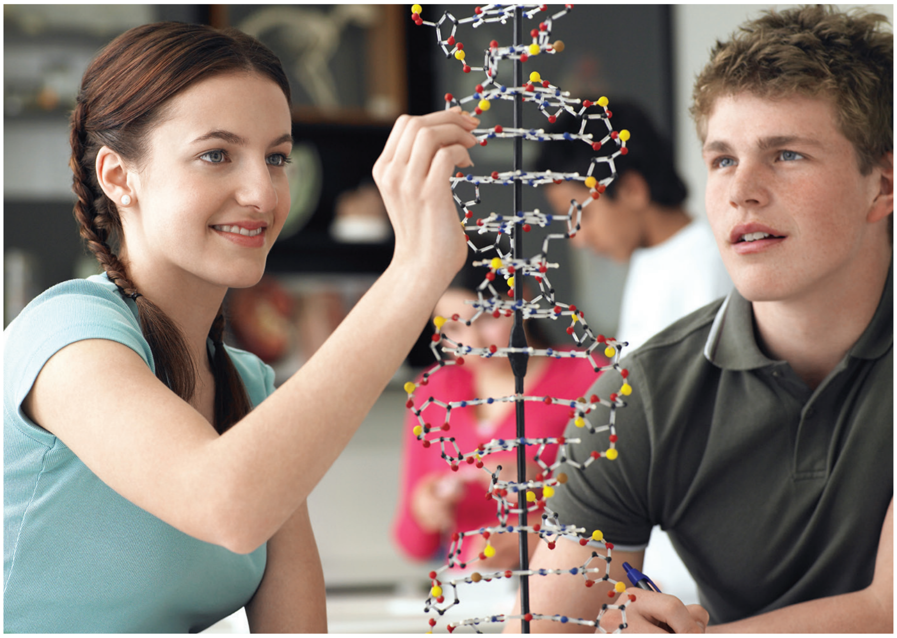

GRADES 6 TO 12

Essential Practices for Literacy Instruction in the Secondary Science Classroom

Deliberate, research-supported efforts to motivate, engage, and and support reading, writing, speaking, listening, and viewing in science

1. Problem-based instruction

Develop and implement interactive, problem-based units of instruction that frame scientific problems and phenomena, as well as engineering problems, to help establish purposes for students to read and write beyond being assigned or expected to do so (e.g. for their enjoyment/interest; to ask and answer questions about the natural and physical world including questions relevant to their communities, health, and lives; to address needs or problems in their community or beyond; and to communicate with a specific audience about science and engineering).

Within these phenomenon or problem-based units, the teacher:

- engages students in asking questions, both practical and theoretical, about the natural and designed world.
- engages students in abstract scientific thinking and reasoning, as well as in iterative design thinking.
- helps students see science and engineering in their everyday lives by reading and engaging in authentic investigations, simulations, and/or engineering design cycles.
- helps students explore scientific theories in order to understand that science can be used to wonder about the world and that such wondering can lead to applications of scientific concepts in the world outside of school.
- creates opportunities for students to enact scientific and literate identities, drawing from both within and outside of school literacy practices (e.g. positions students as science writers and communicators by having them produce educational materials for younger students).
- provides regular opportunities for students to make choices in their reading, writing, and communication.
- offers regular opportunities for students to collaborate with peers in reading, writing, speaking, and listening, such as small-group discussion of texts on questions of interest and opportunities to write within group projects.
- provides scaffolded support to students as needed to assist them in developing their literacy proficiencies, removing supports over time to generate more independence.
- differentiates instructional processes and product expectations to account for varying academic needs and capabilities and appropriately challenge all students.

notes

Gallagher, S. A., Sher, B. T., Stepien, W. J. and Workman, D. (1995). Implementing Problem-Based Learning in Science Classrooms. *School Science and Mathematics*, 95, 136–146.

Kolodner, J.L., Camp, P.J., Crismond, D., et. al. (2003). Problem-based learning meets case-based reasoning in the middle school science classroom: Putting learning by design™ into practice. *Journal of the Learning Sciences 12*(4).

