

National Science Board

Explorations in STEM

PreK-12 Education

Final Report



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Members

Matthew Malkan

Working group lead
Distinguished Professor of Physics
and Astronomy
University of California, Los Angeles

Sudarsanam Suresh Babu

Director of Bredesen Center for
Interdisciplinary Research and
Graduate Education
Governor's Chair of Advanced
Manufacturing and Professor of
Mechanical Engineering and
Materials Science
Oak Ridge National Laboratory /
University of Tennessee

Deborah Loewenberg Ball *

William H. Payne Collegiate
Professor of Education
University of Michigan

Melvin Huff

Lecturer
University of Massachusetts-
Dartmouth

Julia M. Phillips

Executive Emeritus
Sandia National Laboratories

Scott Stanley

Chief Technical Officer and Co-
Founder
Techno Planet Incorporated

Wanda Ward *

Executive Associate Chancellor
for the Office of the Chancellor –
Public Engagement
University of Illinois Urbana –
Champaign

Bevlee Watford *

Professor of Engineering
Education
Associate Dean for Equity and
Engagement
Virginia Polytechnic Institute and
State University

Steve Willard

Biotechnology Executive and
Lawyer

[* denotes members onboarded February 2023]

Addendum

Although the mission of this NSB working group was originally defined as exploring STEM education beginning at the *kindergarten* level, focus shifted early to include pre-kindergarten (Pre-K). This intentional change was driven by data shared by listening session participants highlighting that educational trajectories can be set as early as pre-K (see **Appendix I**). Thus, while historical records such as the mission statement of the working group mentions K-12, the recommendations encompass pre-kindergarten as well. Furthermore, data obtained for K-12 are labeled as such, while that pertaining to pre-K is labeled preK-12. Finally, the name of the working group was updated to reflect these changes.

Executive Summary

The National Science Board (NSB, Board) has identified increasing domestic Science, Technology, Engineering, and Mathematics (STEM) talent as critical for U.S. national security, innovation, and prosperity. In addition to short-term solutions focused on the Skilled Technical Workforce (STW) and higher education, this topic requires a long-term investment in the largest national pool of future STEM-competent adults and STEM workers: the over 54 million students in the preK-12th grade space. In recognition of this important population, NSB launched its *Explorations in STEM preK-12 Education* (ESKE) working group in January 2022. ESKE was charged with evaluating NSB-specific levers in K-12th grade STEM education and articulating opportunities for NSB action (see **Conclusions** and **Recommendations** sections below). In late 2022, the group's activities included a shift to encompass pre-kindergarten as the earliest grade level of interest.

ESKE's work has proceeded through three main phases (see **Appendix I: Report – Activities and Findings** for full details). Major activities have included community and expert engagement through listening sessions, data analysis from National Academies of Sciences, Engineering, and Medicine (NASEM) reports, peer-reviewed articles, *Science and Engineering Indicators* data, and panel discussions. These efforts have given ESKE considerable insight into opportunities the Board may pursue in partnership with other primary and secondary STEM education partners.

The four broad topical area recommendations presented here for the Board to focus on – the *instructional workforce, research, equity, and accountability* – are accompanied by suggested rank-ordered priorities for Board action (**Table 1**). Collectively, they constitute a call for NSF to amplify its work in this space and for NSB to form broad coalitions to amplify solutions. Importantly, these four topical areas align well with the National Science Board's *Vision 2030* and the *CHIPS and Science Act* (**Table 2**). Along with findings of the Board's Socio-Economic Status (SES) working group, ESKE's topical areas seed efforts within the Committee workstreams across the Board, ensuring that the Board's Talent Development focus is coherent and encompasses all entry points for domestic STEM talent.

Finally, ESKE's work has already delivered benefits. Its work contributed to the U.S. National Science Foundation (NSF)'s Directorate for STEM Education (EDU) March 2023 [release](#) of the “Dear Colleague Letter: Supporting Knowledge Mobilization for PreK-12 and Informal STEM Learning and Teaching.”

Working Group Conclusions

First, lack of access to quality preK-12th grade STEM education has been a decade-long challenge to developing a robust domestic STEM-competent adult population and STEM workforce. This lack of access endangers U.S. national security, decreases economic prosperity, and weakens U.S. innovation. Identifying and implementing large-scale solutions to this longstanding problem is a challenge, particularly due to the decentralization of the U.S. educational system. However, to break the repetitive cycle of global competitiveness concerns, the U.S. must take this issue seriously and consider both short- and long-term policy solutions and investment strategies in a national call-for-action.

Second, NSB should commit to improving the quality of and access to STEM education for *all*, across geographic regions and student demographic identifiers, potentially starting in pre-kindergarten. This obligation stems from NSB’s statutory authority, laid out in the NSF Act of 1950, which states that the Board and the Director have a duty to “recommend and encourage the pursuit of national policies for the promotion of research and *education* in science and engineering.” The Board can approach this issue from a policy angle, both internally-facing through a focus on NSF policies and programming and externally-facing in advocating for policy changes in the broader S&E ecosystem. The Board also has an opportunity via the *Science and Engineering Indicators* to further clarify the challenges at hand through data analysis and publications.

Third, improving access to quality preK-12th grade STEM education is an issue that cuts across current Board priorities. These priorities are not just limited to Talent Development in general but affect the Board’s commitment to fostering a diverse and equitable STEM education system – reaching the Missing Millions, students and teachers of low socio-economic status (SES), and students in all parts of the country. As the Board works to develop strategies for expanding domestic STEM talent, the issue of preK-12th grade quality STEM education should be strategically integrated into Board committee workstreams and activities.

