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APPENDIX

Practitioner's guide to integrating literacy and science

Our research brief, *Integrating Literacy And Science: A Powerful Partnership For Student Success*, describes four key components of effective integration of literacy and science instruction at the elementary level. In this practitioner's guide, we describe sample lessons to demonstrate each of these components in action in an elementary classroom.

When schools integrate literacy and science instruction, they create rich learning environments that allow students to develop an understanding of science ideas while improving their reading, writing, and speaking skills *at the same time.* Neither subject takes a back seat. Literacy instruction supports science and science instruction supports literacy.

Effective integration of literacy and science instruction relies on four key components:

1. **Authentic literacy tasks and phenomenon-based instruction**—Engaging students with real-world puzzles and authentic reading/writing/speaking opportunities that spark curiosity and drive investigations and learning.

2. **Rich science vocabulary**—Using science texts and discourse to strengthen students' vocabulary, improving comprehension across subjects.

3. **Cumulative, structured learning**—Sequencing lessons to be coherent from the students' perspective, allowing them to build knowledge over time and make meaningful connections between concepts.

4. **Scientific discourse**—Encouraging students to talk, write, and debate scientific ideas, deepening both their scientific understanding and literacy skills.

We provide an extended example of what integrated instruction might look like for elementary students and illustrate how this example brings the four key components of effective literacy and science integration to life.[1]

We use the above icons to flag lesson elements that are closely aligned to our key instructional components, offering concrete guidance for teachers in their application.

Lesson 1: Introducing the phenomenon

Science phenomena are puzzling things that happen in the natural world around us. They are rich opportunities for scientific investigation. Phenomenon-based instruction can be a useful approach for integrating literacy and science instruction. But what might phenomenon-based instruction look like in the classroom? Imagine you want to help students understand disciplinary core ideas related to the Sun's effect on Earth's surface. Your school might have a playground with different surfaces—including blacktop, sand, concrete, and wood chips. Some areas might be shaded, and others in direct sunlight. Depending on your local weather conditions, the school playground might be uncomfortably hot in some areas during certain times of the day or year.

To introduce the phenomenon, consider using an engaging narrative that draws students into the puzzle and sparks their curiosity. A well-crafted story can set the stage for investigation while reinforcing authentic literacy integration (key component 1). We created this reading with a simple ChatGPT prompt. We've included the prompt at the end of the story. We strongly encourage teachers to adapt the prompt to let AI (ChatGPT or your AI tool of choice) revise the story to make it as relevant as possible for your students.

After students read the story, ask a pair of open-ended questions: **Why are some places on the playground so hot in the summer? What can we do to make it more comfortable?**

Allow students who are old enough to write down their initial ideas and questions in a journal. Encourage them to think about both questions. You won't tackle both at the same time, but it's a good idea to forecast where the lesson set is going. As students think about explanations for hot surfaces,

1 The instruction we describe takes place over nine lessons that last approximately 45 minutes each. Depending on your schedule, these lessons could be daily or could take place over a series of weeks. Lessons 1–3 are appropriate for grades K–6. In Lesson 3, the class settles on a key question they want to answer. We sketched out a possible set of lessons based on a question that is grade-appropriate for older students, making Lessons 4–9 most appropriate for students in grades 3–6.

they might come up with solutions; and as students think about solutions, it might help them consider explanations.

Then ask each student to share at least one idea or question with the class. It's good practice to write students' initial ideas and questions on a piece of chart paper that remains visible throughout the unit. Be sure to include room for students' questions related to the phenomenon. If you write students' questions on sticky notes, you can cluster and sort them on the chart paper. Don't skip the literacy opportunities! This is a chance to integrate authentic speaking, listening, and writing with phenomenon-based science instruction (key component 1).

This is also a great time to have students write about and share related phenomena. Ask students to name other places that might get too hot for people when they are outside on a sunny day. Have they ever been in the same place on the playground when it wasn't hot? Listen for student ideas. Sample student ideas might include a baseball field, the beach, the highway for people doing road construction work, or even a farm. Accept and put all reasonable responses on the chart paper.

