Supporting Literacy Development in Project-Based Inquiry Science
Read, Write, Speak, and Think like Scientists: A Guide to Literacy Development in PBIScience

Features of PBIScience that Promote Literacy in Science

Introduction

The Next Generation Science Standards state that “reading in science requires an appreciation of the norms and conventions of the discipline of science, including understanding the nature of evidence used; an attention to precision and detail; and the capacity to make and assess intricate arguments, synthesize complex information, and follow detailed procedures and accounts of events and concepts. Students also need to be able to gain knowledge from elaborate diagrams and data that convey information and illustrate scientific concepts. Likewise, writing and presenting information orally are key means for students to assert and defend claims in science, demonstrate what they know about a concept, and convey what they have experienced, imagined, thought, and learned.”

Project-Based Inquiry Science (PBIS) integrates opportunities for students to develop all these skills throughout the curriculum. Section A of this document illustrates where and how these standards are introduced, taught, and reinforced.

Drs. Krajcik and Sutherland*, two of the developers of PBIS, identified five instructional and curricular features in developing literacy in the context of science:
(i) linking new ideas to prior knowledge and experiences,
(ii) anchoring learning in questions that are meaningful in the lives of students,
(iii) connecting multiple representations,
(iv) providing opportunities for students to use science ideas, and
(v) supporting students’ engagement with the discourses of science.

Section A also describes how and where each of the above features is integrated into the PBIS curriculum. Instructional strategies that have been developed to support these features and how teachers can use these features in their classroom instruction are highlighted, and examples of how the use of these features is supported by the PBIS CyberPD website is provided.

Anchoring Experiences

At the beginning of every PBIS unit, students engage with anchoring activities around a phenomenon. Anchoring activities are important because they provide students with common experiences to discuss and help them access prior knowledge. They put all students on an “even playing field.” They are an important tool to set the stage for the development of numerous literacy standards.

The following lists the anchoring activities for each (non-launcher) unit:

- **Air Quality**: Students read a parable about a land named Malaire and the changes in the land due to increased air pollution. Then they view several pictures illustrating a human activity and determine its effects on air quality. Finally, they take an “air walk” to look for evidence of air quality in their community.

- **Astronomy**: Students read about a meteorite striking a car in NY, watch a video of a demolition derby, and then participate in tennis-ball “demolition” derby activity.

- **Energy**: Students read about Rube Goldberg and consider what they already know about energy. They view a video of a Rube Goldberg-type machine and identify energy transformations they observe. Students then explore, discuss, and share their ideas about energy transformations in a Rube-Goldberg type machine.

- **Ever-changing Earth**: Students observe maps and photographs of places on Earth where volcanoes and earthquakes occur. Then they read letters from pen pals about an Earth structure that is in a tectonically active region and present the information from their pen pal’s letter to the class.

Ever-changing Earth, pp. EE 4 and 16.
• **Genetics:** Students read food-ingredient labels to identify the grains they contain. Then they read a letter from a young person in the Philippines describing the importance of rice to his family and community and the need to develop rice that can grow when there is not a lot of rain. They conclude by reading a request to participate in a research project to help in developing a new variety of rice.

• **Good Friends:** Students participate in an activity that simulates how an infectious disease might spread through a community. They toss a bean bag that, unknown to them, is covered with glow powder to one another as they share what they know about getting sick. Using an ultraviolet light, they examine the extend of the spread of “germs.”

• **Living Together:** Students make claims about the quality of five jars containing different water samples collected along a river. They make observations of photos, taken at different locations along a river, and match them to the jars of water, explaining their reasoning. They are then introduced to the towns of Wamego and St. George, located on the Crystal River, and the concerns about a new manufacturing company moving into Wamego.

• **Moving Big Things:** Students observe and record how machines are used at a construction site, record their observations. They then test how many threads are required to lift a mass.

• **Vehicles in Motion:** Students explore motion and think about what causes “vehicles,” including cars and skateboards, to change motion. They then participate in an exploratory activity (“mess about”) with a variety of toy cars that have been selected to introduce students to a variety of ways motion can occur. They examine the cars for structure, performance, mechanisms, and design and then compare motion-causing mechanisms among the cars.

• **Weather Watch:** Students briefly read about severe weather and then watch a video that shows several types of severe weather. Through a set of discussion questions, students begin to consider the severe weather they saw in the video and the types of severe weather that might happen where they live.