Recommendations

The Explorations in STEM preK-12 Education (ESKE) working group recommends that NSB focus on four primary topic areas that call on the Board’s statutory authority and policy remit. These are:

- I. Instructional Workforce – primarily focused on preK-12th grade STEM educators in formal and informal settings, the workforce also includes educators at teaching colleges and administrative staff
- II. Research – includes NSF-funded research, in particular educational research, as well as the dissemination of said research to schools, school districts, and curriculum

developers, and the development of useable, evidence-based end-products for classroom practitioners

- III. Equity – focused on the systemic barriers that prevent access to high-quality STEM education and educators, particularly for students and educators of color, rural students and teachers, those with disabilities, and students and educators in high-poverty schools
- IV. Accountability – includes accessibility of data demonstrating the impact of NSF-funded research, as well as increasing and / or centralizing state and national data

A full list of priorities under recommended topical areas can be found in **Table 1** below. A crosswalk between ESKE’s list and the preK-12th grade priorities outlined in the 2022 *CHIPS and Science Act* is shown in **Table 2**.

Table 1: ESKE finalized recommended topical bins and affiliated priorities.

Topical bin	Priority
Instructional workforce	<ul style="list-style-type: none"> • Develop programs to support STEM curriculum literacy for teachers • Offer fellowships, differential bonuses, and other incentives for educators to work on improving STEM education training • Strengthen pre-service teacher opportunities to learn STEM content knowledge for teaching • Develop ways for teachers to be integral partners in STEM education research • Increase and deepen opportunities for practicing teachers to deepen their content knowledge for teaching in STEM fields • Support the development of professional STEM educator networks • Strengthen the “clinical training” phase for teacher candidates and support the development of valid performance assessments as part of licensure • Consider how to add support for the range of teacher responsibilities (wrap-around service / social and emotional needs)
Research	<ul style="list-style-type: none"> • Attend to ways that NSF-funded research can be useful in practice • Extend and develop STEM curriculum resources for preK-4th grade
Equity	<ul style="list-style-type: none"> • Recruit and support skilled and experienced teachers to teach in high-poverty schools • Provide access to tutoring in STEM fields
Accountability	<ul style="list-style-type: none"> • Collect and analyze data to measure the impacts of NSF-funded research

With these four topical areas, ESKE proposes NSB Committees, working groups, and teams do the following:

National Science and Engineering Policy Committee (SEP): Highlight the state of preK-12th grade STEM instructional workforce in *Science & Engineering Indicators* in current and future cycles. Where there are major gaps in available data, explore opportunities for National Center for Science and Engineering Statistics (NCSES) or National Center for Education Statistics (NCES) surveys to fill in the gaps. Of particular interest are:

- STEM teacher recruitment and retention by district and / or state; where possible, disaggregated by teacher and student demographic identifiers and SES status
- Number of STEM preK-12th grade educators who graduate from Colleges of Education versus vacancies by district and / or state; where possible, disaggregated by teacher and student demographic identifiers and SES status of education students

Talent Development (TD) Team: Consider policy products that draw attention to and emphasize the preK-12th grade STEM education landscape, particularly around:

- Instructional workforce, with specific consideration to pre-service exposure to STEM content, the need for improved robust STEM curriculum literacy, and the limited availability of paid STEM education professional development
- Equity, with specific consideration of distribution of experienced teachers across geography and well-resourced versus poorly-resourced schools, as well as accessibility to STEM tutoring
- Research results and needs, with a focus on preK-3rd grade STEM education

External Engagement Committee: When engaging partners on STEM talent development and STEM careers

- Ensure that conversations and actionable items incorporate preK-12th grade students, particularly in the earlier years, and the associated STEM instructional workforce. Working partners must include those at the federal, state, and county levels
- Link domestic STEM worker shortfall implications for national security, innovation, and prosperity to assessments, instructional workforce shortage, and equity in the preK-12 STEM educational system
- Encourage Congress to fully fund the *CHIPS and Science Act*, particularly around preK-12th grade STEM education

Committee on Strategy and Committee on Oversight:

- Ask for evidence and consider the adequacy and impacts of NSF-funded research from the Directorate for STEM Education (EDU) and the Social, Behavioral, and Economic Sciences Directorate (SBE) at the preK-12th grade levels, including, but not limited to instructional workforce programs. This includes funding levels over time, disaggregated

by grade level, STEM subject, participant demographics, and geographic coverage. Doing so effectively will bolster efforts within these directorates to establish metrics and measure outcomes – at the programmatic, portfolio, and single-Primary Investigator (PI) levels. This may require greater administrative data collection and reporting on beneficiaries of NSF-funding.

- Encourage NSF to fund research explicitly in the preK-3rd grade space
- Ask what metrics NSF is using to assess the impact of its research, specifically the efficacy of translation of research into classrooms for use by preK-12th grade practitioners

Merit Review Examination Commission (MRX): Consider adding educators and other members of the instructional workforce who have expertise relevant to proposals being considered on review panels. Take advantage of the MRX’s investigation of community experts more broadly on review panels and uncover ways of bringing teachers – the direct beneficiaries and often community experts of NSF-funded educational research – to the table. Albert Einstein Distinguished Educator Fellows provide an automatic pool of potential classroom education experts who do not have the time limitations of in-class teachers. In addition, the reexamination specifically of the Broader Impacts criterion may impact the evaluation of educational proposals.

Board as a whole: Continue and maintain attention on improving preK-12th grade STEM education and NSF’s role in building up the nation’s largest fraction of our future domestic STEM workforce. This could potentially include fostering discussions with the White House’s Office of Science and Technology Policy (OSTP) and federal agencies writ large around bolstering the nation’s instructional workforce and developing a strategy to effectively remove systemic roadblocks around educational access. In addition, encourage optimization analysis to identify educational successes and bottlenecks.