Ask students to make a sketch in their journals to illustrate and explain their initial ideas about *why* the playground is hotter in some places than others. Ask several students to share their initial models. From these student ideas, sketch an initial consensus model and include it on a piece of chart paper at the front of the class. It's OK if this initial model is inaccurate and/or incomplete. As the lessons progress, you will refine the model.

At the end of the lesson, share with the students that there are a lot of ideas and a lot of questions. Let students know they will spend some time in the next lesson making observations on the playground. Their observations will help them narrow down the specific question they want to answer.

Throughout this appendix, you'll find prompts that help students connect past lessons to the current day's activities and preview what comes next— ensuring they see how each step builds toward explaining the phenomenon. This guidance is in line with key component 3: providing instruction that is sustained, sequenced, and structured—ensuring students see the connections from day to day.

Lesson 2: Making observations

At the start of the second lesson, revisit students' ideas and questions related to why the playground was hotter in some places and cooler in others. This can involve reviewing notes on the chart paper or asking students to review and share something they noted in their journals from the previous lesson. Let students know they will get the chance to make their own observations in the lesson to try to answer the focal questions.

Have students go outside and make observations. Ask them to look for patterns in their observations. They should be trying to narrow down the original focal question to something that is easy to test. Students can make observations of the playground by simply using their hands to touch different surfaces, or if available, use infrared thermometers. Students should have their journals with them to record their observations (key component 1—authentic writing). Younger students might use drawings to support their writing. Encourage students to write their observations in complete sentences using appropriate punctuation. You may want to give students sentence starters such as "we noticed…" or "we observed…." For example, "*We noticed that the blacktop was hotter than the concrete*." or "*We observed that it was cooler in the shade than in the sunlight*."

At the end of the lesson, make sure you reinforce the idea that students gathered important information to help them figure out why the playground is hotter in some places than others. Let them know that in the next lesson they will discuss their observations and try to narrow down their question.

Lesson 3: Reporting observations

Remind students that they gathered important information from the playground in the previous lesson and ask them to share their observations with the class. Record their observations on the phenomenon chart. Students will likely also have more questions. For example, students might ask, "Why is it cooler in the shade than in full sun?" or "Why is the blacktop hotter than the concrete?" Depending on your state's standards, some questions may be better suited for younger students, while others may align more closely with upper elementary expectations. For example, younger students might explore why shaded areas feel cooler than those in direct sunlight, while older students might investigate how different colors of materials affect temperature. Consider your state's standards when selecting the focus question for your students.

Engage students in a discussion about how they might revise their classroom model explaining why some parts of the playground feel hotter than others. Changes to the model might include details that were missing from the original model (objects that produce shade, different color surfaces, etc.). If students bring up ideas, either using technical terms or alluding to technical terms (for example, a student mentions light "bouncing off objects"), then use the discussion to introduce and define vocabulary as the need for the words arises. For example, students could learn the definitions of words such as 'absorb' or 'reflect' and practice using these words as they discuss and suggest revisions to the classroom model. It's important to introduce words as the need arises, rather than introducing words without need or context.

Sharing observations and participating in a classroom discussion about those observations aligns with key component 4: engage students in scientific discourse.

Imagine you are working with a group of fourth-graders, and they noticed that the blacktop is hotter than the concrete on their playground. Students might wonder if this has more to do with the color of the surfaces or the materials. Give students a new question to help them focus their investigation: "If two surfaces are made of the same material, does their temperature in the sunlight depend on color?" At the end of the lesson, guide students in refining a narrow, testable question that aligns with their learning goals and can be investigated through observation and experimentation. You might even encourage students to write a hypothesis for their question based on their prior knowledge or experiences—reinforcing the practices of science and scientific discourse. Let students know that they will design their investigation to answer the question in the next lesson.

Lesson 4: Designing an experiment to answer a question

Remind students of the specific research question they identified in the previous lesson in service of helping them understand why the playground is hotter in some places than others. Students are naturally creative problem-solvers. Given the chance to think for themselves, they are fully capable of designing simple experiments to answer scientific questions. Best of all, allowing students the freedom to design a simple science experiment creates a rich opportunity for students to engage in authentic writing—a natural opportunity to integrate literacy with science instruction (key component 1).

