Hardwired to learn science but left out of the landscape: the role of expanding access to quality science education in America for elementary learners

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Executive Summary: There has never been a greater need for a scientifically literate population, yet science education remains inaccessible for many learners. National STEM priorities continue to focus on older learners and adults while failing to expand access to elementary school students. In the past 30 years, science instructional minutes have decreased dramatically, likely the unintentional outcome of accountability metrics that overemphasize math and reading at the expense of other subjects. In some districts, students do not receive any science until middle grades. Elementary teachers may not receive any instruction in science and lack the confidence and resources to effectively weave content into their already overflowing plate. The National Academies of Science, Engineering, and Medicine recently published two reports that identify widespread disparities in access to science education while also outlining growth opportunities. These reports address the causes and impacts of the disparities, and outline recommended solutions at all levels. Here we present our arguments for integrating high-quality science in elementary classrooms, drawing heavily on the reports for evidence and potential solutions. The pandemic and climate change have focused attention on the vital role of science in our lives; it's time to invest in our youngest learners and natural-born scientists with opportunities to leverage their innate skills and prepare them as the leaders of tomorrow.

I. Introduction

Science is humanity's greatest collective victory; science enhances daily life, generates solutions for complex global problems, and inspires hope for a brighter future (UNESCO 2013). The need for a scientifically literate citizenry in the United States has never been as urgent as now; climate change and the pandemic have brought science to the forefront of public consciousness and policy decisions and elevated trust in science to the highest levels ever recorded (3M 2021). The intrinsic skills and practices of science benefit society at large, beyond simply feeding the STEM career pipeline. For example, each day, we must filter through the constant barrage of information to identify fact from fiction, and we have experienced the consequences of failing to understand the difference. We must communicate, infer, and make predictions based on our determination of the best available information.

The federal government has recognized these needs in the last decade or so, but domestic policy has primarily been directed towards the STEM workforce shortage, diversity, and competition. One critical group remains consistently absent from these policies: elementary school students. Failing to reach this population of natural scientists does little to secure the long-term STEM workforce or the development of a scientifically literate citizenry. Our national ability to address and remedy disparities in access to high-quality science education will determine our future in the global economy.

In the past decade, science education in the U.S. has been reimagined with new standards, practices, and learning theories. At least forty-four states have either adopted or based science standards on the Framework for K-12 Science Education ("the Framework"; NRC 2012), from which the Next Generation Science Standards (NGSS) were designed (NGSS Lead States 2013). These infuse evidence-based explanations of phenomena and encourage experiential practice. The Framework spans all grades and makes a strong case for the importance of science in elementary grades. Thus it is surprising that, although most states have adopted the NGSS or based science standards on the Framework, the amount of time elementary students across the country are experiencing science continues to decline. In fact, the average amount of time elementary students spend on science is drastically less than the time spent on mathematics and reading (Trygstad et al. 2013; NASEM 2021a). The repeated challenge of "Science for All" has been met by disproportionate access for some and near elimination for many, as reading and math dominate the school day.

Limiting or even eliminating science for children makes no sense. Children are hardwired to do science; from birth, they observe and analyze their surroundings; they notice patterns and use reasoning to form conclusions to understand their world. Yet students are consistently denied access to science until middle school, when it may be too late to capture their interest (Gerlach 2018*)*. Curiosity and experience should be harnessed, not extinguished. For the benefit of our country, communities, and children, science education *must* be elevated to the status of reading and math in elementary school.

II. The state of science education in elementary schools

i. Sources of inequity

Several factors shape access to quality science and STEM education. Disproportionate funding, for one, determines access to experienced teachers, materials, and facilities. 92% of school funding stems from state and local revenue, which has heavy consequences for access to quality science education in regions of poverty (Cornman et al. 2020). In 2018, some states spent 50% more than the national average of $14,548, while others spent 30% less. Arizona holds the title for the lowest per-pupil funding, the lowest teacher pay, and unsurprisingly, the highest rate of teacher turnover (Education Resource Strategies 2018).

Schools with a high proportion of students of color experience inequity in multiple ways; because communities of color tend to experience higher poverty rates (CR2PI 2010), schools in these communities receive less state and local funding. In addition, the educator workforce is disproportionately white, which results in students of color not having role models who encourage greater achievement (NASEM 2021a). These factors, among others, perpetuate the cycle of poverty, opportunity gaps, and lack of diversity in both the teacher workforce and in science and STEM fields.

Change the Equation (2015), a STEM education advocacy organization, found that the economic gap between schools has widened, creating greater disparities in access to high-quality experiences than ever before. School funding also depends on income and property taxes, which limit opportunities and access to quality materials. Title I is the largest K-12 federal funding program intended to mitigate these funding discrepancies. However, complicated and conflicting formulas have sent more money to wealthy districts than those most in need (Boser and Brown 2015).

