Research base

Strengthening Reading and Improving Science Learning: The Benefits of Science and Literacy Integration

Rebecca Abbott and Suzanna Loper

Center for K–12 Science, The Lawrence Hall of Science, University of California, Berkeley

Amplify.

Introduction

High-quality science instruction has never been more critical. Engaging students in science beginning in kindergarten, or even earlier, lays a foundation for deep science learning throughout childrens' school careers and supports them in becoming classroom problem-solvers and real-world solution seekers. Our future generations will be responsible for making decisions about issues in which science understanding plays a fundamental role. From addressing realities of a global pandemic, to needing climate-related solutions, to being a critical consumer of science-related news stories, one thing is certain: high-quality, equitable science education for all students is essential if we are to grow the next generation of science innovators and evidence-based thinkers that we so clearly need.

But literacy instruction is also critical in school, and perhaps more all-encompassing, because reading and literacy are so fundamental to a broad range of endeavors. The vision for literacy instruction represented in multiple English Language Arts (ELA) standards across the U.S. includes having students be critical thinkers and discerning readers who are equipped to make well-informed decisions about their personal and professional lives given the vast quantity of information available to them. The goal of reading, writing, listening, and speaking in school is to build knowledge about the world, in multiple disciplines, and to engage in reasoning skills that are needed to be an informed, engaged part of society.

So how do we meet the essential need to support learning in both science and literacy? Education research plays a role in informing educators about best practices in teaching and learning; research studies point us to effective methods for instructional approaches by providing evidence of student learning. In literacy, particularly in reading instruction, educators have been embracing the Science of Reading, or the body of evidence about how people learn to read, and how reading should be taught. Another body of literacy-based research, *disciplinary literacy*, provides an evidence base for instructional approaches that support how students develop language and literacy across subject areas. And finally, we can look to the National Research Council's *Framework for K–12 Science Education* (2012), which lays out a research-based vision for 21st century science teaching and learning.

This paper explores the connections between all three bodies of research—the Science of Reading, disciplinary literacy, and the research on science learning represented in the Framework—and discusses the synergies between the goals of literacy instruction and the goals of science instruction. It will highlight how teaching science in a way that authentically integrates literacy has the potential to boost student reading and improve science instruction, by capitalizing on the mutually supportive aspects of both subjects.

Language comprehension in the Science of Reading

The science of reading refers to a body of research highlighting effective pedagogy and practices about teaching children how to read. The Simple View of Reading and Scarborough's Rope are two frameworks used to describe the complex, years-long process behind becoming a skilled and strategic reader.

The Simple View of Reading (Gough & Turner, 1986) describes how proficient reading requires two main components: Word recognition (or decoding) and language comprehension (oral language skills). The Reading Rope (Scarborough, 2001) further deconstructs the two parts of the Simple View of Reading, decoding and language comprehension, into sub-skills or strands. This model illustrates how the aim of reading instruction is for students to be able to weave together these strands to become increasingly systematic and automatic in their reading. The Reading Rope model emphasizes the need for a comprehensive, deliberate approach to reading instruction and helps us recognize that reading is not a singular skill, but rather a set of interwoven processes (Reading Rockets, 2023). While there has been much attention paid in the field to decoding and word recognition, particularly in the form of phonics instruction in the early grades, researchers argue that language comprehension is an equally critical component of reading (e.g. Silverman, Johnson, Keane, & Khanna, 2020; Cervetti, Pearson, Palincsar, Afflerbach, Kendeou, Biancarosa, Higgs, Fitzgerald & Berman, 2020).

The language comprehension strand of the Reading Rope represents how people make meaning of oral and written language, including skills required for reading comprehension. According to the Science of Reading, this involves students weaving together the skills of background knowledge, vocabulary, language structures, verbal reasoning, and literacy knowledge. As these strands are taught and practiced, readers become increasingly more strategic in their reading—actively engaging with text, asking questions, making connections and predictions, and monitoring understanding (Reading Rockets, 2023).