Building off the question from the previous day (If two surfaces are made of the same material, does their temperature in the sunlight depend on color?), provide students with some materials that might limit the scope of their experiment (e.g., different colors of poster board, infrared thermometers, and duct tape. To make it simpler, you might choose to use just white and black poster board. If you have a lot of rain in your area, you might want to also include heat lamps in your materials so students can conduct their experiments indoors.)

Then ask students to design an experiment to help them answer the question, using the materials provided. They may work in groups for this task. Not every group will have identical procedures—and that's OK. The goal is to get students to write a procedure for the experiment. Encourage them to include a plan for how they will record data. Will they need a table? If so, what will the table look like? What values will they record?

Additional integration of literacy instruction

This is a great opportunity to introduce imperative sentences to students. Provide some examples and encourage students to write their procedures using imperative sentences. For example, a student might write, "Measure and cut one black square and one white square. Be sure the squares are the same size." It might help students understand the different styles of writing by asking them to think about how they might write differently if they were writing a story instead of a scientific procedure.

Depending on time, you might have groups read and review one another's procedures, making comments or posing questions on sticky notes. Reviewing the writing of other students is an excellent way to help students improve their own reading and writing (key component 1—authentic writing).

At the end of the lesson, remind students that they are trying to figure out why some areas of the playground are hotter than others. They have designed some experiments to test if color makes a difference; in the next lesson they will conduct their experiments.

Lesson 5: Gathering more information—Conducting experiments

At the start of the next lesson, remind students of the big-picture question (why is the playground hotter in some places than others?) and that they designed some experiments to see if the color of surfaces makes a difference.

When students have completed their experimental procedures (and you have had a chance to check them all for safety concerns), it's time to let students carry out their experiment. Give students a reasonable time limit (say, 45 minutes), and be available to answer questions if they get stuck. It's important to respect students' intellectual curiosity and allow them to carry out their own experiments as they see fit. Encourage students to take detailed notes throughout their experiment, recording their observations, procedures, and any unexpected results. Encouraging them to document their thinking—what worked, what didn't, and why—reinforces their engagement in the practices of science as well as strong literacy practices. The big science ideas **will** emerge in the class discussion. Not every group has to get the "right answer" immediately. In fact, if you have some disagreement on results, it creates even more opportunities for students to engage in scientific discourse (key component 4). See the section, "Sharing data, findings patterns, and developing consensus" for an illustration of how to leverage disagreement to support literacy instruction.

At the end of the lesson, congratulate students on collecting valuable new information, and let them know they will share their data with the class in the next lesson.

Lesson 6: Sharing data, finding patterns, and developing consensus

At the start of the lesson, remind students that they are trying to figure out why some areas of the playground are hotter than others. Also remind them that they gathered new data to see if the color of a surface makes a difference. They will share their data, look for patterns, and work together as a class to come to consensus on what they found.

Each group of students should share their findings about the focus question with the class. Recall that all students should be answering the same question, even if their methods varied. Record key data on the chart to facilitate discussion. This is a perfect place to encourage the use of rich, scientific vocabulary (key component 2). For example, if a student uses a word like “absorb” or “reflect,” be sure to include it on the chart. You might even ask a student what they mean by a given word. That said, don’t jump into a full explanation of the phenomenon at this stage—doing so would undercut the opportunity for students to engage in further scientific discourse. Students may have contradictory data.

Once each group has reported their data, look for patterns. How many groups found the light color to be hotter? How many found the dark color to be hotter? Were there any groups that found no difference? Ask questions of each group about their methods. Don’t lecture students on which methods were good or bad, simply note them and allow students to reason about each set of data.

Highlighting different data from different groups creates an opportunity for discourse. Encourage students to engage in scientific argumentation. It might sound something like this, **Student A**: “Group 2 found that black is hotter than white, and Group 1 found no difference. I agree with Group 2 because they let their posterboard sit in the sunlight longer than Group 1 did.” **Student B**: “I agree with Group 3 and Group 2 that darker colors get hotter than lighter colors because when I wear a black shirt outside in the summer, I get really hot.”