Table 2: Crosswalk between CHIPS and Science Act and ESKE priorities

Specific CHIPS and Science section	Associated ESKE topical and priority areas
<p>Sec. 10311. PreK-12 STEM education.</p> <p>Supports National Academies study on <i>barriers to the widespread implementation of STEM education innovations</i>.</p> <p>Supports research and development to improve informal STEM education.</p> <p>Establishes a <i>ten-year National STEM Teacher Corps pilot program</i> to recruit and retain high-quality STEM teachers to increase STEM student</p>	<p>Topical areas:</p> <ul style="list-style-type: none"> ➤ Instructional workforce ➤ Equity <p>Priority areas:</p> <ul style="list-style-type: none"> • Limited availability of fellowships, differential bonuses, or other incentives for educators to work on improving STEM education training. • Lack of direct professional STEM educator

<p>achievement and participation rates.</p>	<p>networks</p> <ul style="list-style-type: none"> • Additional teacher responsibilities (wrap-around services/social and emotional) • Lack of robust STEM curriculum literacy for teachers • Lack of a “clinical training” phase with performance assessments before license to practice • Exposure to STEM content in general education programs is limited • Teacher credentialing is not very geographically portable, and may exclude non-traditional teachers • Pre-K teacher pay is too low compared to other grades • Less experienced teachers
<p>Sec. 10321. Programs to address the STEM workforce. Provides for undergraduate scholarships, including at community colleges, graduate fellowships and traineeship scholarships, and postdoctoral awards, to address STEM workforce gaps, including for programs that recruit, retain, and advance students to a bachelor’s degree in a STEM discipline concurrent with a secondary school diploma, such as through existing and new partnerships with State educational agencies.</p> <p>Sec. 10320. Mandatory cost-sharing. Waives mandatory cost-sharing requirements for the Major Research Instrumentation and Robert Noyce Teacher Scholarship programs for 5 years.</p> <p>Sec. 10322. Robert Noyce Teacher Scholarship program update. Requires outreach to historically Black colleges and universities, minority institutions, higher education programs that serve veterans and rural communities, labor organizations, and emerging research institutions.</p>	<p>Topical areas:</p> <ul style="list-style-type: none"> ➤ Instructional workforce <p>Priority areas:</p> <ul style="list-style-type: none"> • Limited availability of fellowships, differential bonuses, or other incentives to work on improving STEM education training

<p>Sec. 10393 [TIP Directorate]. Scholarships and fellowships. Supports scholarships, fellowships, traineeships, and postdoctoral awards in key technology focus areas. Supports a scholarship to enable low-income individuals to pursue degrees in STEM fields.</p> <p>Sec. 10502. Collection and reporting of data on Federal research awards. Requires each Federal research agency to collect comprehensive demographic data on recipients of Federal awards and to report this data to NSF for summarization and publication. The NSF shall establish and update a policy to ensure standardization of the data collected.</p>	
<p>Sec. 10328. Research and dissemination to increase the participation of women and underrepresented minorities in STEM fields. Supports research and development activities to increase the participation of women and underrepresented minorities in STEM studies and careers, including research studies, mentoring programs, research experiences, and outreach to elementary and secondary school students</p>	<p>Topical areas:</p> <ul style="list-style-type: none"> ➤ Instructional workforce <p>Priority areas:</p> <ul style="list-style-type: none"> • Minimal STEM background for elementary level students [education students] • Minimal STEM background for elementary level educators [current educators]
<p>Sec. 10395 [TIP Directorate]. Scaling innovations in PreK-12 STEM education. Supports multidisciplinary research and translation centers to scale effective STEM education innovations.</p> <p>Sec. 10502. Collection and reporting of data on Federal research awards. Requires each Federal research agency to collect comprehensive demographic data on recipients of Federal awards and to report this data to NSF for summarization and publication. The NSF shall establish and update a policy to ensure standardization of the data collected.</p>	<p>Topical areas:</p> <ul style="list-style-type: none"> ➤ Research <p>Priority areas:</p> <ul style="list-style-type: none"> • Translation of NSF research into classrooms

<p>Sec. 10503. Policies for review of Federal research awards. Requires Federal research agencies to regularly assess and update policies and practices to remove or reduce cultural and institutional barriers limiting the recruitment and retention of historically underrepresented minorities, including in reviewing award applications, hiring policies, and workforce policies, and directs agencies to implement evidence-based practices to mitigate bias in the merit review process.</p>	<p>Topical areas:</p> <ul style="list-style-type: none"> ➤ Instructional workforce <p>Priority areas:</p> <ul style="list-style-type: none"> • Teachers are not integral partners in STEM education research
<p>Sec. 10512. National Science Foundation rural STEM activities. Authorizes the National Science Foundation (NSF) to support research to advance innovative approaches in STEM teaching in rural schools and improve participation and advancement of rural students in STEM studies, including through a pilot program of regional rural cohorts that provide peer support, mentoring, and hands-on research experiences for rural STEM educators. Directs the NSF Committee on Equal Opportunities in Science and Engineering (CEOSE) to report to Congress an assessment of NSF activities that support participation of rural students in STEM studies.</p>	<p>Topical areas:</p> <ul style="list-style-type: none"> ➤ Equity ➤ Research <p>Priority areas:</p> <ul style="list-style-type: none"> • None
<p>Sec. 10513. Opportunities for online education. Authorizes NSF to support research on online STEM education and mentoring in rural communities.</p>	<p>Topical areas:</p> <ul style="list-style-type: none"> ➤ Equity <p>Priority areas:</p> <ul style="list-style-type: none"> • Underprivileged students cannot afford STEM tutoring

ESKE priorities not reflected in the CHIPS and Science Act:

- Lack of STEM content created specific to preK-4th grade

CHIPS and Science sections not reflected in EKSE priorities include:

- **Sec. 10319.** Incorporation of art and design into certain STEM education. Supports research to develop STEM educational curriculums that incorporate art and design to promote creativity and innovation.