Differential funding across content areas is tied to accountability systems that determine curricular priorities. National Academies cite an overemphasis on test scores and accountability measures, which leads to increased emphasis on elementary reading and math (NASEM 2021a) to the detriment of all other subjects. In fact, the Center for Education Policy reported that 71% of surveyed districts reduced instructional time in at least one content area to emphasize one of the tested subjects (Kober and Usher 2012). The evidence is clear: we must elevate science to the status of a core subject in elementary school.

ii. No time for science

Despite the growing need for a skilled STEM workforce, our youngest learners experience 40% fewer instructional minutes in science than the previous generation (NASEM 2021b). This is directly correlated to increased emphasis on math and reading, which are solely used to determine achievement in most states. The national average of instruction spent on science in elementary school is approximately 20 minutes per day, while many schools spend even less. In comparison, English Language Arts and Math receive approximately 150 minutes each day (NASEM 2021a). In some instances, testing emphasis has led to doubling the time spent on tested subjects to the exclusion of science, social studies, art, and music.

Students with special needs and language support are impacted even more, as they are often removed from the classroom for individualized programs. These pull-out times are more likely to occur during the instruction of non-tested subjects, such as science, further decreasing equitable access to science opportunities (NASEM 2021b).

The math is simple: less time devoted to science equals less access to it. This compartmentalized practice based on test scores removes the joy of learning and invokes compliance rather than critical thinking (Marco-Bujosa et al. 2020). The *Call to Action* (NASEM 2021a) recommends “frequent, consistent and comprehensive science education for all,” and the National Science Teaching Association recommends at least 60 minutes each day for classroom science, including investigation time, to put science on par with reading and mathematics (NSTA 2018). Removing access to science when interest and need are at their highest is a travesty of justice for students, our STEM workforce, and society.

iii. Materials matter

Curriculum adoption is haphazard and may not even align with state standards (Boser et al. 2015). Quality classroom materials, such as evidence-based and vetted curricula that are aligned with the three dimensions of NGSS, directly correlate with increased student achievement. Yet, no states evaluate the effectiveness of adopted curricula in improving student outcomes (Boser et al. 2015). Nineteen states require or suggest that districts adopt specific products, while others leave curriculum decisions to districts (Boser et al. 2015). Both methods are fraught with issues; state decisions are often made based on a limited quality assessment and may be dominated by political agendas; district decisions are likely to be based on cost rather than quality. The National Academies (NASEM 2021b) call on states to select high-quality materials grounded in investigation and design to support teachers in responding to students' thinking.

iv. Equipped to teach, just not in science

States and institutions determine course requirements for teacher preparation programs. A typical teaching certification program emphasizes the whole child, cognitive structures, and pedagogical preparation. Teachers receive formal education on educational psychology and learning theories, which focus on the practice of teaching. Most elementary certification programs have a class in teaching mathematics and science but little to no science-specific instruction (NRC 2007). Teachers can learn the skills and practices of reading and build basic math competency, but without science-specific coursework, they will not obtain the fluency required to effectively integrate it into their practice. When coupled with pedagogical skills, teachers with strong content knowledge are better prepared as facilitators of science (Young et al. 2017). Accordingly, many elementary teachers lack confidence and subject matter competency in science, which creates another barrier for students to engage in elementary science (Trygstad et al. 2013). Teachers who lack confidence in science can also transfer negative attitudes towards science to students, which disproportionately impacts girls and students of color (Bulunuz 2015; Kazempour 2014). Students in high poverty neighborhoods and communities with a high percentage of students of color face additional barriers such as high teacher turnover, poor teacher training, poor quality materials, and fewer opportunities to engage with science (Marco-Bujosa et al. 2020; NASEM 2021a). In addition, the relatively low wages for teachers ensure that few college graduates with a science major will want to enter the elementary education field when they could be making more money in industry or government.

III. Recommendations

i. Federal policy recommendations
The responsibility for expanding access to quality science education falls primarily on the doorstep of states; however, the federal government must first establish the path. The federal government can elevate STEM as a national priority by including science as an indicator of academic success during the next reauthorization of the Elementary and Secondary Education Act (ESSA) (NASEM 2021a). The federal government should also develop an annual report that documents opportunities to learn science across states and identifies progress toward eliminating disparities in access. Policies should target the nature of accountability and access to quality educational materials and teachers at the state level.

ii. State and local policy recommendations
The United States, unlike many other nations, has no national education system; Therefore, we make the following recommendations for states to facilitate the inclusion of science in elementary school.

Option 1: Improve state assessment reporting systems
Annual reporting of science assessments would allow states to collect data on key metrics related to science education, such as equipment, curricula, and professional development. State science assessments have been required since 2007, yet reporting is not (NASEM 2021b). States that include science accountability metrics in elementary grades reported spending more time on science (NASEM 2021a).