Disciplinary literacy

A separate, but related, body of research is work in the area of *disciplinary literacy*. Literacy researchers have observed that there are specialized literacy skills in different disciplines: scientists, historians, mathematicians and novelists use language in very different ways (Shanahan & Shanahan, 2008). Therefore, reading a science journal article involves different skills and strategies than reading a mathematical proof, a historical argument, or a work of literature. Disciplinary literacy experts argue that reading instruction needs to go beyond general-purpose reading strategies to include guidance in discipline-specific reading, writing, and speaking, and that literacy instruction must continue beyond the primary grades (Snow and Moje, 2010). This perspective is reflected in the organization of the Common Core State Standards (Hillman, 2014; Zygouris-Coe, 2012), made explicitly visible in the full title: English Language Arts & Literacy in History/Social Studies, Science, and Technical Subjects.

Disciplinary literacy researchers have expanded the view of what it means to be a sophisticated reader beyond basic literacy (decoding and word recognition) and intermediate literacy (generalized reading comprehension) to include these discipline-specific skills and specialized strategies. Much of the research on disciplinary literacy has focused on adolescent literacy, but disciplinary literacy approaches have also been identified as important with elementary students (Cervetti & Pearson, 2012). An integration of the concept of disciplinary literacy with some of the fundamental concepts from the Science of Reading research can be imagined by elaborating the components of the Language Comprehension strands in the Reading Rope (Scarborough, 2001) to be discipline-specific (Lawrence, 2021). For example, the type of reasoning used in reading a science text is very different than that used in reading a novel. (See Figure 1).

> "Disciplinary literacy experts argue that reading instruction needs to go beyond general-purpose reading strategies to include guidance in discipline-specific reading, writing, and speaking, and that literacy instruction must continue beyond the primary grades"

Language comprehension in science

A. Knowledge

- Experience with real-world phenomena
- Disciplinary core ideas used to explain phenomena

B. Vocabulary

Active control over domain-specific and generalizable vocabulary used to understand and communicate science ideas

C. Sentences

Using and understanding language structures in explanations and arguments about phenomena based on scientific ideas

D. Reasoning

Engaging in argumentation to compare and evaluate competing ideas based on evidence

E. Mental model

Developing and revising mental models of scientific phenomena based on information from text, diagrams, and experiences

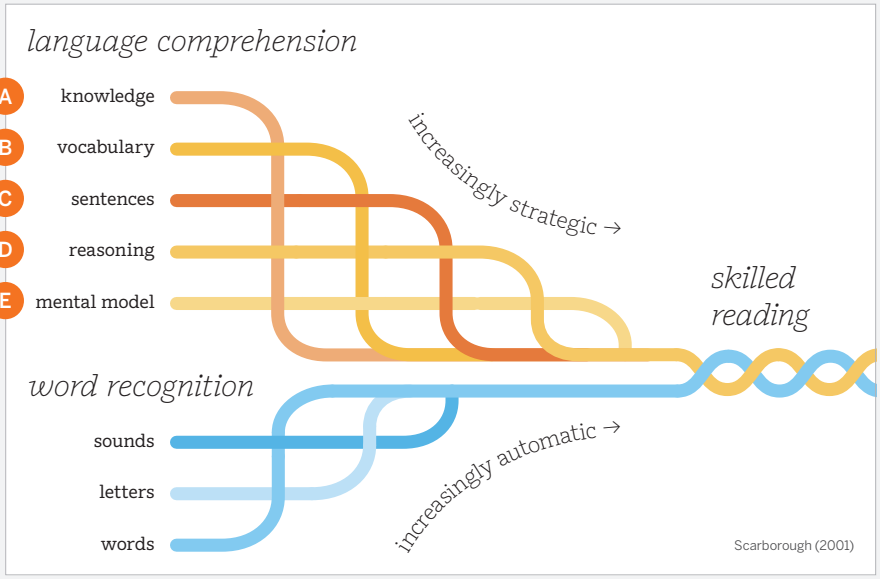


Figure 1: The Reading Rope and language comprehension in science
(adapted from Lawrence, 2021, National Research Council, 2012, & Scarborough, 2001)

Reading in different disciplines places different demands on the reader. Considering the disciplinary-specific aspects of language comprehension can help better understand what is necessary for skilled readers to develop within a specific content area such as science.