Conclusions

The United States is facing an acute emergency that threatens to impact our national security, economic prosperity, and innovation. Our ability to promote scientific progress and societal benefits to every American and to support global innovation is limited by our most precious resource: domestic STEM talent. De-risking requires a suite of federal and state short- and long-term strategies at every major entry point along the talent braided river, with particular emphasis on the beginning of the river – preK-12th grade students and their STEM teachers. Dramatically and quickly improving the STEM education trajectories at this level will have the largest long-term impact on the health and security of our nation. As such, ESKE recommends that the National Science Board and the National Science Foundation focus on bolstering four main areas: the STEM instructional workforce, research, equity, and accountability / data. These areas cut across current Board priorities and can be reinforced by a collection of policy recommendations, amplification of current NSF work, and the formation of broad coalition across the federal government and with other partners.

Appendix 1

Report – Activities and Findings

The Board has long been determined to address the STEM education crisis for the nation’s youngest learners. In its 1983 report to the full Board, the NSB commission on precollege education in mathematics, science, and technology stated the following:

America must not become an industrial dinosaur. We must not provide our children a 1960s education for a 21st century world...We must return to basics, but the “basics” of the 21st century are not only reading, writing, and arithmetic. They include communication and higher problem-solving skills, and scientific and technological literacy – the thinking tools that allow us to understand the technological world around us...These new basics are needed by all students – not only tomorrow’s scientists – not only the talented and fortunate – not only the few for whom excellence is a social and economic tradition.

Their recommendations – which are echoed through more recent NSB products – included leadership recommendations for the White House, federal, state, and local governments, a focus on all students (including those that “still suffer from the consequences of racial, social, and economic discrimination”), quality teaching and earlier and increased exposure, teacher training, curricular changes, informal education, and finances. These themes have echoed in subsequent NSB pieces.

The work of this Commission was next taken up in 1995 by the Committee on Education and Human Resources (CEH) which was active for 20 years. Its activities included producing reports and statements on STEM education and the STEM workforce, providing guidance to NSF management on strategic priorities, exploring issues of particular relevance to NSF (e.g. NASEM reports, OSTP reports, reports of the President’s Council of Advisors on Science and Technology (PCAST)), and increasing Board members’ general knowledge about STEM education research, related NSF-funded research, and associated policy issues. CEH was disbanded in 2016 as a result of restructuring of the Board’s committees – much of its work was absorbed by the Committee on Science and Engineering Policy (SEP) predominately via *Science and Engineering Indicators* and by the Committee on Strategy (CS).

In its *Vision 2030*, NSB suggested two actions regarding preK-12th grade STEM education:

1. Support NSF strategies to further the broad adoption and use of NSF-funded STEM education research, including research on teaching critical thinking, problem-solving, creativity and digital literacy, and on STEM pedagogy and practices for diversity and inclusion.

2. Advocate for more science and engineering teaching in K-12 education, with an emphasis on increasing contact hours and exposure to science in early education and improving the quality of STEM education at all levels.

In addition, *Vision 2030* stated that the “U.S. needs ‘all hands-on deck’ to modernize its education system and reinvest in public K-12 and post-secondary education in order to support the STEM skills that workers will need throughout their careers.” To ensure that the preK-12th grade STEM educational space is integrated in the Board’s broader focus on Talent Development, ESKE was launched *to identify specific NSB value-add to the national STEM education discourse*. The focus was on actionable items and working to fulfill *Vision 2030*. The following report details ESKE’s 18-month process, data collection and analysis, and final recommendations for action areas presented to the full Board at the May 2023 Board meeting. Specific action-oriented recommendations for Board committees and working groups are laid out in the body of the main report – see **Recommendations** section.

Phase I – Defining ESKE Scope

To help guide their work, ESKE planned to adopt the strategy successfully employed by the Skilled Technical Working Group in 2017. This included first defining its scope to identify NSB-specific topic areas (see Mission Statement below).

Mission Statement: The mission of the National Science Board (NSB; Board) Explorations in STEM K-12 Education (ESKE) working group is to systematically evaluate the levers NSB must improve within the K-12 STEM education landscape. ESKE’s activities will include exploring opportunities and challenges related to K-12 STEM education systems, students, and educators, considering relevant data and studies, and engaging with diverse stakeholders within and outside of the government, through meetings, roundtables, and listening sessions. ESKE will report regularly to the Board on its activities and lead a discussion at the October 2022 NSB Retreat on its findings and possible goals and actions for Board consideration.

Rationale: The formation of ESKE stems from NSB’s commitment to Talent Development outlined in *Vision 2030*. Specifically, it is motivated by the nation’s **lackluster** and stagnant academic achievement in science and mathematics. In addition, disparities in average science and mathematics achievement among student populations by race, ethnicity, and socioeconomic status must be addressed to ensure that all Americans benefit from the S&E ecosystem. To maintain its global standing as a **keystone nation**, the U.S. must support all parts of the S&E enterprise, including the nation's largest talent pool: K-12 students interested in STEM. Long-term, strategic investments in K-12 STEM education will help meet the needs of a growing U.S. STEM workforce and ensure that the U.S. remains globally competitive for decades to come.

