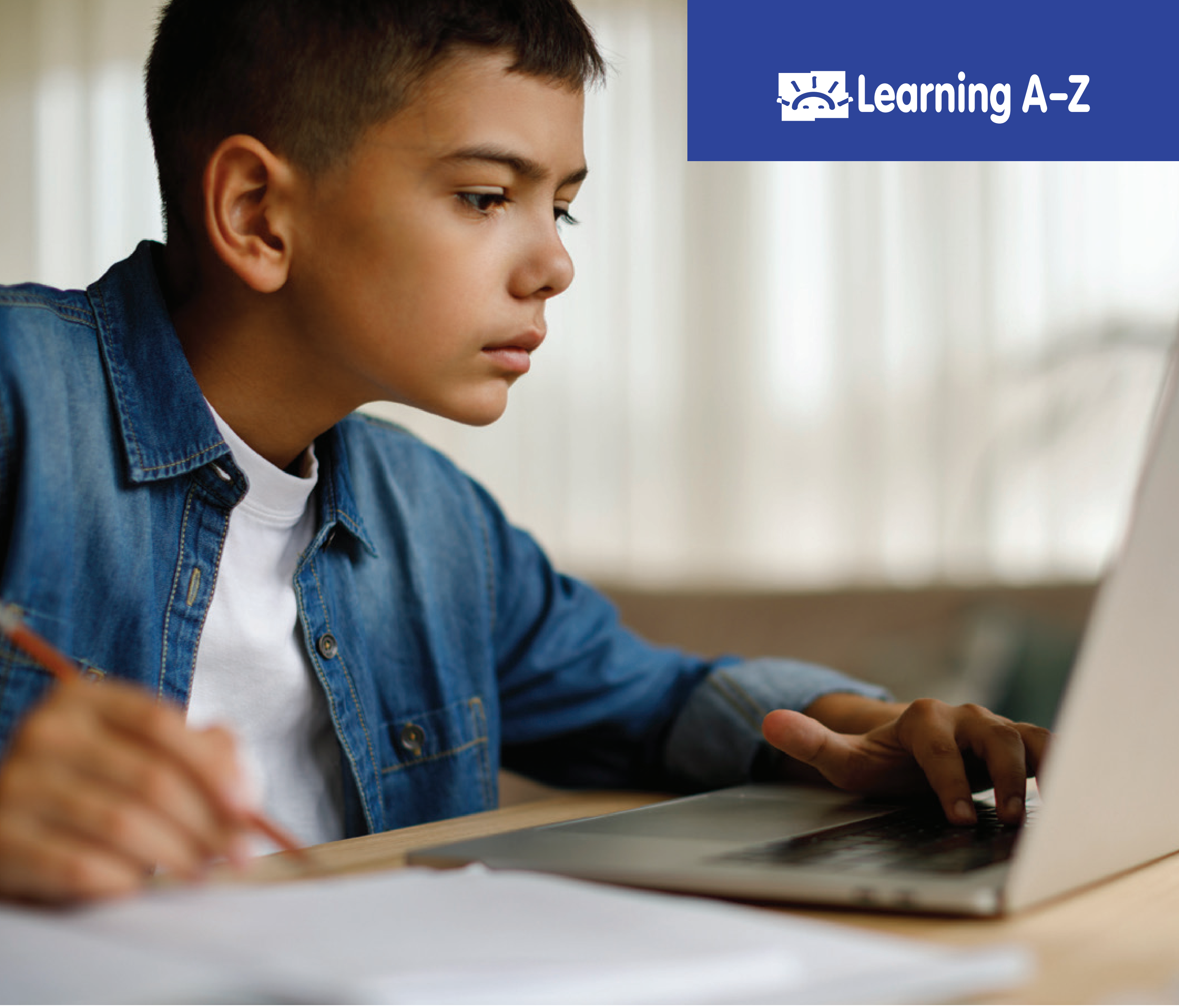

TEACHING SCIENCE:

Scientific Literacy and Inquiry

Teaching Science: Scientific Literacy and Inquiry

Introduction

Students must develop skills and knowledge in science, engineering, technology, and mathematics at higher levels than previously required in order to keep up in an increasingly information- and technology-rich world (National Science Board, 2007). To make informed decisions about aspects of daily life such as personal healthcare and public policy issues, every person needs at least a basic understanding of science and engineering (National Research Council, 2012; Organization for Economic Cooperation and Development [OECD], 2017).