A new view of science

When we integrate disciplinary literacy concepts with the Reading Rope as depicted in Figure 1, it provides a model of how a student becomes a skilled reader in the discipline of science, but what is missing from this model is the how and why: what are students doing to acquire the components of language comprehension, and what motivates them to do it? The shifts in science education represented by the Framework for K–12 Science (National Research Council, 2012) help answer these questions, by proposing a model of science learning that involves *figuring out phenomena* by engaging in science practices.

A key element of the Framework's vision is that science knowledge–facts and concepts, or *disciplinary core ideas* as they are named in the Framework–is not acquired for knowledge' sake, but for the purpose of figuring out and explaining phenomena that we observe in the world. For example, rather than memorizing the names of different types of clouds or reciting the steps in the water cycle, students should be using an understanding of the water cycle and cloud formation to explain a phenomenon such as the fact that storms of different strengths form under different conditions.

A second key element of the Framework's vision is a focus on Science and Engineering Practice (SEPs). The idea of *practices* goes beyond more narrow definitions of inquiry skills that existed in previous national standards (National Research Council, 1996), in order to "stress that engaging in scientific inquiry requires coordination of both knowledge and skill simultaneously." (National Research Council, 2012, p. 41). The SEPs are what students are doing as they figure out the Disciplinary Core Ideas and use them to explain phenomena. The Framework defines the following eight SEPs:

1. Asking questions (for science) and defining problems (for engineering)
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations (for science) and designing solutions (for engineering)
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

In a closer examination of the eight SEPs, it might seem clear that practices 6, 7, and 8 are particularly suited to having students develop language as they read, write, listen, and speak about science. However, engaging in any of these SEPs are opportunities to use and practice the disciplinary literacy represented by the elements of the science-specific Reading Rope. For example, when students engage in argument from evidence they learn and practice key oral and written language structures and practice verbal

reasoning as they evaluate how well evidence supports a claim. Or, students might be asking questions as they investigate with text and make sense of what they read. The overlap between these SEPs and the practices of literacy (as well as math) is represented in Figure 2 below. Thus, literacy practices are essential for engaging in scientific thinking.

