



Elementary Science

Equipping Students Through Inquiry and Integration

Summary

Science tends to be viewed as a completely separate subject area from reading and math. This is the case even in elementary school, where academic content may be more intertwined than in later years. But scientific thinking and processes are valuable across all areas of learning and for career success. Waiting until the middle grades to give science an equal place among the academic subjects not only handicaps students' performance in reading — background knowledge is necessary for comprehension — it means they have less time to develop important thinking skills that will benefit them in *all* subjects.

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Science's role in the economy

In the drive to improve students' reading and math achievement in the elementary grades, science has sometimes fallen by the wayside. This is despite widespread acknowledgement of the importance of STEM fields — science, technology, engineering and math — to the current and future workforces. The National Research Council pointed out in 2011 that “[a]n increasing number of jobs at all levels — not just for professional scientists — require knowledge of STEM.” The math, computer science and problem-solving skills students develop in STEM courses are increasingly valuable to employers in many industries.

Job prospects in STEM fields are expected to remain high. The McKinsey Global Institute estimates that the top-growing occupations from 2016 to 2030 will include health care and the skilled trades. The field of health care relies heavily on science, and many workers in skilled trades — carpenters, electricians, plumbers — use math and engineering skills daily. White-collar professions like engineer, scientist, technology expert and architect will also remain vital to the economy. And as SREB explained in 2019's *Unprepared and Unaware*, the middle-skills jobs supporting these professions will grow, too. Preparing students for such careers ensures that they have bright futures resistant to technological changes and automation. This requires a solid STEM background.

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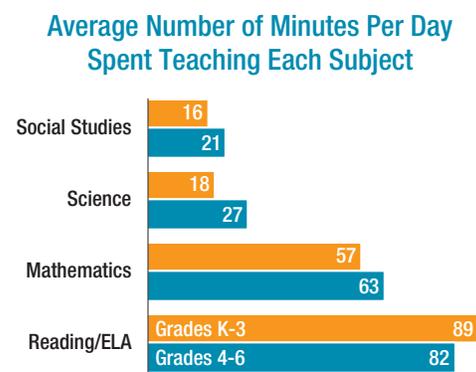
An underappreciated subject in the elementary grades

Children’s scientific knowledge and thinking skills begin to develop early in life, both in and out of the school building. The National Science Teaching Association noted in 2018 that children’s “innate curiosity about the world and how it works” makes them want to investigate the world around them. Adults can encourage this curiosity well before school through play and by engaging children verbally. A pilot project in Philadelphia is helping families do just that using spatial art and puzzles at bus stops.¹

Nurturing children’s natural interest in the world in the early grades helps them expand and deepen their understanding of scientific concepts and processes in the middle grades, high school and beyond. As with reading and math, the learning progression of science extends from childhood across all grade levels. Later learning in science depends on a strong early foundation.

This means setting aside time in the school day for science instruction and inquiry — a difficult task at times, given the extensive focus on reading and math in elementary school. The 2018 National Survey of Science and Mathematics Education found that, while 99% of K-3 teachers reported teaching math all or most days each week, only 17% said the same of science. The remaining teachers surveyed were nearly evenly split: 40% reported teaching science every week but for three or fewer days, and 43% reported teaching science some weeks, but not every week. And the average amount of time K-3 teachers said they spent teaching science? Just 18 minutes per day, compared with 89 minutes for reading and 57 minutes for math.

The lack of attention given to science in elementary school is reflected in fourth graders’ performance on the National Assessment of Educational Progress, or NAEP. In 2015 — the most recent year the science assessment was given — 76% of fourth graders in the median SREB state performed at or above Basic on NAEP in science. This figure includes the 37% of fourth graders who performed at or above Proficient. These percentages are about the same as those for math in 2017, and better than those for reading. However, nearly a quarter of SREB fourth graders in 2015 were not even partially meeting grade-level expectations for science.



Source: SREB, based on data from the 2018 National Survey of Science and Mathematics Education

Time spent on science instruction matters. Researchers have found that students in classes that spend more time on science instruction tend to perform better on the fourth grade NAEP science assessment and other standardized assessments of science achievement.^{ii, iii} Yet, while many states have policies mandating that elementary schools spend a certain amount of time on reading or literacy instruction — often 90 or 120 minutes per day — the same can’t be said of other subjects, including science.

Where does science fit into elementary learning?