Phase II – Listening Sessions

To fulfill its mission of systematically evaluating NSB-specific levers in the K-12th grade STEM education space, ESKE listened to a broad and substantive cross-section of experts, including the Department of Education, teacher groups (professional associations, classroom teachers, and administrators), STEM education researchers, researchers, and the National Science Foundation. The full list of participants can be found in **Appendix II**.

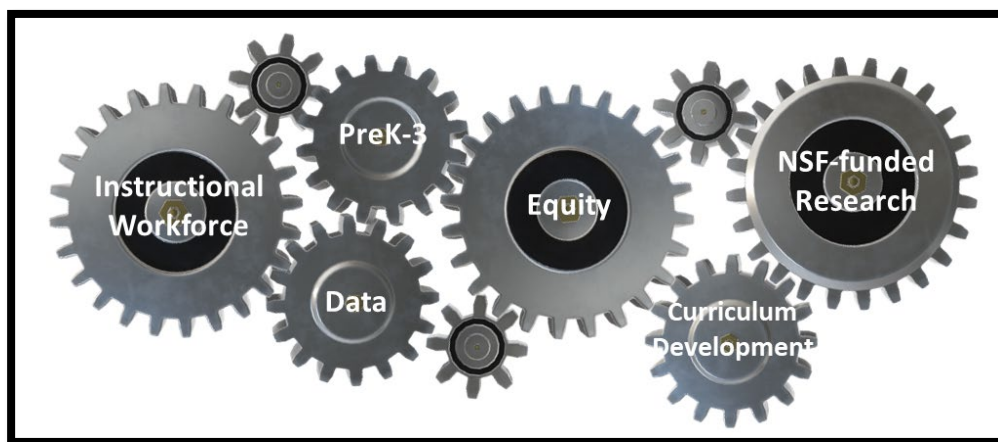
Data from NASEM reports, academic literature, previous NSB reports on the subject, and NSF reports was also assessed (full list in the **Reference** section at the end of the Appendix). Finally, ESKE – along with other members of the Board and the public – heard from educational experts across two Board meeting public engagement panels:

The Uneven Geography of K-12 STEM Education

Panelists: Pam Buffington (Director of Rural STEM Initiatives, Education Development Center), Brandy Huderson (Assistant Professor of Biology, University of the District of Columbia), Eric Jolly (President & CEO, Saint Paul & Minnesota Foundation, Michael Guarraia (Albert Einstein Distinguished Educator Fellow)

Beyond the Test Scores: Into the Pre-K-12th Grade STEM Classroom

Panelists: Vidalina Treviño (Albert Einstein Distinguished Educator Fellow), Sarah Leaman (4th Grade Teacher; Master Teacher Fellow, Math for America), Shakiyya Bland (Math Educator in Residence; Just Equations), Jennifer Kennedy (PK-3 STEM Specialist), Michael Lach (Assistant Superintendent for Curriculum, Instruction, and Assessment)



Based on the culmination of data analysis and expert and partner engagement, ESKE organized the information into five interdependent topical areas – broadly instructional workforce, curriculum development, NSF-funded research, preK-3rd grade, equity, and data. Each area is

defined below and includes a general overview of what ESKE members learned. In addition, specific recommendations by listening session participants were made and can be found in **Appendix III**.

Note: The following sections and content herein do not represent or imply endorsement by ESKE or NSB. They are included as a historical documentation of what was shared with ESKE by listening session participants and panelists. Quotes from listening session participants and published report data are identified as such.

On STEM Teacher Recruitment, Retention, and Support

ESKE members heard that preK-12th grade education in general has become a high-stress profession. Teachers are expected to provide academic content, socio-economic development support, address food insecurity, and provide physical protection, while existing at the crossroads of culture wars where their content can be legislatively censored. While wrap-around service expectations and social pressures are increasing, these growing responsibilities are not matched with pay increases (which have stagnated), professional respect, or increases in professional development including expanded professional networks.

Individuals looking to enter teaching as a profession, as well as current teachers, highlighted the following concerns:

- The educational debt to income ratio is high, especially for STEM education students
- Little to no time is provided for *paid* professional development that typically occurs during weekdays, instead of weekends
- Lack of professional networks, particularly in rural areas where STEM teacher to school ratios are high (in some cases, there is only one teacher for an entire *district*) and in high-poverty areas where the teacher workload is higher
- Perceived low social value – teachers are not valued for their expertise
- Teachers have low autonomy in the classroom

On the STEM teacher shortage issue specifically, ESKE heard different perspectives. National data suggests that recruitment, rather than retention, is the major labor force driver for the teacher shortage, while local perception suggests that retention (especially within the first three years) is a major driver. Increases in teacher turnover now appear to be driven now primarily by teachers with less than 5 years of experience, whereas in 2020 (at the onset of the COVID-19 pandemic), it was driven by mid- and late-career stage teachers. The pandemic has exacerbated teacher recruitment and retention efforts particularly in high poverty schools (see discussion in **Equity** section).

Different states – and even different districts within states – experience differential strain to teaching hiring, with variable pools of viable candidates. The teacher shortage issue requires a

nuanced set of solutions, especially since there is great geographic variability in the causes of the shortage. The numbers from colleges of education are more clear-cut in painting a national picture. Jacqueline Rodriguez from the American Association of Colleges for Teacher Education (AACTE) reported to ESKE that in 2020 / 2021, 40% of AACTE members reported enrollment drops of 10% or more, resulting in fewer educators overall entering the instructional workforce.

