive observations</td>
</tr>
<tr>
<td>• Understand Science Vocabulary</td>
<td>• Understand science vocabulary</td>
<td>• Demonstrate a range and control of science vocabulary</td>
<td>• Use precise vocabulary in writing products</td>
</tr>
</tbody>
</table>
# Light Energy ELL Accommodations across 5 sessions

<table>
<thead>
<tr>
<th>Session 2.1</th>
<th>Session 2.2</th>
<th>Session 2.3</th>
<th>Session 2.4</th>
<th>Session 2.5</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Why Do Scientists Disagree?</strong></td>
<td>Which Materials Transmit Light?</td>
<td>Writing about Transmission</td>
<td>Which Materials Block Light?</td>
<td>Making Sense of Shadows and Blocking</td>
</tr>
<tr>
<td>READING</td>
<td>SCIENCE INQUIRY</td>
<td>LITERACY DEVELOPMENT</td>
<td>SCIENCE INQUIRY</td>
<td>SCIENCE/ LITERACY</td>
</tr>
<tr>
<td>Reading with a Purpose p. 155</td>
<td>Affective Strategy p. 169</td>
<td>Writing Scaffold p. 185</td>
<td>Facilitating Science Language use p. 193 (85,37)</td>
<td>Promoting English Learners’ Native Languages p. 213</td>
</tr>
</tbody>
</table>
Reading with a Purpose. To help English learners understand this book, some accommodations before, during, and after reading are needed.

Before reading,
- Remind the students about idioms. Tell them many common expressions use words that have two meanings. On the board write the following idiomatic expressions: "spread out all over the world" (page 5), "disagreement moves science forward" (page 11), and "the father of science" (page 18). Have the students turn to these pages and read the phrases in context. Discuss and record the meaning of each idiom. Point out the ways in which spread, forward, and father—when used in these idioms—have meanings different from their usual meanings.

During reading, provide students with a sticky note and tell them to place it on a page where they had some trouble understanding the book.

After reading, discuss strategies for rereading difficult sections and explain that this is one way to help students understand difficult sections of text. With the class, choose one passage that many students found difficult. Guide them through the rereading process by having them discuss the meaning of the passage with a partner and then reread the passage slowly. When they finish reading, discuss the meaning of the passage as a group.
Before Reading:
Awareness of Idioms in *Why Do Scientists Disagree?*

From page 5

The scientific community is spread out all over the world. Still, all scientists are connected. They all want to learn more about how the world around them works.

From page 18

Today, scientists all over the world remember Galileo. He was brave enough to disagree. He always supported his claims with evidence. Some people call Galileo “the father of science.” They mean that he set a great example for other scientists to follow.

From Page 11

Scientists often disagree. Some people think of disagreement as a bad thing, but it is very important in science. Disagreement moves science forward.
Idiomatic Expressions. To help English learners understand this book, some accommodation may be needed to help them understand idiomatic expressions. Before reading, discuss idiomatic expressions in general. Write on the board "Finishing my homework is a piece of cake." Tell the students this sentence contains a phrase that means something different from what you might think based on the words. In this case, the phrase does not mean the homework is made of cake! Ask the students if they think the sentence means that the homework is easy or hard. Write on the board these five idiomatic expressions found in the book: "light is creeping in"; "none, nada, zip, zilch"; "put the fire out"; "dive under your bed"; and "a smile crosses your face." Have students work in pairs to find and read the page where the idiom is found and figure out what is meant. As a class, discuss the meaning of each idiom.
Supporting the Development of Strategic Behavior
(Session 2.3)

**English Language Learners**

**Writing Scaffold.** English learners may need extra help writing scientific explanations. Provide them with sentence starters they can use in writing their evidence sentences. Caution them to think carefully about which starters to use for each sentence. You could write the following sentence starters on the board, or photocopy a sheet with the sentence starters for each student who needs them.

For example, ________________ does transmit light.
For example, ________________ does not transmit light.
I know this because ________________.
When I tested ________________, I observed ________________
In addition, ________________.
Finally, ________________.

English Language Learners

Facilitating Science Language Use. If you started the Science/Everyday Words chart in earlier sessions, add the following word pairs to the appropriate section of the chart: *transmit/let through* and *material/stuff.* Tell the students that while these word pairs have similar meanings, *transmit* means to let all or part of something pass through and is often used when talking about letting through light, sound, or electricity. *Material* is the stuff that objects are made of, such as wood, plastic, or foil. Tell them that when talking or writing about science, they should use the science words instead of the everyday words to convey a more precise meaning.
Affordances of Vocabulary in Science
(from Cervetti & Bravo, 2008)

Multiple exposures: Hard words in science texts are frequently repeated; science instruction focuses on the core ideas indexed by these science words.

Key science term: reflect
Light Energy
Inquiry Words
Three “Gold Standard” Studies

• Grades 2/3 Soil Habitats & Shoreline Science
• Grades 3/4 Light Energy
• Grades 4/5 Planets and Moons

Several Sub Studies focused on English Language Learners
Positive Results Across the Board:

**STUDENTS**
- Outperform control students on measures of:
  - science conceptual knowledge
  - science vocabulary
- Perform equivalently or higher than control students on measures of:
  - science reading comprehension
  - science writing

**TEACHERS**
- Spend more time teaching science than control teachers
- Have more student-to-student talk in their classrooms
- Find value from the educative features of the Teacher’s Guide
How does Seeds of Science help teachers learn?