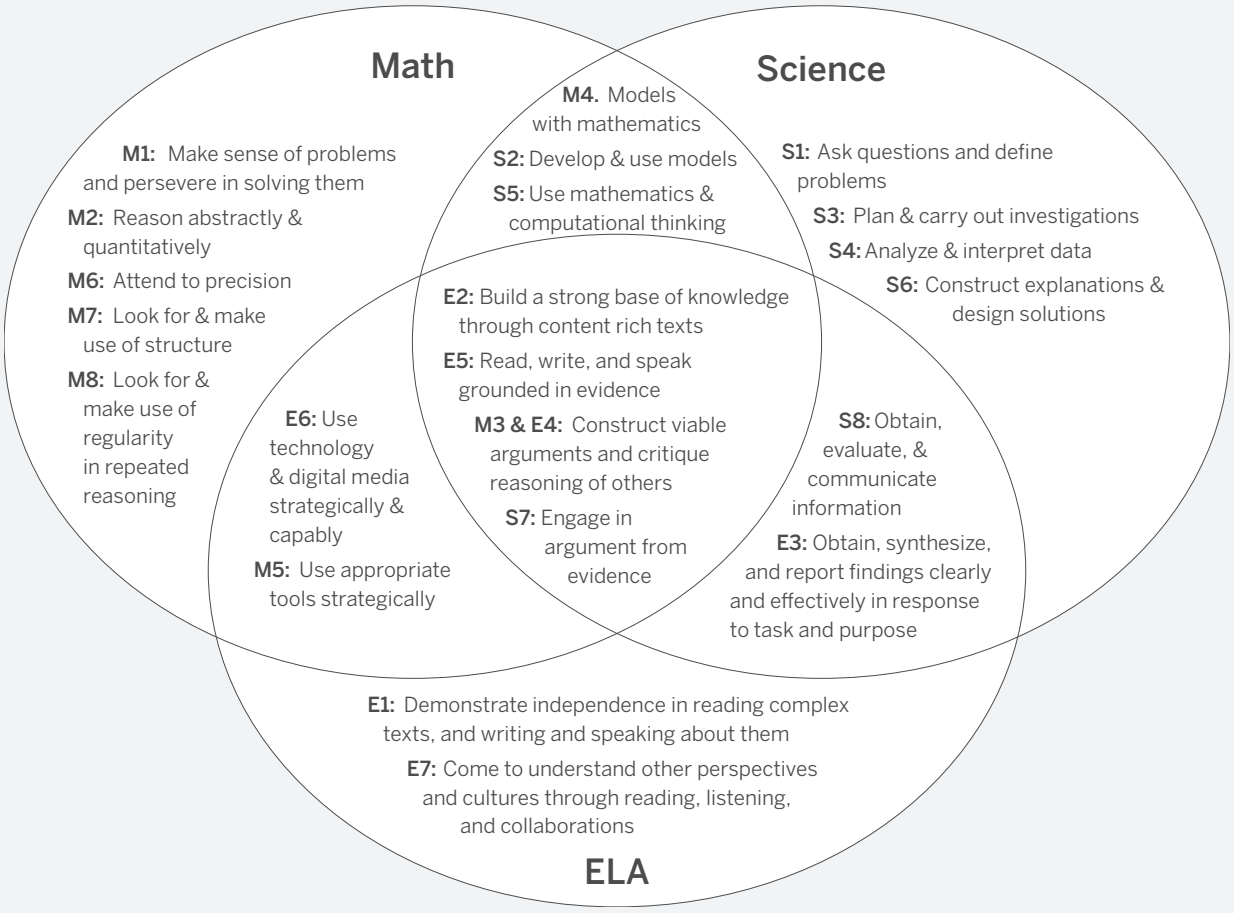


Figure 2: Relations and convergences in literacy, math, and science and engineering practices (Stage, Asturia, Cheuk, Daro & Hampton, 2013)

In sum, the current vision of science learning, represented by the Framework, is well aligned with the research underlying both the Science of Reading and disciplinary literacy. What, then, are the benefits of the alignment between science and literacy, and how can educators capitalize on this alignment in their classrooms?

Putting it together: Benefits to an integrated approach

An integrated approach to science and literacy—one in which literacy instruction is authentically situated in a science context—allows educators to capitalize on the alignment between the two subjects. There are several benefits to engaging in an integrated approach: (1) it builds stronger readers, (2) it builds better scientists, and (3) it provides an authentic purpose for engaging in reading, as well as in writing and oral literacy practices.

Building stronger readers

One of the primary goals for reading instruction is to support students in being able to read and comprehend a wide range of informational texts. This means students go beyond simply finding information in text and should increasingly be able to analyze, integrate, and critique ideas and information in what they read (NAEP, 2008). The complexity of these texts should increase as students progress through the grades in order to ensure students are able to meet the expectations for college- and career-level reading by the end of grade 12 (Adams, 2009). This is a critical issue in reading instruction because the impact of exposure to too-low levels of reading material throughout a student's schooling career can contribute to later difficulties in reading and to a widened equity gap (TNTP, 2018).

An integrated approach can provide support for reading and comprehending complex text by building students' background knowledge, an essential component of reading comprehension. (Smith, Snow, Serry & Hammond, 2021). How much readers understand about the text's topic before they read is a major factor in how much they understand while and after they read it (Cervetti and Wright, 2020). However, developing background knowledge goes beyond memorization or accumulation of facts; rather knowledge should be accumulated over time to ensure a level of depth that allows for a critical analysis of the subject matter (Catts, 2021).