Option 2: Include flexible accounting systems in annual assessments
State Departments of Education should include science in accountability but should be discouraged from relying upon high stakes assessments that will add stress to children and further divide students by socio-economic status (NASEM 2021a; NASEM 2021b). States are allowed_flexibility in assessment methods and are not bound to traditional standardized testing (NASEM 2021b). In addition to traditional assessments, conceptual skills could be demonstrated through learning artifacts of student work, such as creative writing or project outcomes. Traditional assessments simply evaluate knowledge, whereas authentic assessments demonstrate student ability to transfer understanding and skills to real situations. One assessment solution, supported by the National Academies (2021a), is to develop multiple authentic assessment tasks in which students engage with scientific processes to explain real-life phenomena and solve problems through hands-on scientific investigations. For example, students might present research findings to their city council to help leverage their ideas on the use of green spaces. Both student research findings and the presentation could be evaluated as an authentic assessment that demonstrates not just knowledge but the ability to apply that knowledge to a relevant and authentic situation. Districts can leverage Title II funds, designed to improve teaching quality and effectiveness, to build professional development in support of this new approach to assessment and simultaneously support teachers in their scientific content knowledge.

Option 3: Financial support for equity-based science professional development
Teachers must have opportunities to experience engaging, hands-on science and to challenge existing anxieties and attitudes. To mitigate the expected backlash by teachers, who already feel overburdened with curricular responsibility, funding could be shifted from mandated programs for students to those mandated for educator support; this approach is allowed by ESSA. Nadelson et al. (2013) found that even a three-day summer workshop profoundly impacted teachers' confidence, content knowledge, and efficacy in science teaching.

Strong preparation, quality materials, district alignment of professional learning, and sound leadership are critical in fostering educators' capacity to make effective shifts in instruction (NASEM 2021b). Administrators and teacher leaders will play a vital role in creating these opportunities for educators to build capacity in science, thereby improving elementary STEM experiences for students.

Option 4: Include science in teacher preparation programs
State credentialing agencies should require pre-service elementary teacher preparation programs (certification programs at institutions of

higher education) to include science coursework. Requiring specific science coursework aligned to the Framework will support the development of educator competencies, ideas and beliefs, and empower teachers to build on student assets and experiences.

Option 5: Establish and expand existing STEM ecosystems
At least a dozen states have an existing ecosystem of STEM Alliances or Hubs. These coalitions of stakeholders in STEM Education include PreK-12 schools, institutions of higher education, industry partners, and non-profit organizations. They amplify and improve STEM education and expand the STEM workforce pipeline by responding to community and state workforce and education needs. Most state systems of STEM Hubs or Alliances started in response to Math-Science Partnership initiatives from the National Science Foundation and the U.S. Department of Education in 2010, but this federal funding was discontinued with the passage of ESSA. There is now a strong need for funding to form and expand successful alliances with educator preparation programs, universities, and other community partners, which can foster rich opportunities for both educators and students to experience science. Alliances can identify and work towards common goals and priorities specific to the needs of districts, which will further enhance the student experience. Oregon State's Regional STEM Hub network is just one example; the thirteen STEM Hubs identify needs and assets in their communities and bring together education and industry partners to build equitable STEM access that addresses regional needs. The Frontier STEM Hub in southeast Oregon, for example, has built CTE and STEM programs for students, including flight programs and Maker Spaces, while the Oregon Coast STEM Hub has developed a strong program of teacher professional development and student competitions and activities related to marine sciences, among many other programs. Many of these regional STEM Hubs have also developed strong computer science components to their education programs.

IV. Enhancing quality curricular connections

High-quality science education will require integrating, not sacrificing, other content areas. Curricular topics do not have to be compartmentalized and rarely are outside of school. A critical shift could incorporate a holistic approach to elementary education that weaves scientific phenomena into math and reading. This approach can add time for science, while enforcing math and language skills and leveraging students' natural scientific strengths. If instruction were framed around science, teachers could focus on the interconnections between content areas and build high caliber learning opportunities in all subjects. Integrating science provides context for the use of communication and computation, which increases engagement with math and reading. One method for this integration can be found in project-based learning (PBL).

With PBL, a relevant, central, and complex problem is presented to or by students. Students work together to solve the problem, and in doing so, they naturally integrate research, problem-solving, and communication skills. Most projects will also require mathematics or computational thinking to solve the problem, so students naturally integrate these skills as they work on the central problem. The end product is something meaningful and of importance to students and community. With PBL, the project is the vehicle for learning rather than an assessment product (BIE n.d.).

There are many examples of schools and districts using a PBL approach to integrate content and help students develop critical thinking skills. One such is the New Tech Network (NTN), a network of schools that uses PBL to prepare students for college and work situations in which they have developed a suite of skills and knowledge that mirror real-life problems. NTN has found that using integrated PBL for core subjects with goals of collaboration, knowledge and thinking, communication, and agency, has resulted in greater engagement and academic and developmental success (NTN 2021).

V. Conclusion

As Carl Sagan famously stated, "every kid starts out as a natural-born scientist (until we beat it out of them)." Scientific literacy skills encompass young learners' quests to make sense of and understand the world around them and how they fit into it. All students can do science (NSTA 2018). A qualified STEM workforce is important, but this is much greater: access to science education is an act of justice that eliminates opportunity gaps and increases opportunities for later academic and career success. Science instruction, experience, and opportunity have been removed when interest and curiosity are at their peak. Policymakers must act now to reverse this trend, or the next generation will not have the skills necessary to care for the world they inherit. Quality science education is both a means and an end to a better, more equitable democracy for all Americans.

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