On STEM Teacher Preparation, Translation of Research, and Content and Curriculum Development

Participants across different listening sessions highlighted that high-quality teachers know the content material, the craft of teaching, and their students – all three are critical. Recruitment (see above) must be about training teachers properly, not just increasing numbers. ESKE learned that teachers can impact students for good or for harm – listening session participants mentioned that two good teachers back-to-back (especially in the early years) can move a student from the lowest performance quartile to the highest performance quartile. Good teachers know content *and* how their students think and approach that content. Thus, teacher preparation must actively include the *practice* of teaching, not just content learning, which is currently the primary focus of teacher preparation and professional development.

The practice of teaching requires:

- *Understanding* the students, the knowledge they are already bringing to the classroom, and their experiential frameworks. This understanding allows educators to engage students in content relevant to them (increasing student success), to develop student-centered pedagogical practices that are particularly amenable to STEM content, and to cut through some of the systemic barriers for students most under-served by current educational models. This student-centered approach was highlighted in [The Uneven Geography of K-12 STEM Education](#) panel as well.
- *Curriculum literacy* (as opposed to curriculum building) allows educators to assess and adapt content for their students. Over 90% of teachers use internet searches to identify content material to build their STEM lesson plans, without having strong *curriculum literacy* that enables them to separate good from harmful or inaccurate content. The majority of educators do not use evidence-based approaches when building their lesson plans.
- *Access* to well-articulated, easy to implement, evidence-based STEM interventions and content material.

Two main access points for STEM educational content were discussed by multiple participants – the [What Works Clearinghouse](#) (WWC) and [Regional Educational Laboratories](#) (RELs). The WWC was built by the Department of Education’s Institute of Education Sciences (IES) for educators and content developers to easily identify evidence-based interventions. It has been and

continues to be highlighted by NSF's EDU directorate as a landing place for NSF-funded STEM pedagogical research. Multiple participants stated that the WWC is hampered by limited data and maneuverability. The number of interventions for math and science are 155 and 12, respectively, they are poorly disseminated, and there is a paucity of data on equity issues in STEM classroom practice. By contrast, RELs – established by the Education Science Reform Act to disseminate information to classrooms across the US – were more favorably discussed across three listening sessions, although dissemination and use of data are still problematic. Participants stressed that technical assistance to increase the use of educational databases must be integrated into solutions.

A number of educators who participated in the ESKE listening sessions mentioned a desire to see increases in accessibility of teacher-to-teacher peer mentoring programming, increases in master teacher designation, and peer networking. While the initiation of these practices would require a larger time commitment upfront, maintenance would likely require several in-service days per year.

Final overview point: Unlike other professions, teachers lack a “clinical training” (residency) phase in their training, as well as performance measures that assess individuals *before* they are granted license to practice. The lack of these components in certification are unacceptable in many professions and should be practices that are emphasized and required for teacher certification.

On The Early Curiosity-Driven Years

The early curiosity-driven years are defined as preK-3rd grade. ESKE heard that young children have an inherent brilliance and that their interaction with the natural world lends itself to a mathematical, scientific, and engineering framework that may be taught *out* of them through the formal STEM education they receive. The largest jump occurs at the kindergarten level (“a mathematical wasteland”) where students enter with stronger mathematical thinking skills than when they depart. Coherence between transition points (*eg.* PreK to K and 4th grade to 5th grade) needs to be part of a comprehensive STEM education strategy. To implement STEM teaching in early education requires long-term investment (on the 5-year timeframe at a minimum) across entire school districts. Often early education teachers are incorporating some STEM learning into their teaching, however outside of math, they are not articulating science and engineering activities as such. Listening session participants who intersect with students at all ages highlighted repeatedly that what happens in elementary school impacts the interest and excellence of middle and high school students – *“This age level must be a federal priority.”- Listening session participant*

Fostering a strong STEM education for the early curiosity-driven years involves:

- More educational developmental research, particularly in science and engineering, for this age group
- An integrative approach – not merely increased classroom hours spent on science. Integration, particularly through an engineering lens, matches the experiential approaches to which kids of this age group are naturally drawn
- Higher pay for early education teachers – nationally, preschool teacher median pay in 2022 was almost 60% less than that of elementary and high school teachers [Census 2022]
- Making this age group a priority for the Department of Education research and funding
- Making this age group a priority for the NSF
- Creating more experiential learning experiences sponsored by federal agencies, schools of education, and local/state/national partnerships for preK-3rd graders
- Creating content that is *specific* to preK-3rd grade students, not content that is modified from that developed for older students

On NSF Strategy to Fund Impactful Research / Programming

Multiple presenters mentioned that the problem with educational research is not just translation into the classroom, but that the research itself is out-of-touch with the needs of educators and schools. The work done by the academic community does not serve preK-12th grade students because it does not focus on the questions that *educators* need answered.

This disconnect is driven by several factors:

- Research-practice partnerships have a power and trust imbalance.

“When academics come to us to be partners, we are incredibly disenfranchised. We are the low people on the totem pole, so when some academic from a fancy institution with NSF money comes to partner with us, we don’t speak that language, we don’t have the same power to say – no, you should be focusing on this, instead of that.” - Listening session participant

Teachers are not treated like the experts that they are. Giving teachers agency in research problems is critical. Because the research questions often do not focus on the needs of the community, teachers do not trust academics. Instead, they rely on more experienced teachers for information and content development, which may be outdated.

- The change in the educational field away from “does an intervention work” to “what are the conditions and context for this intervention to be most successful.” This relies on teachers, department chairs, principals, etc. who understand that their local

communities must be pulled into the educational-research partnerships *early* in the process.