During science instruction, students can be provided these kinds of sustained opportunities to build deep background knowledge as they investigate questions to figure out phenomena. Engaging in multiple modalities—doing science investigations, reading books, having discussions, visualizing ideas, and writing—provides students with various opportunities to gather and make sense of evidence to explain phenomena. Notably, students can build knowledge not only from science texts, but from all of these modalities; and doing so reinforces their ability to learn from science texts. This deep learning helps students access complex content in texts that might otherwise be difficult to grasp. Additionally, using informational text in the context of science offers opportunities to develop discipline-specific yet generalizable reading comprehension strategies that are supported by the Science of Reading research—strategies such as summarizing, making inferences, and making predictions.

Furthermore, literacy-rich science learning is synergistic with other aspects of the language comprehension strands of the Reading Rope:

- Gaining active control over **vocabulary** plays a key role in comprehension, where being able to read, write, and speak using words such as *molecule*, *environment*, *evidence*, and *data* fluently and accurately, and to have a deep and nuanced understanding of what these words mean in context. This kind of vocabulary learning goes beyond simply understanding definitions and allows students to make meaning of written and oral language.
- Engaging with science text and with oral and written arguments and explanations provides opportunities to focus on language at the **sentence** level. For example, students need to recognize and use particular language structures for argumentation, or to explain causes and effects.
- Students focus on verbal **reasoning**—they need to be able to recognize and use particular language for argumentation so they can support claims with evidence.
- Students develop and refine **mental models** as they gather ideas and evidence from books, articles, tables, visual representations and other sources of information.

Building stronger scientists

Just as much as a science context can help meet essential reading goals, engaging in literacy contributes to deeper understanding of science. Science naturally involves language and literacy; scientists gather information, communicate claims, leverage evidence, draw conclusions from data, and share their ideas through oral and written explanations and arguments. A number of research studies have found evidence that integrating literacy and science can result in deeper science learning (Cervetti, Barber, Dorph, Pearson & Goldschmidt, 2012; Harris, Murphy, Feng & Rutstein, 2023; Romance & Vitale, 1992).

In an effective integrated approach, well-aligned, grade level science texts can provide information, evidence, and support for investigations. For example, if students are investigating a phenomena about a mag-lev train that hovers over tracks, they might explore and investigate magnets to see if what they observe provides any insight into how something could float. In an effective integrated approach, these investigations might be paired with reading a carefully written book or article that includes diagrams and key vocabulary related to forces. In subsequent sensemaking discussions about the text and the investigation, students would use those vocabulary words, and draw diagrams to figure out some key ideas about magnets and magnetic force, be able to explain new understandings, and apply them back to an explanation of how the train works.

As they deepen understanding over time, and work to provide a more thorough explanation of a phenomena, an integrated approach should allow students to have a number of opportunities to engage with complex text and to discuss ideas in student-to-student conversations. In other words, engaging with literacy in science is mutually supportive—it builds students' capacity to read strategically while simultaneously building their understanding of science content.

Providing an authentic purpose to engage in reading (and writing and speaking)

Finally, situating literacy in a content area like science provides an authentic purpose for reading, as well as for speaking, listening and writing—to better understand the natural world. The Framework and NGSS emphasize a phenomena-based approach, one in which students engage in the Science and Engineering Practices to figure out why and how things occur in our everyday lives, or in the larger world. Phenomena are the things that get scientists and the rest of us curious and asking questions, things which we can use our scientific knowledge to explain and predict.

Phenomena are a natural way to engage students in asking real questions about the world, and provide opportunities to make connections to their own experiences and to scientific phenomena in their everyday lives and in their community (Rebora, 2023). Language is a fundamental aspect in these investigations, because students gather and make sense of ideas from books, from visuals, from discussions—not just for reading and writings' sake, but rather in service of a purpose, to figure out and communicate their ideas about real-world phenomena.

> "...engaging with literacy in science is mutually supportive—it builds students' capacity to read strategically while simultaneously building their understanding of science content."