To help address this need, the National Research Council (2012) produced *A Framework for K–12 Science Education.* The goal of the framework is

> "to ensure that by the end of 12th grade, all students have some appreciation of the beauty and wonder of science; possess sufficient knowledge of science and engineering to engage in public discussions on related issues; are careful consumers of scientific and technological information related to their everyday lives; are able to continue to learn about science outside school; and have the skills to enter careers of their choice, including (but not limited to) careers in science, engineering, and technology" (p. 1).

Learning A–Z's science products were designed to support the development of students' scientific literacy and inquiry skills.

I. Scientific Literacy

Scientific literacy, as defined by the OECD, is

> "the ability to engage with science-related issues, and with the ideas of science, as a reflective citizen. A scientifically literate person is willing to engage in reasoned discourse about science and technology, which requires the competencies to explain phenomena scientifically, evaluate and design scientific enquiry, and interpret data and evidence scientifically" (OECD, 2017, p. 15).

The NRC's (2012) Framework For K–12 Science Education and Next Generation Science Standards specifies three major dimensions on which science education should focus to produce scientifically literate citizens: (1) scientific and engineering practices, (2) cross-cutting concepts, and (3) core ideas in four disciplinary areas: physical sciences; life sciences; earth and space sciences; and engineering, technology, and applications of science.

Scientific and engineering practices include the practices in which scientists and engineers engage. Familiarity and experience with these practices can help students better understand how knowledge about the world develops, how problems are solved and new technologies created, and how science and engineering are intertwined. These practices include:

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 (NRC, 2012, p. 49).

Cross-cutting concepts are concepts that "unify the study of science and engineering through their common application across fields" (NRC, 2012, p. 2). The committee who developed the framework identified seven cross-cutting concepts important for students to learn: patterns; cause and effect; scale, proportion, and quantity; systems and system models; energy and matter: flows, cycles, and conservation; structure and function; and stability and change.

Core ideas are those ideas that:

1. Have broad importance across multiple sciences or engineering disciplines or are a key organizing principle of a single discipline
2. Provide a key tool for understanding or investigating more complex ideas and solving problems
3. Relate to the interests and life experiences of students or connect to societal or personal concerns that require scientific or technological knowledge
4. Are teachable and learnable over multiple grades at increasing levels of depth and sophistication. That is, the idea can be made accessible to younger students but is broad enough to sustain continued investigation over the years (NRC, 2012, p. 31).

In the physical sciences, core ideas include: matter and its interactions; motion and stability—forces and interactions; energy; and waves and their applications in technologies for information transfer. In life sciences, core ideas include: from molecules to organisms—structures and processes; ecosystems—interactions, energy, and dynamics; heredity—inheritance and variation in traits; and biological evolution—unity and diversity. Core ideas in earth sciences include: Earth's place in the universe; Earth's systems; and Earth and human activity. In engineering, technology, and applications of science, core ideas include engineering design and links among engineering, technology, science, and society (NRC, 2012).

II. Scientific Inquiry

The Framework for K-12 Science Education recommends that "the learning experiences provided for students should engage them with fundamental questions about the world and with how scientists have investigated and found answers to those questions. Throughout grades K-12, students should have the opportunity to carry out scientific investigations and engineering design projects related to the disciplinary core ideas" (NRC, 2012, p. 9).