Ensuring that children become proficient in reading and math in elementary school is critical for their future success, as explained by SREB reports *Ready to Read, Ready to Succeed* (2017) and *Early Math Matters* (2019) on elementary reading and math. The National Academies of Sciences, Engineering, and Medicine argued in 2016 that foundational literacy and numeracy skills are prerequisite to the development of science literacy, which they define as “familiarity with the enterprise and practice of science.”

But reading, math and science don’t have to compete for classroom time to the extent that they currently do, especially later in elementary school. Key skills related to reading proficiency — like vocabulary and background knowledge — can actually be developed at the same time as scientific

content knowledge. In fact, knowledge and reading skills are inextricably intertwined. Students may be excellent decoders, but if they lack the vocabulary and background knowledge to recognize the words they sound out, they will not understand what the text says.

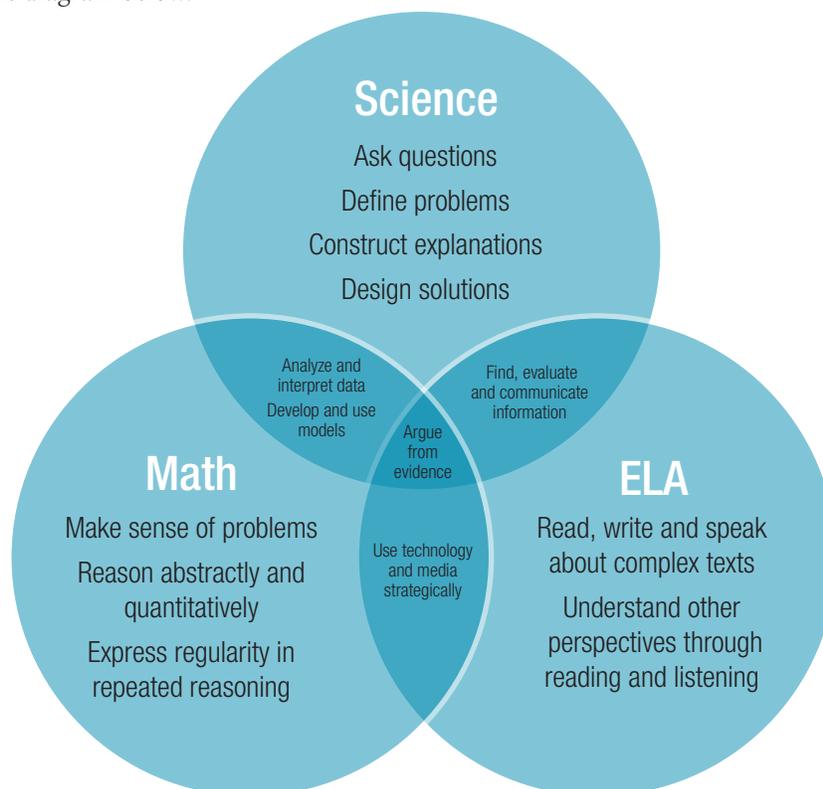
Texts can play many roles in the learning of science. For example, as researcher Gina Cervetti points out, they can provide context for scientific investigation and convey scientific content to students. As students engage with texts, they practice skills important to both reading and scientific inquiry: metacognition, acquiring information, solving problems and making connections. Students build additional background knowledge both by making sense of new terms and making connections between things they already know.

The idea of integrating science and literacy is not new — the two are natural partners. “No scientist simply walks into a lab and starts manipulating materials, tools and phenomena,” notes researcher P. David Pearson. Or as the National Research Council explained in 2012, “Reading, interpreting, and producing text are fundamental practices of science in particular, and they constitute at least half of engineers’ and scientists’ total working time.” Strong reading and writing skills, along with the ability to correctly interpret diagrams and charts, are essential for scientific learning, so it makes sense that students who practice reading in the context of science will develop these skills. The inverse is also true: students can learn science content while reading.

Science is also closely connected to mathematics. Skills in both fields include the ability to analyze and interpret data, find patterns in that data, and develop models to make predictions. The logical and analytical nature of mathematical thinking, in turn, strengthens one’s ability to engage in scientific inquiry. All three subjects — science, math and language arts — are inextricably intertwined, as depicted in the diagram below.

“Science is a way of knowing about the world.”

National Academies of Sciences, Engineering, and Medicine



What should elementary science instruction look like?