Conclusion

Educators need evidence-based instructional practices to support deep and equitable learning. The alignment between three bodies of educational research—the Science of Reading, disciplinary literacy, and the research underlying the *Framework for K–12 Science*—offers a promising basis for effective instruction that promotes both literacy and science development. Authentic integration of literacy with science allows students to build knowledge that makes them stronger readers, while developing disciplinary literacy skills that make them better scientists. As a side-benefit, integration can help science fit into the instructional day, which is a high priority in elementary classrooms (NAESM, 2021). Integrating literacy instruction in a discipline-specific context also benefits students more broadly, helping them to "grow brain power," as noted by Zaretta Hammond, "because it's about nuance, word consciousness, and building knowledge" (Rebora, 2023). Science-literacy integration thus holds the promise to create powerful readers, scientists, and learners.

References

Adams, M. J. (2009). The challenge of advanced texts: The interdependence of reading and learning. In E. H. Hiebert (Ed.), Reading more, reading better: Are American students reading enough of the right stuff? (pp. 163–189). New York, NY: Guilford.

Catts, H. (2021) Rethinking How to Promote Reading Comprehension. *American Educator*, Winter 2021–2022

Cervetti, G. N., Barber, J., Dorph, R., Pearson, P. D., & Goldschmidt, P. G. (2012). The impact of an integrated approach to science and literacy in elementary school classrooms. *Journal of Research in Science Teaching*, 49(5), 631–658.

Cervetti, G., & Pearson, P. (2012). Reading, writing, and thinking like a scientist. *Journal of Adolescent & Adult Literacy*, 55(7), 580–586.

Cervetti, G. N., Pearson, P. D., Palincsar, A. S., Afflerbach, P., Kendeou, P., Biancarosa, G., Higgs, J., Fitzgerald, M.S. & Berman, A. I. (2020). How the reading for understanding initiative's research complicates the simple view of reading invoked in the science of reading. *Reading Research Quarterly*, 55, S161-S172.

Cervetti, G. N., & Wright, T. S. (2020). The role of knowledge in understanding and learning from text. In E.B. Moje, P.P Afflerbach, P. Enciso, & N.K. Lesaux, (Eds). *Handbook of Reading Research, Volume 5* (pp. 237–260).Routledge

Gough, P.B., & Tunmer, W.E. (1986). Decoding, reading, and reading disability. *Remedial and Special Education*, 7(1), 6–10.

Harris, C. J., Murphy, R., Feng, M., & Rutstein, D. (2023). *Supporting science learning and literacy development together: Initial results from a curriculum study in 1st grade classrooms.* WestEd.

Hillman, A. M. (2014). A literature review on disciplinary literacy: How do secondary teachers apprentice students into mathematical literacy? *Journal of Adolescent & Adult Literacy*, 57(5), 397–406.

Lawrence, J. (2021). What can the simple view of reading teach us about disciplinary literacy?. *Reading Ways Publications*, 2(4).

National Assessment of Educational Progress (NAEP) *Reading Framework for the 2009 National Assessment of Educational Progress*. U.S. Department of Education, National Assessment Governing Board, 2008.

National Governors Association Center for Best Practices and Council of Chief State School Officers (2010). *Common Core State Standards for English Language Arts & Literacy In History/ Social Studies, Science, And Technical Subjects.* NGA Center for Best Practices and CCSSO: Washington D.C.

National Research Council. (1996). *National science education standards.* National Academies Press: Washington, DC.

National Research Council. (2012). *A framework for K–12 Science education: Practices, crosscutting concepts, and core ideas.* National Academies Press: Washington, DC.

National Academies of Sciences, Engineering, and Medicine (2021). *Science and engineering in preschool through elementary grades: The brilliance of children and the strengths of educators.*

Reading Rockets (2023) *Models of Reading*. ReadingRockets.org

Rebora, A (2023). Teaching Word Consciousness: An Interview with Zaretta Hammond. *EL Magazine* ASCD, Vol. 81, No. 4

Romance, N. R., & Vitale, M. R. (1992). A curriculum strategy that expands time for in-depth elementary science instruction by using science-based reading strategies: Effects of a year-long study in grade four. *Journal of Research in Science Teaching*, 29(6), 545–554.

