Bridging Science and Literacy in Secondary Science Instruction in Support of Science Literacy

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Introduction

- The goal of the *Carbon TIME* project is to support students in developing environmental science literacy through a six-unit curriculum focused on carbon cycling at multiple scales.
- In this study, we:
  - ➢ Explored how literacy can be integrated into three-dimensional science instruction.
  - ➢ Worked with teachers to co-design literacy tools.
  - ➢ Evaluated the enactment of those literacy tools in instruction.

Problem Statement

- Environmental science literacy consists of the ability:
  - to participate in evidence-based discussions about socio-ecological issues.
  - to make decisions that are informed by science.
  - To engage and make sense of uncurated (i.e., not developed for the classroom) phenomena and uncurated media and texts that people encounter in their lives.
- As such, environmental science literacy includes literacy practices.
  - These literacy practices are incorporated into the Next Generation Science Standards (Wright & Domke, 2019).
- The work of scientists and scientifically literate individuals includes literacy-based practices (e.g., Latour & Woolgar, 1986).
- Therefore, literacy needs to be incorporated into science instruction.
- However, literacy is currently integrated through discrete strategies in many classrooms (Moje et al., 2010). This type of integration does not support three-dimensional figuring out of phenomena.
  - For example, 70-85% of science teachers surveyed felt that vocabulary should be introduced and defined at the beginning of a unit (Wilson, Schweingruber, & Nielsen, 2015). Yet, this practice is negatively related to student learning gains in middle and high school instruction (Lin, Frank, & Anderson, 2019).

Design Goal

- The design goal of this work is to:
  - Work with teachers to co-design literacy tools that support students in the science and literacy practices of writing explanations and reading science-related texts.

Methods

- The study is a design-based research project (Barab & Squire, 2004; Design-Based Research Collective, 2003).
  - This study aims to improve both classroom practice related to literacy within three-dimensional instruction as well as the informing theory related to students use of and production of disciplinary texts.
- The co-design occurred with two secondary science teachers from different midwestern districts.
- The co-design started with a two-day professional development workshop at the beginning of the summer and continued throughout the rest of the summer.

Explanation Writing Scaffolds

Revised Explanation Checklist

Scientists explain many processes in nature by connecting the things we can see with things we can't see, such as chemical changes at the atomic-molecular scale. You can use the Three Questions as a guide to explaining these processes. Your explanation should include steps for each of the four numbered questions, and the checklist below will help you make sure you include important information. Remember that a good explanation also answers the question; return to your prompt to be sure you have answered yours.

Setting the stage

a. Did you name the system (what fuel, plant, animal, or decomposer) where the process is happening?
b. Did you name the carbon transforming process?

1. Matter movement: How do molecules move to the location of the chemical change?

a. Did you "zoom in" to a location (a cell or part of a flame) where the change takes place?
b. Did you identify the molecules that move to that location?
c. Did you describe where those molecules came from?
d. Did you say how they got to the location?

2. Matter change: How are atoms in molecules being rearranged into different molecules?

a. Did you identify the reactants—the molecules that go into the chemical change?
b. Did you identify the products—the new molecules that are created when the atoms from the reactants are rearranged?
c. Did you follow the rule that "atoms last forever:" Are all the atoms that were in the reactant molecules in the product molecules?

3. Energy change: What is happening to energy?

a. Did you identify the form(s) of energy before the chemical change?
b. Did you identify the form(s) of energy after the chemical change?
c. Did you follow the rule that "energy lasts forever:" Is all the energy that was there before the change still accounted for after the change?

4. Matter movement: How do molecules move away from the location of the chemical change?

a. Did you identify the molecules that don't move away and the molecules that do move away after the chemical change?
b. Did you explain what happens to the molecules that move away—how they go to other parts of the system or leave the system?

Other Elements to Consider

a. Did you use scientific vocabulary correctly?
b. Did you organize your explanation logically to tell a story that flows?

- The teachers wrote "ideal" explanations. The checklist was revised based on what the teachers determined to be components of "ideal" explanations.
- The components include attention to both science and literacy aspects of the performance of writing explanations.
- The checklist serves to provide structure for the practice of constructing an explanation by decomposing it into smaller parts (Quintana et al., 2004).

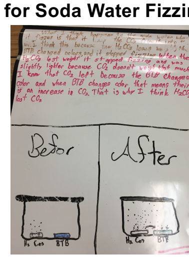
Collaborative Explanation Writing Protocol

Approximate Time	
Prior to lesson	Students fill out front side of Explanations Tool.
5 minutes	Individually students will write their explanations.
5-10 minutes	Students share with other members of their groups. Review small group sharing protocol. One person read their explanations. Other students will ask clarifying questions. Then the next student shares. During this time teachers should be moving from group to group checking for understanding and asking clarifying questions.
15 min	Small groups will create a group explanation using ideas from their individual explanations.
10 min	The first time doing the small group explanations take some time to come up with a list of what should be included in the explanations. Once the list is created, have groups switch papers with another group. As a group they need to read and mark of what the group has included from the checklist. They also need to suggest ways to improve their explanations. List of suggested items included in explanations. • Addresses all three questions. • Names the transforming process(es) • Defines the system (where is process occurring at) • Connects to the phenomenon (real life or prior experiences) • Uses key vocabulary appropriately • Organized logically to tell a story (has a topic sentence)

- We co-designed a protocol for collaborative explanation writing to support students in refining their ideas.
- This aligns with the theoretical idea of situated leaning in which learning occurs through practice within community (Lave & Wenger, 1991).