2. Diverse texts and abundant reading opportunities in the school

The teacher:

- engages students in the exploration of compelling phenomena or problems to generate questions and set purpose for the use of texts and other resources in order to make sense of complex ideas.
- provides access and regular opportunities to draw on text to support explanation of phenomena and solution of problems with
  - ❖ a wide range of science and engineering texts of varying complexities and types (i.e. print, audio, visual, and multimodal) including e.g., scientific reports, science related policy documents, research notes, newspaper articles, magazines, journals, data representations, diagrams, infographics, documentary videos, science websites, technical manuals or instructions, etc.
  - ❖ a wide range of science and engineering texts that help students see science and engineering as connected to their lives and interests and that reflect their backgrounds, cultural experiences, and interactions with the natural and designed world.
- engages students with digital and/or online texts, databases, and tools in the service of scientific explanations or engineering design.

notes

O'Reilly, T., & McNamara, D. S. (2007). The impact of science knowledge, reading skill, and reading strategy knowledge on more traditional "high-stakes" measures of high school students' science achievement. *American Educational Research Journal*, *44*(1), 161-196.

Pearson, P. D., Moje, E., & Greenleaf, C. (2010). Literacy and science: Each in the service of the other. *Science*, *328*(5977), 459-463.

Greenleaf, C., Brown, W., & Litman, C. (2004). Apprenticing urban youth to science literacy. *Bridging the gap; Improving literacy learning for preadolescent and adolescent learners in grades 4, 12*, 200-226.

3. Intentional and standards-aligned instruction in disciplinary reading

The teacher:

- establishes compelling reasons for reading in science and/or engineering as related to the phenomenon to be explained or problem to be solved (see recommendation #1 above).
- teaches students to recognize and analyze different purposes and audiences for science and engineering writing.
- Provides opportunities for students to apply disciplinary tools and concepts when working with text.
  - ❖ explicitly names, describes, and models the dispositions, strategies, and patterns of thinking utilized by scientists and engineers.
  - ❖ models* through think-alouds how to ask reasonable scientific questions of texts.
  - ❖ teaches students how to ask testable questions of ideas in texts and define problems to be explored through experimentation, observation, design cycles, or discussion and/or writing.
  - ❖ teaches students to critically comprehend and evaluate a range of scientific explanations** of processes and phenomena.
  - ❖ teaches students to critically engage with scientific argumentation** by
    - ■ analyzing claims found in text and evaluating the supporting evidence provided.
    - ■ modeling the analysis and interpretation of data to produce evidence to support claims, and providing students supported opportunities to do so as well.
    - ■ modeling the questioning of evidence for possible challenges or rebuttals to claims, and providing students supported opportunities to do so as well.
  - ❖ models how to draw and present claims based on evidence in oral and written language.
  - ❖ models for students how to comprehend and evaluate texts to interpret results of investigations.
  - ❖ teaches students to read, analyze, and interpret artifacts and data that scientists might use to build scientific arguments.
  - ❖ models how to interpret and use data gathered in the process of engineering design cycles in order to explore and/or optimize possible solutions
- engages students in real-world investigations about questions of interest to them using a range of texts that

Continued on next page

3. Intentional and standards-aligned instruction in disciplinary reading (continued)

should include tables, charts, graphs, diagrams, videos, and articles:

- ❖ collects and analyzes data with students.
- ❖ models how to record data observations systematically and rigorously, and supports students as they learn how to do so, by:
  - ■ employing multiple forms of representation to record data or model phenomena or relationships (e.g. drawings, numbers, graphs, charts, word-based descriptions, etc.).
  - ■ teaching students how to translate from one representation of data to another in the process of data analysis.
- ❖ models how to discern data patterns and determine significance, and use evidence to support claims or inform engineering design solutions, and provides students supported opportunities to do so
- ❖ teaches students how to strategically use and analyze a range of science and/or engineering texts and tools, including digital texts and tools.

- engages students in creating, analyzing, and evaluating a wide range of scientific models of phenomena, or engineering models of potential solutions to a design problem.
- scaffolds reading activities as appropriate using a range of strategies.

Kolodner, J.L., Camp, P.J., Crismond, D., et. al. (2003). Problem-based learning meets case-based reasoning in the middle school science classroom: Putting learning by design™ into practice. *Journal of the Learning Sciences 12*(4).

Greenleaf, C., Brown, W., & Litman, C. (2004). Apprenticing urban youth to science literacy. *Bridging the gap; Improving literacy learning for preadolescent and adolescent learners in grades 4, 12*, 200-226.