Academics have to *“work closely with teachers and school leaders to figure out not just what works, but what works for which kids and for which teachers in which schools in which districts to get the kind of results we want for kids.”* - Listening session participant

- NSF’s Merit Review process does not use a targeted approach for what schools need. For example, when the Next Generation Science Standards (NGSS) were rolled out, the Merit Review process became a hinderance in generating material needed to implement NGSS-based curriculum. The Merit Review process blocked out NSF from more actively participating with the national movement on NGSS implementation. Other suggested funding vehicles discussed included Rapid Response Research (RAPID) grants, discretionary funding the ADs have, and new solicitations that can be written to target funding in specific areas (currently solicitations are too broad).

“Do more of that. Be much more targeted. The political risk is that some people will not get to fund what they want, but if you show leadership and are targeted, you’ll end up being better for the country.” - Listening session participant

- Published research does not offer a serviceable product for educators – what is needed includes a module or kit that the educator can use immediately that helps the teacher create opportunities, save time, improve curricular content.
- Funded research is more about getting researchers tenure than about educator, school, or student needs.

In addition, data on how the EDU directorate divides its funding across different STEM disciplines and classroom needs – how much on math, how much on science, how much on teacher prep, how much on curriculum development, how much on systems change how much at each grade level, etc. – is not collected and / or made public. This makes it difficult to ascertain if NSF is funding the best proportion that aligns with the needs of the nation. It also makes it difficult to determine which investments are best to scale up to improve preK-12 outcomes more broadly.

“I think we have got to be smart and we need to think about how we make the kinds of incremental change over each term of an administration and buffer things so... we can keep going. I’ve never seen NSF play that kind of game that I know NASA and the Department of Ed play. So, I’d encourage you to think in those big systems perspectives. And collect data on how the funding is done so you know where you are going.”

- Listening session participant

On Equity

ESKE heard that differential access to quality STEM preK-12 education in the United States continues to be an impediment for millions of students. These data are corroborated by *Science and Engineering Indicators* data and have been highlighted by NSB, most recently in [The U.S. Must Improve K-12 STEM Education for All](#) (Figure 1).

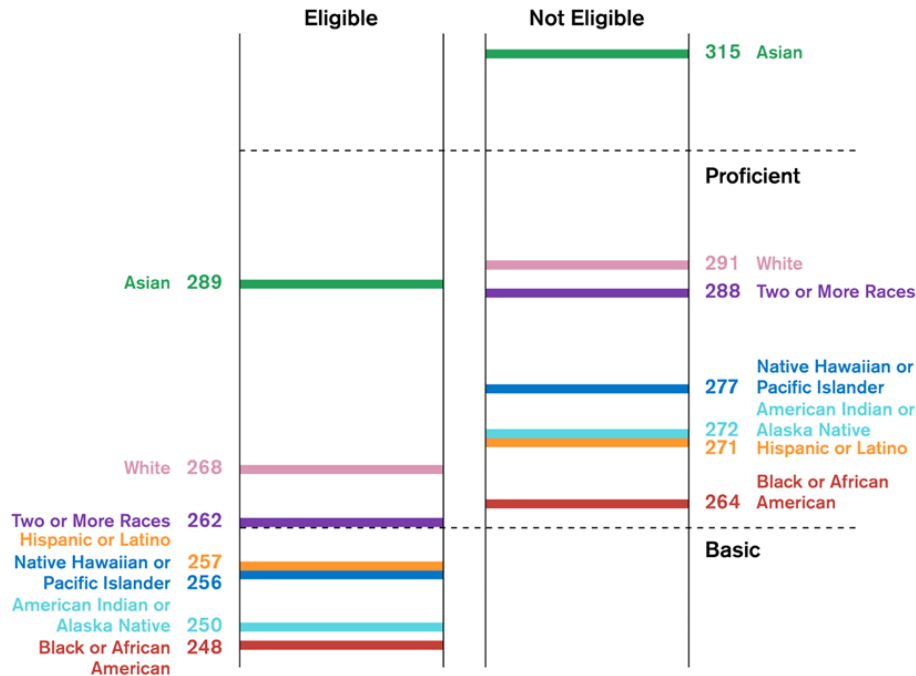


Figure 1: Average score for 8th grade students on the National Assessment of Educational Progress (NAEP) mathematics assessment, by race, ethnicity, and eligibility for free or reduced school lunch show large gaps in STEM achievement. Derived from NSB’s 2022 policy piece: [The U.S. Must Improve K-12 STEM Education for All](#)

Poverty is the major driver of geographic inequities. Students in poverty-stricken districts continue to be impacted by:

- Teachers who are carrying higher wrap-around / social safety net loads
- Teachers who more likely to have had a non-comprehensive education
- Teachers who do not have or who do not explore the unique experiential frameworks their students bring to the classrooms
- Higher mental health stress
- Higher teacher turn-over rates

- Large class sizes
- Lack of funding for teacher professional development
- Limited access to technologies
- Limited access to broadband

Equity is also affected by a teacher workforce that is disproportionately impacted by educational debt burden, lack of professional support, limited certification, and systemic bias – all of which most impact teachers of color, teachers from low-socio-economic backgrounds, and teachers isolated geographically from each other and / or from major colleges of education. The AACTE reported to ESKE that white teachers comprise 75% of the instructional workforce (compared to all fields at 62%), Hispanics at 11% (compared to 15%), Black at 7% (compared to 13%), and Asian/Pacific Islander 2% (compared to 7%).

Teacher solutions *must* include diversification of the instructional workforce. While all students benefit from a diversity of teachers, robust data sets show that Black teachers – over white teachers – have dramatic impacts on the positive trajectory of their Black students. This diversification has benefits for millions of students and means that solutions to improve teaching outcomes and attractiveness of teaching careers for teachers of color and those without generational wealth is essential.

“Culturally responsive teaching, social justice issues, environmental justice issues, and respect for those that have teaching and education careers are all part of the systemic issues facing education in the future. STEM is uniquely poised to tackle some of these issues, and doing so through equity lenses can only benefit marginalized students.”