The question of what science instruction should entail has received a lot of attention in recent years. While several organizations developed guiding documents to address the issue, these share many of the same overarching goals and ideas. The College Board released a science framework for K-12 instruction which emphasizes the importance of inquiry-based learning, interdisciplinary connections with other academic subjects, and consideration of both the depth and breadth of instruction.

In 2012, the National Research Council published *A Framework for K-12 Science Education*, which noted that science education in the United States was disorganized and misaligned across grade levels; emphasized discrete facts and had a broad but shallow focus; and did not provide students with enough opportunities to actually experience science. The framework's purpose was to reorganize K-12 science education into a coherent approach with three main dimensions:

- Scientific and engineering practices
- Crosscutting concepts that unify the study of science and engineering
- Core ideas in physical sciences, life sciences, earth and space sciences, and engineering, technology and applications of science

Following the release of the framework, state leaders and experts from 26 states, the National Research Council, the National Science Teachers Association, and the American Association for the Advancement of Science coordinated to develop the Next Generation Science Standards, which are centered on these elements. In the years since their 2013 release, 42 states across the nation have adopted new science standards, 22 based on the NRC Framework and 20 based on the NGSS. In the SREB region, eight states now have science standards based on the NRC Framework and another four have adopted the NGSS.^{iv}

The Organisation for Economic Co-operation and Development's Programme for International Student Assessment went on to develop its own Science Framework, released in 2019. This formed the basis of the 2018 PISA test of scientific literacy and identifies three competencies that together, combined with knowledge, make up scientific literacy:

- Explaining phenomena scientifically
- Evaluating and designing scientific inquiry
- Interpreting data and evidence scientifically

Building scientific literacy through the NRC framework's concept of three-dimensional learning is the core work of all teachers of science. Hutner and Sampson outlined five indicators of good science teaching in 2015. They describe good science teachers creating in students "a need to learn" and making thinking visible by providing opportunities for students to make predictions and explain their reasoning. In such classrooms, students explore scientific phenomena *before* being formally exposed to the content. This "activity before content" (ABC) approach has students engage in scientific practices — the behaviors and thought processes used by scientists — by asking scientific questions, planning and conducting investigations, analyzing and interpreting data, using evidence to engage in argument, and obtaining, evaluating and communicating information.

Finally, students in classrooms with strong science teaching practice negotiating meaning. Rather than being passive receivers of information, students "think deeply about the content during a lesson and about what they know and how they know it. They must determine what is and isn't relevant and decide how to explain or represent what they know so other people can understand it." This last skill is important not just for the field of science, but throughout life.

Researcher P. David Pearson described the ideal integration of science and reading as hands-on exploration followed by text-based investigation and writing.^v This is similar to what actual scientists do: conducting experiments, consulting existing studies and literature, and writing about their findings. Pearson's chart (right) shows an example of what this approach could look like in the classroom.

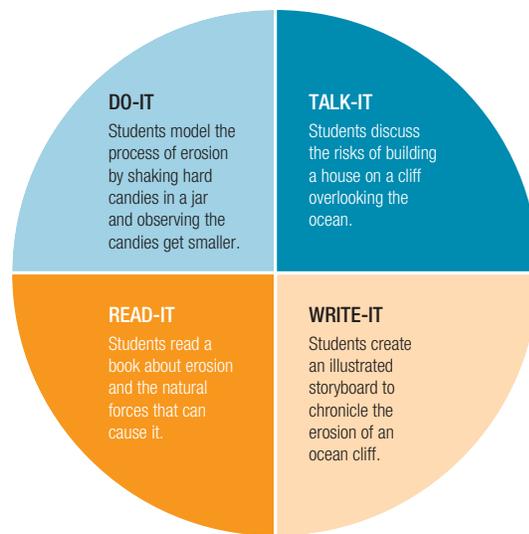
What do elementary teachers need to know to teach science well?

To facilitate scientific learning, elementary teachers need content knowledge themselves, as well as knowledge of scientific thinking and processes. Studies show that this is often a problem. Most elementary teachers in the 2018 National Survey of Science and Mathematics Education reported that they felt less prepared to teach science than other subjects. While 77% of teachers reported feeling very well prepared to teach reading/language arts and 73% felt very well prepared to teach math, this dropped to just 31% for science. A combined 27% of teachers surveyed felt they were not adequately prepared or were only somewhat prepared to teach science. These rates were just 3% for language arts and 4% for math.