Sample Explanations

Collaborative Explanation for Soda Water Fizzing



Individual Student Explanation for Ethanol Burning

I am Answering: What happens to ethonol when it burns? I think that when ethonol burns the ethonol releases H_2O and CO_3 into the air. I know that ethonol needs oxygen to burn. If ethonol did not have oxygen it wouldn't be able to burn. I allso know that when ethonol burns it losses atoms because we measured it before and after we burned it. We figured out that Ethonols atoms are C_2H_3OH this makes up ethonol. When ethonol burns the C_2H_5OH turns into $2CO_2$ and $3H_2O$ with is Carbin dioxide and water. Now that we know CO_2 and H_2O goes into the air that means Ethonol evaporates. In conclusion When ethonol burns it turns into heat and light energy and the goes into the air. we also figured out that the energy before it burns is chemical but the energy while it burns is heat and light energy.

Reading Scaffolds

Teacher's Versions of the Readings

Activity 1.2: Teacher's Version of Systems and Scale Storyline Reading Learning from the Work of Elizabeth Fulhame

> With their partner, have students discuss what they observed when you burned water and ethanol.

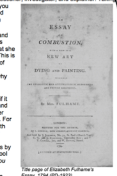
> Read the purpose for reading statement aloud to students before they start reading with their partner. Provide students with an overview of the text. For example, "Today we're going to learn from the work of Elizabeth Fulhame, a female scientist in the 1700s."

Purpose for reading: *As you read this text, work to make sense of the roles you will take on during this unit and how those roles relate to the work scientists do.*

Why does one clear liquid, ethanol, burn and another clear liquid, water, not burn? To answer this question, you will take on the roles of questioner, investigator, and explainer. Taking on these roles will allow you to make sense of what you observed when your teacher tried to burn ethanol and water. Scientists take on these same roles to explain things they see and experience in the world.

Let's see how Elizabeth Fulhame-a chemist and artist-studied how and why things burn. Fulhame was Scottish and lived in the 18th century. Aside from what she published in an essay, little is known about her life. This is because her work drew less attention than the work of male chemists. However, she had new ideas that contributed to chemists' understanding of how and why things burn. In her work, she was a questioner, investigator, and explainer.

> After students read this section and discuss it with their partner, ask "how do you think process of science today is similar to and different from the process of science in the 18th century?"



Title page of Elizabeth Fulhame's Essay, 1794 (PD-1923)

Fulhame was a questioner. She wondered if it was possible to dye fabric or paint with gold, silver, and other metals by using chemical reactions. Each of her questions could be answered by collecting evidence. For example, she wondered if charcoal could be used with gold to dye fabric. Her question can be answered by collecting evidence. During this unit, you will be a questioner. You will develop good scientific questions by thinking about your ideas on the Expressing Ideas Tool and through discussions with your peers. *What do you think makes a good scientific question?*

> After students read Fulhame was a questioner, make a list of students' answers to the question in the text. Have them look back their Expressing Ideas Tool. Have them evaluate their questions and edit them to make them better scientific questions.

Fulhame was an investigator. Over fourteen years, she conducted a series of investigations to answer her questions. She designed the investigations based on what other scientists had already learned about similar chemical reactions from their investigations and what she was learning from hers. She documented how she conducted each investigated and the results. *Why was it important for Fulhame to document her investigations?*

During the unit, you will be an investigator. You'll make predictions and then collect evidence to help answer the questions you asked earlier in the unit. It will be important to keep notes of your predictions, your methods, and the evidence you collect on the Predictions Tool, the investigation worksheets, and the Evidence-Based Arguments Tool. Your notes will help you remember your ideas and evidence and then share ideas with your peers.

After Fulhame completed her first investigations, she had some evidence about how fabrics could be dyed using chemical reactions and how materials burn. However, her evidence left some questions unanswered, which led to more questions. She wondered if other metals would do the same thing as the ones she had tested. She wondered about what role each

- The teacher's versions of the readings were designed to support teachers in helping their students make connections between the readings and the other components of the unit through discussion.
- They align with situated learning theory as it engages students in collaborative sensemaking around the readings and with the RAND heuristic of reading comprehension as the questions are part of the activity that students engage in (Lave & Wenger, 1991; RAND Reading Study Group, 2002).

Questions, Connections, Questions Reading Strategy

When you read, think about...

Questions

1) What words or sentences were hard to understand?
2) What questions do you have about them?

Connections

3) How does this reading connect with what you have been learning in class?
4) How does this reading connect with things that we see in the world around us?
5) How does this reading connect with other things that you have read or heard?

Questions

6) What new questions do you have after reading this?

- The Questions, Connections, Questions Reading Strategy engages students in sensemaking around the readings with their peers.
- The reading strategy serves as a scaffold because it decomposes the complex task of making sense of a science-related reading into its component steps (Quintana, 2004).
- Moreover, it aligns with the theoretical idea of situated learning as students will engage in the reading strategy with their peers (Lave & Wenger, 1991).

Discussion and Future Work

- ❖ Attention needs to be given to how to incorporate literacy into three-dimensional science instruction at the secondary level in order to support students in developing science literacy and environmental science literacy. These tools are the beginning of such work.
- ❖ These tools are designed based on multiple theories of learning. Consideration is needed around how these theories of learning work together to support student learning.
- ❖ Current and future work is exploring how these tools work in classrooms. Initial findings suggest that the tools promote increased teacher attention to the literacy elements of science instruction and support students' literacy practices.

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