Examples that follow are drawn from the Light Energy sessions we just experienced (Sessions 2.1 – 2.4)
YEAR ONE

• 58 4th and 5th grade Teachers with high % of English learners

• Randomly assigned to teach either the treatment version or the comparison version of *Planets and Moons*

• Developed, administered and refined measures
YEAR TWO

• Invited 16 high implementers for second implementation of *Planets and Moons*

• Administered revised measures

6 treatment teachers        10 control teachers
Figure 2.

Trajectories in Use of Strategies for ELL Across Five Observations by Treatment Group
Mean Observed Use of Different Strategies for ELL Across Five Observations

![Range of Strategies Used with ELL](image)

- **Treatment**
- **Comparison**

Observations (Obs):
- Obs 1
- Obs 2
- Obs 3
- Obs 4
- Obs 5
Figure 4

Mean Number of ELL Strategies Per Segment by Teacher, Treatment Group

Average Number of ELL Strategies Per Observed 10-minute Segment by Teacher: Treatment

[Graph showing average number of ELL strategies per observed 10-minute segment by teacher, with different lines for different teachers (20-04, 20-09, 20-10, 20-11, 20-50, 20-62).]
Figure 5

Mean Number of ELL Strategies Per Segment by Teacher, Comparison Group

Average Number of ELL Strategies Per Observed 10-minute Segment by Teacher: Comparison
Advantage for ELL Students:

- In two different studies, English language learners (ELL) outperform ELL control students on measures of:
  - science conceptual knowledge
  - science vocabulary

(Bravo and Cervetti, 2011; Duesbury, Werblow and Twyman, 2011)
Subset of students: Struggling Readers

**Light Energy Struggling Readers**

Percent Growth in Students' Writing Strategies

(*p<.05, **p<.01)

- **Strength of Conclusion**
  - Business-as-Usual Students (n=55): 2.3%
  - Seeds/Roots Students (n=56): 19.0%*

- **Overall Clarity**
  - Business-as-Usual Students (n=55): 7.2%
  - Seeds/Roots Students (n=56): 14.8%

- **Strength of Introduction**
  - Business-as-Usual Students (n=55): 8.9%
  - Seeds/Roots Students (n=56): 27.7%*

- **Use of Evidence**
  - Business-as-Usual Students (n=55): 10.9%
  - Seeds/Roots Students (n=56): 34.1%*
Struggling Readers, continued

Light Energy Struggling Readers
Percent Growth in Students' Writing
(**p<.01)

Correct Use of Science Concepts
- Business-as-Usual Students: 12.3%
- Seeds/Roots Students: 36.7%**

Use of Science Vocabulary
- Business-as-Usual Students: 9.7%
- Seeds/Roots Students: 42.9%**

Overall Writing Score
- Business-as-Usual Students: 9.2%
- Seeds/Roots Students: 34.4%**
Science Writing

What do you know about forces? When you write your answer, be sure to name, describe, and give examples of at least two forces.

I do not know what a force is but I think it is like a person forces someone to do something.
Science Writing

What do you know about forces? When you write your answer, be sure to name, describe, and give examples of at least two forces.

I know that there are 3 different kinds of forces: gravity, magnetic force, and electrostatic force. Gravity pulls stuff to earth. Magnetic force attracts and repels electrostatic sticks things. A magnet sticking to iron is an example of a magnetic force. A kid kicking a ball is an example of gravity. Electrostatic force needs an object charged.
Table Interaction

Working with your tablemates, correlate the English Language Learners Considerations to the Four Principles that Make Science Accessible for ELL’s.

Discussion Topic:
How can your work benefit from the work shared here?

How can/will your office help meet the language demands of science for all learners?
What solutions does SEEDS offer and for whom?

• Success for English Language Learners and other struggling readers and writers. Who?
  – Districts with high percentages of ELL students
    Holyoke, MA
    Fresno, CA
    Minneapolis, MN
  – English Language Development
    Santa Barbara, CA
  – Program improvement schools who are looking to provide more ELA instructional minutes
    Vineland, NJ
www.scienceandliteracy.org
twierman@berkeley.org

This material is based upon work supported by the National Science Foundation under Grant #s ESI-0242733, 0628272 and 0822119.
How do *Seeds/Roots* students compare?
SEEDS makes more of a difference

<table>
<thead>
<tr>
<th>Type of Intervention</th>
<th>Average Effect Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Participation of elementary students in one 8-10 week SEEDS unit</td>
<td>.61</td>
</tr>
<tr>
<td>Computer-based instruction</td>
<td>.45</td>
</tr>
<tr>
<td>Cooperative learning with elementary students</td>
<td>.3</td>
</tr>
<tr>
<td>Use of inquiry methods in science</td>
<td>.3</td>
</tr>
<tr>
<td>Class size reduction</td>
<td>.2</td>
</tr>
</tbody>
</table>