4. Intentional and standards-aligned instruction in disciplinary writing

The teacher:

- establishes various compelling reasons for writing in science (see recommendation #1) and teaches students to:
  - ❖ write for different purposes, such as to process and analyze scientific texts, develop and carry out an investigation, to research and/or explain a phenomenon, to put forth an evidentiary claim or scientific model, or to communicate about engineering design processes and solutions.
  - ❖ write for different audiences, such as scientific, engineering, and public audiences.
  - ❖ consider how language choices and conventions can shift depending upon purpose and audience.
- provides regular time for students to write, aligned with instructional practice #1, both formally and informally, including the use of iterative writing processes (e.g. drafting, revising from feedback, editing, publishing)
- explicitly names, describes, and models the dispositions, strategies, and patterns of thinking typical of different forms of science writing.
- provides instruction in discipline-specific writing processes, strategies, and conventions, and discusses why those writing norms exist in the discipline (e.g. notation conventions) such as:
  - ❖ recording observations and other data in systematic ways (e.g. logs, notebooks, spreadsheets, tables, sketches, diagrams, etc.)
  - ❖ analyzing and interpreting data.
  - ❖ designing appropriate and flexible systems for recording, documenting and analyzing data and/or engineering design decisions.
  - ❖ developing models of relationships and patterns in data.
- teaches students how to write scientific arguments by:
  - ❖ using examples of well-written scientific arguments to help students learn the features of strong scientific arguments.
  - ❖ Iteratively writing scientific arguments on a regular basis.
  - ❖ providing explicit instruction as needed in the use of text features, writing mechanics and other standards-aligned content.
- provides students scaffolded opportunities to explore and use different text features (e.g. headings; table of contents; glossary, etc.) and text structures (cause and effect; problem / solution; sequence of events; etc.) in their writing about science and engineering.
- engages students in using both paper/pencil and digital media tools to process investigations and develop models.
- moves students to independent levels of research, reading, and writing.
- scaffolds writing activities as appropriate using a range of strategies.

Duschl, R.A. & Osborne, J. (2002). Supporting and Promoting Argumentation Discourse in Science Education. *Studies in Science Education* 38 , 1.

Pearson, P. D., Moje, E. B., & Greenleaf, C. (2010). Literacy and science: Each in the service of the other. *Science, 328*, 459-463.

5. Higher-order discussion of increasingly complex text across varying participation structures

The teacher:

- establishes compelling reasons for engaging in discussion of texts (see recommendation #1), including texts produced by students, and involves students in
  - ❖ discussion of observations, investigations, models, or prototypes as they apply to a phenomenon or problem that is the focus of learning.
  - ❖ discussion of text genres, structures, and discursive practices of the discipline.
  - ❖ discussions that surface, in productive ways, students' ideas (regardless of scientific accuracy) about the science phenomenon and principles.
  - ❖ discussion in which they iteratively formulate explanatory models by integrating and synthesizing concepts across science domains and within engineering.
  - ❖ discussions of scientific claims in which they evaluate the evidence and reasoning used to support the claims.
- teaches students how to engage in productive discussions, making visible common purposes or outcomes of discussion and dialogue in science and engineering (e.g. forming hypotheses; triangulating data; testing hypotheses and forming conclusions based on analysis; defining an engineering problem; exploring how to optimize a design solution).
- allocates time for whole-group, small-group, and pair discussion of text, and uses a range of discussion and grouping strategies.
- poses questions that foster textual understanding and higher-order engagement with text (e.g. questions that move students beyond literal understanding into inferential and extended thinking about ideas in text) and provides modeling and instruction to teach students how to generate their own higher level questions.
- has students read and discuss the findings and significance of multiple scientific accounts or explanations of a similar problem or phenomenon (e.g. comparing findings from two studies on the same question, or evaluating differing design solutions to the same problem).
- supports students explaining phenomena from a scientific perspective and often using age-appropriate and accurate scientific language.
- engages students in discussion around digital and media literacies as used in science and engineering practices, and engages students in dialogue through digital tools to share and communicate ideas.

notes

Duschl, R.A. & Osborne, J. (2002). Supporting and Promoting Argumentation Discourse in Science Education. *Studies in Science Education* 38 , 1.

Greenleaf, C., Brown, W., & Litman, C. (2004). Apprenticing urban youth to science literacy. *Bridging the gap; Improving literacy learning for preadolescent and adolescent learners in grades 4, 12*, 200-226.