Encourage students to write down their answers to the research question (If two surfaces are made of the same material, does their temperature in the sunlight depend on color?) based on their own evidence and that of their peers. They should also write why they agree with some groups’ findings and disagree with other groups’ findings. There may remain some disagreement at this stage (key component 1: authentic writing; key component 3: leverage rich vocabulary of science; and key component 4: engage students in scientific discourse).

In reading or writing persuasive text, students must often evaluate evidence—reflecting on the quality of the evidence and how well it supports a given claim. A common practice in science classrooms is to write claims using a “claim, evidence, reasoning” framework. Teachers might initially scaffold this kind of writing by giving students a template: “My claim is _______________. The evidence that supports my claim is ____________. I believe my evidence supports my claim because _____________.” By purposefully creating space for disagreements in the science classroom and encouraging students to reflect on claims and the evidence behind the claims, they gain an important opportunity to practice a skill that will carry over into reading and writing outside of science.

As a class, identify any remaining disagreements. Note that students may have figured out that darker colors get hotter in the sunlight than lighter colors, but they may not yet understand *why*. Getting to why will be a focus of the next lesson.

At the end of the lesson, emphasize that they may still have some disagreements. Highlight those differences and let students know that in the next lesson they will do some reading to find out more information to help them settle their differences.

Lesson 7: Reading with a need to know

At the start of the lesson, remind students of their specific research question (If two surfaces are made of the same material, does their temperature in the sunlight depend on color?) and how it relates to the larger question of why the playground may be hotter in some places than others. Also remind them of their disagreements in the findings. Let them know that you found some information to read that might help them answer the question.

When students have different results in their experiments, they will be motivated to read because they have a genuine "need to know." Provide students with age-appropriate reading materials related to the question. These might include short articles found online, trade books, or even excerpts from a textbook. As students read, encourage them to write down unfamiliar vocabulary words to a growing word list in the back of their notebooks (key component 2: leverage rich vocabulary of science texts). Discuss the meaning of new terms as a class. It's a good idea for students to write definitions of new vocabulary terms on their word list in their own words and using sketches if necessary. Students who are emergent multilinguals might even write their personal definitions in their language of choice.

Students might read about how dark colors absorb more energy from the Sun than light colors because light colors reflect the Sun's energy while darker colors absorb the Sun's energy. They might even follow up with a news article about how engineers are trying to make playgrounds more comfortable for students year-round, or even design their own playgrounds to apply what they have learned (key component 1: authentic reading).

Remind students that they were trying to answer a small question related to a larger one: Why are some places on the playground hotter than others? Emphasize that they have gathered more information to help them answer that question. Remind them of the new vocabulary terms they have identified. In the next lesson, tell them they will revise their explanations in their journals and will revise the classroom model. They will then use the revised classroom model to explain or predict related phenomena.

Lesson 8: Revise conclusions and explain related phenomena

At this point in the series of lessons, students should have a strong understanding that dark colors absorb energy from the Sun, while light colors reflect that energy. This makes light colors cooler than dark colors after they sit in the sunlight for a while.

Have a group discussion and ask students to share their new thinking, *using new vocabulary words gained from the reading*. Be sure to write a class consensus answer on the chart paper that holds students' comments and questions. The class consensus answer should include key vocabulary words identified in the readings.

Then turn to the class consensus model. Ask students to suggest changes to the model. The final consensus model should now include some kind of representation of light from the Sun falling on surfaces of different colors. The representation should indicate that sunlight can transfer energy to objects. It should also show that the sunlight reflects off light-colored objects but is absorbed by dark-colored ones. Include short captions on the classroom consensus model to clarify what the images mean.

Ask students to use the classroom consensus model to explain or predict related phenomena (e.g., why is it so hot to do construction work on the highway in the middle of the summer?). Remind them that they brainstormed related phenomena in the first lesson. Students can choose from the classroom list of related phenomena or pick a new one. In their journals, they should use the model, including pictures and words, to explain the related phenomenon (key component 1: authentic writing).