The *PBIS* student edition is unlike traditional student textbooks. Science content is presented in the student edition, but the student text also provides support for many of the activities that students participate in as student scientists. In this case, the student edition provides students and teachers with the prompts they need to help them effectively engage in the anchoring experiences.
For example, in *Weather Watch*, pages WW 5-6, students are provided *Stop and Think* questions to read before viewing a video of severe weather and then write answers and orally share them with the class after they have seen the video. In this situation, students are building visual literacy. Excerpts from the student edition are shown below. Notice that the student edition provides details about what students should focus on during their viewing. Students are also guided in how to participate in class discussions, to listen carefully and ask questions about what they do not understand. In this particular introductory activity, English-language learners specifically are encouraged to contribute by sharing weather events that they are familiar with in the regions they have lived. These opportunities are provided in many instances throughout each unit. Be aware of and use these opportunities, as they arise, to promote literacy.

It is not anticipated that students read and process the text in these subsections independently. It is important that you read these text passages along with the class and discuss how to productively engage in these practices. These types of text passages appear throughout all the units.

Further support for developing literacy is provided on the *PBIS CyberPD* site. For example, in *Air Quality*, beginning on page AQ 3, students read a parable about a land called Malaire. *Teaching Strategies* provided include some of the following:
If you wish, you can provide these questions and prompts to students on a separate sheet of paper or on a white board. Note that all the Stop and Think and Reflect questions for all the units are available as editable Word documents on the website. This provides you the opportunity to modify any questions to meet the individual needs of your students at their reading level.
The **PBIS Project Board**

As noted, at the beginning of every *PBIS* unit, students engage with an anchoring experience around a phenomenon. Through this experience, and the recall of previous classroom and real-life experiences, students begin to engage in a fundamental practice of science and an important component of science literacy: asking questions. More specifically, students begin to engage in the creation of the **Project Board**. They begin by recording information initially in the first two columns, “What do we think we know?” (students establish what they already think they know) and “What do we need to investigate?” (students formulate empirically answerable questions related to the anchoring experience and the *Big Question/Challenge*). The **Project Board** provides an opportunity to activate prior knowledge and to link that prior knowledge to what they are learning. A student’s understanding of a text can be improved by activating their prior knowledge before dealing with the text.

The **Project Board** is similar to the familiar KWL (Know, Want to Know, Learned) chart that has been used now for several decades to help students become better readers of expository text. However, the **Project Board** extends the KWL chart to include evidence and connections to the *Big Question/Challenge*, making it more suitable for fostering literacy in science.

In each *PBIS* unit, students create the **Project Board** at the end of the *What’s the Big Question/Challenge* introductory section. They are introduced to the **Project Board** and its use in *Learning Set 3* of the launcher units *Digging In* and *Diving Into Science*, and reminded again in each unit. Both the student edition as well as the *PBIS CyberPD* site provide guidance for how to develop and use a **Project Board**.

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*Digging In, pg. 51.*  
*CyberPD Welcome Page.*
As the unit proceeds, students revisit and update the Project Board, determining what questions have yet to be satisfactorily answered, while continuing to ask new questions based on their learning experiences. As the class works together to create and update the Project Board in all PBIS units, they are engaged in several science, engineering, and reading, writing, and speaking/listening practices, as articulated in both the Framework for K-12 Education and Common Core State Standards, ELA, respectively.

Columns three and four of the Project Board require that students make claims (column 3) that are supported by evidence (column 4), important science practices and literacy skills. Students develop their claims during learning experiences (e.g., investigations, demonstrations, thought experiments). Evidence generally comes from the qualitative and quantitative data students collect during these various learning experiences. Students may also support claims from evidence that they draw from the texts they read. These practices are vitally important to building literacy in science. The evidence-based claims that are tracked on the Project Board provide additional support for students as they construct written explanations of the phenomena they explore throughout the unit. The explanations of phenomena and recommendations for solutions to the problems posed in PBIS are recorded in the last column of the Project Board. This column provides students with opportunities to tie together in a logical, coherent way all that they have been learning throughout a unit. It is an opportunity for students to use science ideas.

To create and update the Project Board, the teacher facilitates collaborative discussions. The ideas that end up on the Project Board are generally the result of consensus-building class discourse. As they participate in Project-Board discussions, students are expected to engage in argument from evidence. Specifically, students come to the Project-Board discussion prepared with evidence-based claims they have collaboratively developed during their PBIS experiences. They are expected to follow the norms previously developed as a class for how to participate productively in discussions. As students or groups of students present their evidence-based claims, peers are expected to contribute to the conversation either by adding new information in support of each other’s claims, or by providing counterarguments with appropriate justification. Students are also expected to ask each other questions: to receive clarification on claims presented; to press their peers to explain their ideas more; or to challenge their ideas.
Conferences and Communicates

In PBIS, students spend a lot of time in the classroom working in small groups. The student text always includes hints and prompts to help students know how to participate and what to listen for or notice while working in small groups. These small-group activities are called Conferences. During Conferences, for example, students may discuss what they experienced or read together or try to explain why things happened as they did. The example shown below, from Air Quality, shows how PBIS uses several reading strategies to help students cooperatively comprehend and make sense of a “newspaper article.”