Scarborough, H. S. (2001). Connecting early language and literacy to later reading (dis)abilities: Evidence, theory, and practice. In S. Neuman & D. Dickinson (Eds.), *Handbook for research in early literacy* (pp. 97–110). Guilford Press.

Shanahan, T., & Shanahan, C. (2008). Teaching disciplinary literacy to adolescents: Rethinking content-area literacy. *Harvard Educational Review*, 78(1), 40–59.

Silverman, R. D., Johnson, E., Keane, K., & Khanna, S. (2020). Beyond Decoding: A Meta-Analysis of the Effects of Language Comprehension Interventions on K–5 Students' Language and Literacy Outcomes. *Reading Research Quarterly*, 55(S1), S207–S233.

Smith R., Snow, P., Serry, T. & Hammond, L. (2021): The Role of Background Knowledge in Reading Comprehension: A Critical Review. *Reading Psychology*, 42(3), 214–240.

Snow, C., & Moje, E. (2010). Why is everyone talking about adolescent literacy? *Phi Delta Kappan*, 91(6), 66–69.

Stage, E. K., Asturias, H., Cheuk, T., Daro, P. A., & Hampton, S. B. (2013). Opportunities and challenges in next generation standards. *Science*, 340(6130), 276–277.

TNTP (2018). *The opportunity myth: What students can show us about how school is letting them down—and how to fix it.* Retrieved from: https://opportunitymyth.tntp.org

Zygouris-Coe, V. (2012). Disciplinary literacy and the common core state standards. *Topics in Language Disorders*, 32(1), 35–50.

Visit us online for more information on Amplify's products and services.

amplify.com

Amplify.

The Lawrence Hall of Science
UNIVERSITY OF CALIFORNIA, BERKELEY

Amplify.

Discussion guide

Strengthening Reading and Improving Science Learning: The Benefits of Science and Literacy Integration

As you read the white paper, use this to guide to note key takeaways, exchange ideas, and fuel meaningful discussions with your fellow educators.

Discussion questions	Note catcher
1. Why is science instruction critical to how future generations navigate the real world?	
2. What skills and qualities do the ELA standards in your state help build in your students?	
3. What are some practices you currently have in place to encourage collaboration between science and ELA or literacy teachers? Are there any in-class activities or curriculum (like Amplify Science) that help build transdisciplinary skills and connect these two subjects?	

Discussion questions	Note catcher
4. When thinking about the Science of Reading, specifically the Simple View of Reading and the Reading Rope, what are some key takeaways you find? How can principles here influence or improve science instruction and understanding?	
5. Why is disciplinary literacy important? (Tip: You can use your Reading Rope handout to see examples of the integration between the Science of Reading and disciplinary literacy in science.)	
6. According to the Framework for K–12 Science, why is science knowledge acquired? What are some examples of this (besides the one provided)?	
7. What are the eight SEPs? (Tip: Use page 5 of your handout.)	
8. What are some ways that the SEPs present opportunities to use and practice disciplinary literacy? How do they support language acquisition?	

Discussion questions	Note catcher
9. When looking at Figure 2, what are some interesting things you notice? How could this influence the way you collaborate with math and ELA teams in your school?	
10. What are three benefits to an integrated approach to science and literacy? What are some other benefits you can think of?	
11. Now that you've read the full white paper, what were some of your key takeaways? What do you want to know more about? What are some ideas you have to start finding these connections in the classroom?	

The Reading Rope and language comprehension in science

A. Knowledge

- Experience with real-world phenomena
- Disciplinary core ideas used to explain phenomena

B. Vocabulary

Active control over domain-specific and generalizable vocabulary used to understand and communicate science ideas