6. Opportunities for and instruction in speaking and listening

The teacher:

- establishes compelling reasons for presenting and listening to teachers' and peers' presentations, including the sharing of scientific explanations, arguments, and models; as well presentation of engineering design processes and solutions.
- makes visible the importance of audience and purpose for different types of scientific communication and provides opportunities for students to develop presentations for different audiences and purposes, both real and simulated.
- provides regular opportunities for students to listen and respond to oral presentations, including those that incorporate visual and quantitative evidence or data to make students' conclusions public (e.g., debate, reports, presentations to external audiences).
- models and teaches strategies for effective oral communication in science.
- teaches students strategies for listening and responding to presentations.

notes

Duschl, R.A. & Osborne, J. (2002). Supporting and Promoting Argumentation Discourse in Science Education. *Studies in Science Education* 38 , 1.

Greenleaf, C., Brown, W., & Litman, C. (2004). Apprenticing urban youth to science literacy. *Bridging the gap; Improving literacy learning for preadolescent and adolescent learners in grades 4, 12*, 200-226.

7. Intentional efforts to build age-appropriate scientific vocabulary and conceptual knowledge

The teacher:

- presents vocabulary as language in use (rather than presenting scientific terms from decontextualized lists).
- capitalizes on students reading, writing, speaking, and listening experiences around phenomenon to identify and use age-appropriate scientific words and principles.
- identifies multiple meanings or nuanced meanings of a scientific word across different contexts and encourages students to use new scientific words accurately in meaningful contexts (e.g., discussion of texts, discussions of content area learning, concept or semantic maps, diagrams).
- provides iterative opportunities for students to explore, review, and use new vocabulary over time, both verbally and in writing, including discussing ways that new vocabulary words relate to one another and to students' existing conceptual knowledge.
- when needed, explicitly teaches words that build necessary knowledge for reading and writing texts of instruction.
- engages students in morphemic analysis (i.e., analysis of the meaning of word parts) of unfamiliar words.
- selects Tier 2 and Tier 3 vocabulary words to teach using disciplinary texts.
- encourages productive talk among students, particularly during disciplinary learning and students' discussions of print or digital texts.
- encourages students to identify, explore and then appropriately use new words independently and provides learning opportunities to support this process.

Duschl, R.A. & Osborne, J. (2002). Supporting and Promoting Argumentation Discourse in Science Education. *Studies in Science Education* 38 , 1.

Greenleaf, C., Brown, W., & Litman, C. (2004). Apprenticing urban youth to science literacy. *Bridging the gap; Improving literacy learning for preadolescent and adolescent learners in grades 4, 12*, 200-226.

8. Ongoing observation and assessment of students' language and literacy development that informs their education

The teacher:

- engages in observation and assessment guided by:
  - ❖ an understanding of language and literacy development (e.g. understanding the difference between literal comprehension and inferential comprehension of any text, including scientific texts, is helpful for teachers when developing and analyzing text-based assessment items).
  - ❖ students' strengths, areas for improvement, and socioemotional needs.
  - ❖ relevant standards documents.
- Prioritizes multiple forms of student work as data for making instructional decisions rather than to standardized test scores which can mask proficiencies and areas in need of development.
- administers multiple forms of formative assessment as one source of information to determine which students may need additional instructional supports .
- employs formative and diagnostic assessment tools as needed to inform specific instructional targets (e.g., assessing knowledge of specific vocabulary words taught, reading and writing strategies being used and not used) and engage in the instructional practices described in this document.
- provides timely and specific formative feedback to students to guide learning and literacy development.
- involves students in the development of learning goals, as well as in supported, productive self and peer assessment / feedback.
- develops assessment that analyzes how students apply disciplinary tools, concepts, and literacy practices.
  - ❖ assesses students' ability to analyze data and use evidence to support a scientific claim

Keeley, P. (2015). *Science Formative Assessment, Volume 1: 75 Practical Strategies for Linking Assessment, Instruction, and Learning*. Corwin Press.