3.2 Read

Case Study: Pollution in Los Angeles

L.A. COURIER
Los Angeles, California
May 1, 2006

The Most Polluted City in America

Once again, Los Angeles has topped the American Lung Association's Air Quality Index, a list of the most polluted cities in America. The association found that the Los Angeles city area had the worst air in the United States.

"Nobody is surprised that L.A. has an air pollution problem," said Martin Nisen, president of the American Lung Association. "The problem is not one of the reasons we have the Clean Air Act, but it is important for people to know that there has been some improvement!"

Stop and Think

1. Think about what you know about the activities that produce the six worst air quality problems. Which of these activities do you think are common in Los Angeles? Look back at the article on the previous page and at the paragraph above to help you answer this question.

2. What do you think might cause the air pollution problem in Los Angeles? What do you think might make the problem so much greater in Los Angeles than in other cities?

Conference

Share with your group your ideas about what affects the air quality in Los Angeles. Discuss which sources of pollution you are sure about and which sources of pollution you are still unsure about. It is important for all members of your group to discuss their ideas. As a group, use a Sources and Effects of Air Quality chart to create a list of possible sources and effects of air quality in Los Angeles. This chart should be similar to those you made earlier in the unit when discussing your community.

Air Quality, pp. AQ 128-130.

After Conferences, students participate in Communicates, whole-class discusses. PBIS includes many different types of Communicate activities – Investigation Expos, Plan Briefings, Solution Briefings, Share your Explanations, Share your Ideas, and Solution Showcases. In a Communicate, each small group of students has a chance to present results or ideas or what they are learning to the rest of the class, and in many cases, each small group holds court while the class discusses what they have presented. They make public presentations of their results, ideas, or solutions, submitting them for peer review and comment. Then the class discusses what can be learned by considering the entire set of presentations. These social, literary practices give students opportunities to engage in doing science together—they learn from each other, they help each other, sometimes they need each other’s solutions. During Communicate activities, they collaborate as scientists do.
Multiple Representations

Multimodal and multiple representations are used extensively in science literature and communication and are important in developing literacy in the context of science. These representations may include photographs, videos, models, diagrams, tables, mathematical equations, simple text, or any other forms used to communicate concepts in science. **PBIS** often represents the same concept through a variety of different forms. The curriculum also provides students repeated exposure to the same concept.

The example from *Weather Watch* below, illustrates how students use prior knowledge, student and teacher-generated models, increasingly more detailed diagrams, and text to make sense of where rain comes from. Note that in **PBIS**, each section, whether it is an *Explore, Investigate*, or *Read* section, ends with a summary, *What’s the Point?*

Weather Watch, Sections 3.2-3.4, pp. 135-156.
Creating Explanations and Making Recommendations

Scientific explanation is the science and literacy practice of using science knowledge to provide an account, that is clear and can be understood by others, of why something happened. Explaining, in PBIS, is presented to students as a social and literacy practice and an iterative science activity. Students often create basic explanations early in a unit or Learning Set, identify what they need to learn more about to make their explanations better, and then iteratively refine their explanations as they generate more evidence and learn more science content. Deriving an explanation provides the opportunity for students to use and apply science content they are learning and to identify where their mental models of that content are incomplete or inaccurate.

The first time in the school year that students are asked to create an explanation, a Be a Scientist box in the Launcher Unit helps them understand what an explanation is, the parts of an explanation, and how to form one. Initially, you should work through creating an explanation with the class using concepts with which the students are familiar. Each subsequent time they are asked to explain, they are presented a question they must answer with their explanation, asked to make a claim that answers the question, and then reminded of what evidence they have collected and the science content they have learned that they might use in an explanation statement. They might also be provided with sentence frames (see next page) to help them begin their explanation statement. The PBIS CyberPD website provides additional support for teachers to help students develop this practice.

Digging In, pg. DIG 77-79. Students are introduced to the practice of creating an explanation.

Create Your Explanation Blackline Master.
Students make two types of explanations. Some are centered on claims about scientific phenomena, while others are centered on recommendations. In this way, they get practice using and applying the science they are learning in two ways—to explain phenomena they have experienced and to make predictions about what will happen in other situations.