In a meta-analysis of 61 studies on science teaching strategies, Schroeder, Scott, Tolson, Huang, and Lee (2007) found that enhanced context strategies were highly effective, with effect sizes ranging from 0.65 to 1.48. Such strategies include: using problem-based learning, taking field trips and encouraging reflection; collaborative strategies involving arranging students in groups to engage in inquiry projects and discussions; questioning strategies; and guided inquiry activities. In a meta-analysis examining the effects of different components and levels of guidance on inquiry learning, Furtak, Seidel, Iverson, and Briggs (2012) found that inquiry-based teaching overall had a positive effect on student learning, with teacher-guided instructional activities including epistemic (e.g., nature of science, drawing conclusions based on evidence, and generating and revising theories) or a combination of procedural (asking scientifically oriented questions, experimental design, executing scientific procedures, recording data, and representing data) and social (e.g., participating in class discussion, arguing/debating scientific ideas, and working collaboratively) components resulting in the greatest effect sizes.

Inquiry can occur along a continuum with various levels of support and guidance for students. Banchi and Bell (2008) described an inquiry continuum consisting of four main levels, with the most appropriate level depending on students' inquiry skills.

1. **Confirmation Inquiry:** Teachers provide students with a familiar science topic to explore with the aim of confirming existing content knowledge.
2. **Structured Inquiry:** Students are given a research question to which they do not know the answer and work to identify relationships between variables to propose an explanation.
3. **Guided Inquiry:** Teachers provide students with only a research question and leave students to design and execute an experiment to answer that question.
4. **Open Inquiry:** Students develop their own research questions and experiment, design, and collaborate to draw evidence-based conclusions.

Learning A–Z Resources to Support Scientific Literacy and Inquiry

Science A–Z

- **Investigation Packs** are group science activities designed to help students apply scientific practices and engage in scientific argumentation. Investigation Files feature high-interest, in-depth informational text. Students do a close reading of the Investigation Files and then cite evidence that helps them solve the Mystery File in each pack through group discussion.
- **Project-Based Learning Packs** include inquiry-based science projects and activities that promote collaboration and critical thinking. Students work in teams to investigate an overarching science question or to design solutions for an engineering challenge.
- **Storylines** include phenomenon-driven lesson plans and assessments designed around the three dimensions of the Next Generation Science Standards* (NGSS). Each Storyline includes an exploration of Disciplinary Core Ideas and Crosscutting Concepts through engagement in Science and Engineering Practices within an integrated series of lessons.
- **Debates** are structured exercises designed to help students develop skills in scientific argumentation based on evidence. Students are presented with a fictional but realistic scenario and must consider arguments for or against a proposal, take a position, and defend it in a friendly, structured format. Debates integrate science content and research with critical thinking, communication, and collaboration as students learn to conduct research, form opinions, communicate with peers, consider other points of view, and reach new conclusions based on arguments supported by evidence.
- **FOCUS Books** include text on high-interest topics and are designed to help students focus more deeply on individual concepts presented within the broader unit content. The books come with reading comprehension assessments and hands-on, inquiry-based science activities.
- **Process Activities** are hands-on science activities and experiments. Students identify and solve problems and communicate their findings through speaking, listening, and writing. Students also practice proposing new solutions, designing experiments, and testing new ideas as they collaborate with peers.

- **Interactive Lessons** teach core science concepts and principles using multiple representations and carefully designed examples and non-examples. Throughout each lesson, students respond actively to novel examples and receive feedback to ensure deep understanding of the concept or principle.
- **Science in the News** is a monthly edition of multilevel science news articles that engage students in exploring recent STEM advancements.
- **Science Videos** show real science in action and serve as virtual field trips that help students visualize science concepts.
- **Unit Nonfiction Books** offer informational text at multiple reading levels across science content areas.
- **Science Fair Resources** include lists of science fair project ideas for students to choose from or use as inspiration for their own research questions.

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