Bailey, A. L., & Heritage, M. (Eds.). (2008). *Formative assessment for literacy, grades K-6: Building reading and academic language skills across the curriculum*. Corwin Press.

notes

9. Community networking to tap into available funds of knowledge in support of developing students' science knowledge and identities

The teacher provides learning activities that:

- help students connect and build on their in-school and out-of-school literacy practices and identities.
- connect science learning to family and community issues, local and regional problems or concerns, and economic and political decisions.
- tap into community activities and audiences to address and explore scientific questions, or natural and social concerns.
- connect to youth and popular cultural activities and concerns.
- leverage students' literacies, learning, and knowledge to benefit their school, district, and/or community (e.g. peer education, research fairs, student to student mentoring, service learning).
- invite people representing a range of occupations who use STEM practices in their work to the classroom (either face-to-face or via digital tools) to work with and engage in conversation with students.
- connect to and engage with informal and out-of-school time science experiences in local communities (museums, laboratories, universities, community colleges, governmental agencies such as health departments, etc.).
- enable students to communicate their own and others' scientific models and explanations and engineering problems to authentic audiences through argumentation.

González, N., Neff, D., Amanti, C., & Moll, L. (2006). Funds of knowledge for teaching: Using a qualitative approach to connect homes and classrooms. In *Funds of knowledge* (pp. 83-100). Routledge.

Moje, E. B., Ciechanowski, K. M., Kramer, K., Ellis, L., Carrillo, R., & Collazo, T. (2004). Working toward third space in content area literacy: An examination of everyday funds of knowledge and discourse. *Reading research quarterly*, *39*(1), 38-70.

10. Metadiscursive awareness within and across academic and cultural domains (attention to language use at the "meta" level, e.g. talking about talk)

The teacher:

- supports students connecting and building on their in-school and out-of-school literacy practices and ways with words by identifying language processes and discussing how language is used based on different purposes and audiences.
  - ❖ e.g. discussing the role of audience and purpose with students by having them compare how they communicate with friends about an issue or problem to how they might communicate about the same topic with an authority figure like a principal, and then using this discussion to help them consider other comparisons of language use such as the differences between writing a text message and writing a scientific presentation.   The goal is to make them aware of how language can and should shift in different contexts.
- engages students in metalinguistic discussion about ways with words within and across the disciplines.and areas in need of development.
  - ❖ e.g. discussing how and why the meaning of a word like product changes in meaning across academic contexts
  - ❖ e.g. noting how the use of first person in writing changes across academic disciplines and genres
- provides learning activities that teach students to evaluate how language is used in powerful and effective ways in the discipline based on the purpose, audience, historical and social context, and genre of the text.
  - ❖ e.g. having students analyze important, influential texts in the disciplines of the sciences (e.g. Darwin's Origin of Species) and discuss why and how that particular text made an impact, with a focus on language use
  - ❖ e.g. teaching students about the standards of evidence in different forms of science writing and using these to create powerful arguments

Greenleaf, C., Brown, W., & Litman, C. (2004). Apprenticing urban youth to science literacy. *Bridging the gap; Improving literacy learning for preadolescent and adolescent learners in grades 4*, *12*, 200-226.

Campbell, T., Oh, P. S., & Neilson, D. (2012). Discursive modes and their pedagogical functions in model-based inquiry (MBI) classrooms. *International Journal of Science Education*, *34*(15), 2393-2419.

Essential Practices for Literacy Instruction in the Secondary Science Classroom

*Models and modeling are important terms to briefly discuss as they have different, although related, meanings in terms of general pedagogy as compared to scientific and mathematical practice.

In this document, when referring to general teaching practices, such as "teacher models how to discern data patterns," modeling is the teaching practice of demonstrating a process for students in order to show them how it is done. Effective modeling involves breaking down complex practices into steps when helpful, questioning learners about what they are seeing, thinking out loud, and engaging them in dialogue about the practice or process once demonstrated.

More specific to science and mathematics, modeling refers to the development of representations of complex concepts or systems that help to explain a phenomenon or to make predictions about the phenomena. Models can be mental representations or other external representations that exist in diverse formats, from drawings to 3D models to physical enactments of systems.

**The terms argument and explanation are often used interchangeably in science education. In this document, we are operating with the understanding that they are related, but different practices. See the statement below from stemteachingtools.org.

Explanations are constructed from models and representations of reality—not out of data and warrants. With arguments, scientists attempt to logically reason from the data to a conclusion using appropriate warrants. Argumentation often involves comparing different explanations for natural phenomena in an evidence-based way. The two practices are deeply linked to each other, but they do different intellectual work for scientists.

http://stemteachingtools.org/brief/1

notes

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