**Diving Into Science, pg. DIV 67. Students make recommendations about a whirligig design.**

**Genetics, pg. GEN 90. Examples of sentence starters.**

**Weather Watch, pg. WW 154-155. Students explain the phenomenon of how Sun’s energy causes precipitation.**

**Explain** sub-sections are always followed by **Communicates** in which students share their explanations with the class. Then the class works together to derive an explanation that the whole class will accept. These are often followed by **Reflects** in which students think about the science in their explanations as well as how good their own explanations were and what makes for a good explanation. After students learn more, they are asked to revise their explanations. **Revise your Explanation** sub-sections may also followed by **Communicates**, class revisions, and **Reflects**.

Students use **Create your Explanation** pages (shown on the previous page) each time they explain a phenomenon or make a recommendation. Explanations are iteratively revised, and when learners cross out and revise parts of their explanations, they experience the progress they are making. Because they articulate explicitly their claims and the science and evidence that justify them, they can present their claims and reasoning easily to the class, and they have the basis for engaging in scientific argumentation. Students work collaboratively in small groups and as a class to make meaning of what they are learning.
Special-Purpose Pages (“Blackline Masters”) and Other Literacy Strategies

Associated with each of the units, there are also special-purpose pages on which students record their data, record graphs and charts, and record their interpretations of their data. These pages include questions and advice to prompt students to notice and record relevant phenomena in their investigations and their readings and engage in productive reasoning. They also provide students with suggestions how to design procedures for investigations and design tests.

Students record the information they gather as they read about communicable diseases throughout the Good Friends and Germs unit.

In Ever-changing Earth, students use a separate Project Board page to organize information as they read about and investigate the region assigned to their group.

Air Quality, pg. AQ 114. Students use a Sickening Sick page to take notes as they listen to a play.

In Vehicles in Motion, pg. VIM 32, students design a performance-test procedure for their coaster car.

These special-purpose pages and student-edition instructions make use of different reading strategies. For example, Air Quality, Section 3.1, shown above left, suggests that students use the “re-read the text” reading-comprehension strategy and provides them with a structured way to take notes. The cartoon illustrations of the pollutants also help students’ comprehension.
Students are also encouraged to use concept mapping/graphic organizers. For example, in *Ever-changing Earth*, students iteratively build a picture map as they learn new concepts and new vocabulary throughout the unit.

**Build a Picture Map**

While you began to answer the Big Question, you learned these geologic terms: topographic features, topography, elevation, depth, sea level, longitude, latitude, satellites, topographic maps, and contour lines. You also looked at some of the different representations scientists use to investigate the characteristics of your region—color maps and satellite images.

Record each of the italicized terms on a separate index card, using large letters so that others can see. On the back of each card, draw a picture to represent its geologic term. Make your picture as accurate as possible. Be sure to include features that would help someone else understand the geologic term.

When you have completed each card, share them with your group. Carefully, as someone in your group describes each geologic term, offer your ideas for how the description of each of the geologic terms might improve. Then, lay the cards on the table to show how the ideas connect.

**What is Work?**

When a force acts on an object and the object moves a distance in the direction of the force, scientists say that work has been done. You did work when you pulled the mass straight up. You did work when you pulled the mass up the inclined plane. But you probably be surprised to learn that when you pushed on the heavy bucket and it did not move, scientists would say that you did not do any work. You may have tried hard, but the bucket did not move. According to the scientific definition of work, it does not matter how hard you push or pull on an object if the object does not move; no work has been done.

Science definitions are often different and more exact than the way you use words in everyday conversation. Work is one of those words that has a different meaning scientifically than it does when you use it in everyday conversation. You might talk about "working hard on an assignment" or "working with others to get something done." In everyday terms, that means you tried hard and did things together. From a scientific point of view, there was work being done only if what you were doing was moving something from one place to another.

The inclined plane makes it easier for you to do work. One function of a machine is to help you do work more easily. However, a machine does not change the amount of work that is done. It changes only the...

In general, *PBIS* does not ask students to read science content until after they have experienced the scientific phenomena they are learning about. Reading sections were written keeping in mind what we know about how people construct, revise, and connect mental models. Each takes into account what learners are expected to already know, the misconceptions they might have, and the experiences they have had. Each often has a title in the form of a question that students have already raised and that the reading answers. A reading frequently begins by reminding students about what they already know, what they have experienced, and what they have been wondering about. Then each goes on to provide some detail about the science behind what they experienced. In general, each focuses first on what the students experienced and presents the science behind that phenomenon. Then each helps students consider other situations and what might happen in those situations and why.