At the end of the lesson, congratulate students on figuring out that sunlight transfers energy to objects; light-colored surfaces reflect energy from sunlight, and dark surfaces absorb that energy. Let them know that in the next lesson they will work to propose solutions for making the playground more comfortable.

Lesson 9: Extension—Engineering solutions

Depending on the time you have available for this series of lessons, you may want to allow students to design their own solutions for making a cooler playground. These activities would help students answer the second question that introduced the phenomenon: Why are some places on the playground so hot in the summer? and **What can we do to make them more comfortable?**

Students should begin their designs by making a design claim supported by evidence from their previous investigations. They should use the claim, evidence, reasoning framework when they propose their design solutions (key component 1: authentic writing). Be sure students apply their classroom consensus model as well. The resulting product should include a combination of written description and explanation alongside illustrations. An ideal response would include the following elements:

- A claim about how they think their solution will reduce the surface temperature of a specific location on the playground
- Evidence from their experiments in support of their claim
- Scientific reasoning in support of the claim (this is where the consensus model comes into play)
- A persuasive conclusion, explaining why their recommendation should be implemented

If time allows, have students share their designs with the class. Students should be encouraged to ask clarifying questions of their peers.

Students could simply design their new playground spaces in drawings and text or could build models of a playground. The task is easily adaptable to expand to take more or less time, depending on your needs. Be sure to continually integrate literacy instruction and opportunities for reading and writing throughout the process to ensure accelerated learning in both literacy and science.

Summary—How the sample lessons apply the key components

Situating learning within real-world experiences and the simultaneous application of literacy and science opportunities can result in greater learning in both areas than if either were taught separately or outside of an authentic experience. This sample set of lessons illustrates the application of our four key components. We summarize how each key component was put into action in the following paragraphs.

Key component 1: Use phenomenon-based instruction to support engagement in authentic reading, writing, and science activity.

Effective integrated literacy/science instruction begins with a puzzling, everyday scientific phenomenon as a motivating context. Authentic reading, writing, and discursive activities help students explain the science phenomenon in question.

A good phenomenon is at the heart of authentic integration of literacy and science in the classroom. In this set of lessons, we chose a phenomenon (that some places on a playground feel hotter than others) that could be explained if students mastered our focal science concepts. It is flexible enough for use with K–2 students (with an emphasis on the concept of shade/no shade) or older students (with an emphasis on how white/black surfaces absorb energy differently). Notice that the entire set of lessons are driven by the single phenomenon.

Key component 2: Leverage the rich vocabulary of science to enhance reading comprehension across domains.

Science books, including texts, trade books, and journals, offer a rich opportunity for students to develop stronger vocabularies that support learning across subjects.

When students were reading about the relationship between color and temperature, they had the opportunity to write down key vocabulary words and use those words in their final explanations. The puzzling phenomenon motivated students to learn, and the acquisition and application of new vocabulary in explaining the puzzling phenomenon will enhance students' reading comprehension going forward.

Key component 3: Provide instruction that is sustained, sequenced, and structured—ensuring students see the connections. Ensure students recognize key conceptual connections from day to day.

When instruction builds from day to day, students develop the context for incorporating new ideas with old ones. Students don't learn science facts in isolation, they develop ideas that build as part of a storyline to explain a phenomenon.

Notice that linking the entire series of lessons to a single phenomenon allows students to understand what they did yesterday, what they need to do today to move forward in answering their question, and how what they learned today motivates what they need to learn tomorrow.

Key component 4: Engage students in scientific discourse.

Talking about scientific evidence, in favor or against possible explanations of scientific phenomenon, can support students' scientific understanding and improve literacy.

Creating space for different research designs and different findings allows space for scientific discourse. Students benefit immensely from hearing different perspectives and different types of evidence, leading them to confirm or reject their own findings based on what they hear from other students. In writing their final explanations, rebutting some evidence and accepting others, students engage in a sophisticated literary task—one that will help them analyze persuasive texts in future lessons.

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