As is the case with reading and math, even elementary teachers with strong science backgrounds will not be well prepared to teach science to young children unless they receive the proper training in educator preparation programs. According to the National Research Council (2012), this training should “develop teachers’ focus on, and deepen their understanding of the crosscutting concepts, disciplinary core ideas, and scientific and engineering practices.” Teachers also need to understand “how students think, what they are capable of doing, and what they might reasonably be expected to do under supportive instructional conditions.”

Developing this expertise in elementary teachers requires courses designed specifically for these goals, rather than general college-level science courses in topics like chemistry and biology. Science courses also need to ground future teachers in the NRC framework's three main dimensions. And the NRC felt that a single science methods course — which equips teachers with subject-specific skills to carry out instruction — was not sufficient for developing the knowledge teachers need across all elementary grades.

Elementary teachers may teach all core subjects, but this does not mean instruction needs to be clearly divided into language arts, math, science and social studies. The NRC noted that cross-subject literacy issues like “integrating text with pictures, diagrams, and mathematical representations of information” are rarely given much time in teacher preparation programs, despite the fact that this is something K-12 students often encounter in the study of science. The ability to integrate textual and non-textual information in any subject area is a critical skill — in school, in the workplace and in daily life. Teachers deserve training that equips them to interweave instruction across content areas.



Adapted from Pearson, P.D., Moje, E., & Greenleaf, C. (2010). Copyright by the Regents of the University of California. Used with permission.

Solutions

Here are some things stakeholders can do to prepare students for success in science, both in elementary school and beyond:

Ensure that science receives adequate time in the classroom. The National Science Teachers Association’s 2018 position statement on elementary science recommends that science receive the same amount of attention as other core subjects. The position statement encourages schools to aim for at least 60 minutes of science instruction and science investigations per day. This would be two to three times the average number of minutes elementary teachers reported spending on science instruction in the 2018 National Survey of Science and Mathematics Education.

Encourage interdisciplinary instruction. Schools can increase the time spent on science without taking it away from other subjects by helping teachers integrate science with topics like literacy and math. Studies show that combining literacy practice with science learning in the upper elementary grades can result in greater gains in both subjects.^{vi} Teaching in this way can be hard to do, though, without resources and support. A 2012 review concluded that scientific journals for teachers contained few articles that would help them provide interdisciplinary science instruction.^{vii} This was especially true for combinations of science and math.

Equip elementary teachers to use inquiry-based, three-dimensional learning. All teachers deserve the preparation they need to engage and encourage children’s natural interest in science. This requires both content knowledge and instruction in effective teaching methods for science — including integrating reading, writing, math and science skills. Teachers also need to be equipped to unify scientific practices, crosscutting concepts, and core ideas of scientific learning in their instruction. States can examine their standards and requirements for teacher preparation programs to determine whether they adequately address these needs.

Endnotes

- ⁱ Sparks, S.D. (2019, May 29). Bus Stops May Be as Good a Place as Any for a STEM Lesson. *Education Week*. Retrieved from http://blogs.edweek.org/edweek/inside-school-research/2019/05/science_at_the_bus_stop.html
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- ⁱⁱⁱ Curran, C.F. & Kitchin, J. (2019). Early elementary science instruction: does more time on science or science topics/skills predict science achievement in the early grades? *AERA Open*, 5(3), 1-18. Retrieved from <https://journals.sagepub.com/doi/pdf/10.1177/2332858419861081>
- ^{iv} National Science Teaching Association (unk). About the Next Generation Science Standards. Retrieved from <https://ngss.nsta.org/About.aspx>
- ^v Shapiro, D. (July 14, 2006). Science and Literacy—A Natural Integration. NSTA Reports Online Exclusive. National Science Teaching Association. Retrieved from <https://www.nsta.org/publications/news/story.aspx?id=52301>
- ^{vi} Romance, N.R. & Vitale, M.R. (2012). Expanding the role of K-5 science instruction in educational reform: implications of an interdisciplinary model for integrating science and reading. *School Science and Mathematics*, 112(8), 506-515. Retrieved from http://scienceideas.org/RefDocs/2_C-RomanceandVitale2012PDFofArticle.pdf

vii Yarker, M.B. & Park, S. (2012). Analysis of teaching resources for implementing an interdisciplinary approach in the K-12 classroom. *Eurasia Journal of Mathematics, Science & Technology Education*, 8(4), 223-232. Retrieved from https://www.researchgate.net/publication/241279452_Analysis_of_Teaching_Resources_for_Implementing_an_Interdisciplinary_Approach_in_the_K-12_Classroom

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