C. Sentences

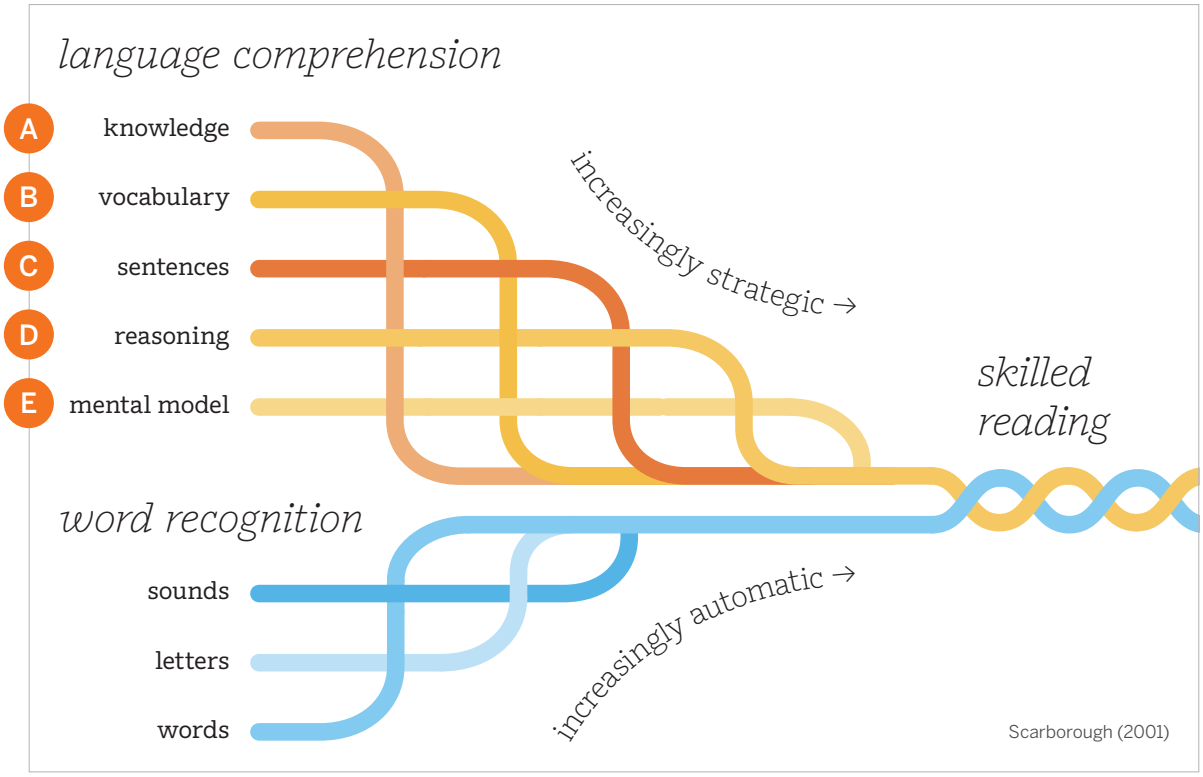
Using and understanding language structures in explanations and arguments about phenomena based on scientific ideas

D. Reasoning

Engaging in argumentation to compare and evaluate competing ideas based on evidence

E. Mental model

Developing and revising mental models of scientific phenomena based on information from text, diagrams, and experiences



Adapted from Lawrence, 2021, National Research Council, 2012, & Scarborough, 2001

Opportunities for building disciplinary literacy

The Reading Rope provides a model of how a student becomes a skilled reader in the discipline of science, but what is missing is the how and why: What are students doing to acquire the components of language comprehension, and what motivates them to do it? The shifts in science education represented by the Framework for K–12 Science help answer these questions, by proposing a model of science learning that involves *figuring out phenomena* by engaging in *science practices*.

These eight Science and Engineering Practices (SEPs) are what students are doing as they figure out Disciplinary Core Ideas and use them to explain phenomena that we observe in the real world. Engaging in any of these SEPs presents opportunities to use and practice the disciplinary literacy represented by the Reading Rope, such as:

1. Asking questions (for science) and defining problems (for engineering).
2. Developing and using models.
3. Planning and carrying out investigations.
4. Analyzing and interpreting data.
5. Using mathematics and computational thinking.
6. Constructing explanations (for science) and designing solutions (for engineering).
7. Engaging in argument from evidence.
8. Obtaining, evaluating, and communicating information.