– Listening Session Participant

On federal agencies – IES admitted that they have not done a good job tracking their grants to see the reach of diversity, although many grants target populations with higher needs. They are currently rethinking their annual reporting mechanisms to better track impact.

Finally, teacher-student relationships dictate student success. Some students are given diets of science and math, others are not. Early sorting (often dictated by teacher / systemic bias) impacts long-term success and who enters college. Student trajectories are impacted by whether they are in class or not, and the disproportionality of suspensions assigned to students of color is a crucial factor. Although the causes of this disproportionate discipline require further study, the effects persist: students of color have their academic work interrupted to a greater degree due to more frequent school suspensions (Department of Education, Civil Rights Data Collection; Epstein, Blake, and Gonzalez. 2017). These disciplinary measures exclude students from in-class time, leading to lack of engagement and progress in school – the very same students that are often missing from STEM careers. Improving the practice of teaching can directly impact the Missing Millions entering STEM education and the STEM workforce.

On Standards, Assessments, and Data Availability

STEM *standards* were discussed broadly in the context of curriculum literacy / content and teacher education, and specifically, with the adoption of the Next Generation Science Standards (NGSS). The NGSS were built on a large body of scientific and educational evidence. They integrate science, engineering, and math in the performance expectations, with an emphasis on flexible curriculum building. They marry concepts with methodology to increase experiential learning and are dependent on administrative support for teacher professional / curriculum development.

Discussions on *assessments* – particularly their utility and accuracy – occurred in most listening sessions. Varying opinions reflected the political volatility around assessments in the national discourse. The largest point of agreement among participants was that current national and state assessments do *not* match well with content being taught and do not acknowledge the variety of larger social frameworks that the heterogeneous US population has (*e.g.* Indigenous approaches, rural vs. urban). Several participants stated that assessments need to align with the country's educational values, and when it comes to STEM, need to be less content-driven and more process / problem-solving driven. Many listening session participants advocated for local assessments to be incorporated into national assessment platforms, with some push for portfolio versus test-only assessments to be used. While science assessments in early years was encouraged by NSTA to increase science hours in the classroom, others cautioned that pitting science and engineering against math and literacy was a hard hill to climb and, ultimately, not beneficial. Rather, they countered that an integrated curricular approach is better for student learning and is more feasible politically. Finally, early childhood experts reiterated that the brilliance of young children is underestimated because assessments don't match what children inherently know.

Missing or incomplete *data* sets were alluded to in almost all sessions. They included:

- STEM teacher recruitment and retention by district and state, disaggregated by race, ethnicity, SES status, gender, etc.
- Survey data by state / district on teacher departures, including retirement
- Production of STEM preK-12 teachers per state compared to district and state vacancies and future needs
- Data on education graduates – by demographic identifiers, but also grade (*eg.* early education versus middle school) and debt load (disaggregated by teacher demographic identifiers)
- Measured impact of NSF-funded EDU research

- Longitudinal data on student success for those who have received a variety of STEM interventions from What Works Clearinghouse, RELs, and other NSF-funded EDU research
- Number of educational researchers focused on early education in science, engineering, and technology

Note: Much of the “missing data” are likely housed in state educational databases. Centralizing and making accessible that data has proven politically and fiscally challenging.

Phase III – Data Analysis and Identifying Opportunities for Action

Phase III was divided into three subsections. In the first, ESKE reviewed the quantitative and qualitative data collected in Phase II as well as the curated list of action items generated directly from listening session participants (see **Appendix III**). This list was cross-checked during ESKE meetings against previous and current NSB work in this space. Discussion involved consideration of which (if any) of these priorities could be buoyed by recent legislative action, particularly the CHIPS and Science Act (see **Table 2**).

These conversations and the review of data from educational experts culminated in the second part of Phase III – generating a list of ESKE priorities to bring to the full Board. The list of priorities was whittled to 13 and were presented to the full Board at the NSB meeting in February 2023. At the request of the Chair and Vice-Chair, ESKE members used a weighted-voting system to vote on their top two internally-facing and top two externally-facing priorities. This part included votes from the newly onboarded NSB members. The results were presented at the NSB May 2023 meeting to the full Board.

In reviewing ESKE’s documents and notes across the 18-month period, NSB member Wanda Ward suggested an organizational framework to better capture all of ESKE’s priorities. The four topical bins proposed – instructional workforce, research, equity, and accountability – reflect ESKE’s original listening sessions topics and support points raised by several ESKE members over the 18 months. ESKE obtained the support of the Chair and Vice-Chair to present these topical bins in ESKE’s final **Recommendations** (see section under **Executive Summary**).

Appendix II

Listening session participants

- From the National Science Teachers Association ([NSTA](#)): Erika Shugart, Elizabeth Mulkerrin, Julie A. Luft
- On the “Teacher shortage – Who, why, where?” listening session panel: Dan Goldhaber (Washington University; Center for Analysis of Longitudinal Data in Educational Research – [CALDER](#)); American Institutes for Research – [AIR](#)), Jacqueline Rodriguez ([American Association of Colleges for Teacher Preparedness](#)), Nate Schwartz ([Annenberg Institute](#)), John Ewing ([Math4America](#))
- From the NextGen Science Standards ([NGSS](#)): Jenny Sarna, Tanuya Nesin, Vanessa Wolbrink
- On the “S&E in the early curiosity-driven years” listening session panel: Doug Clements ([NASEM Report](#)), Megan Franke (UCLA; Development and Research in Early Mathematics Education – [DREME](#))
- From the Department of Education: Christina S. Chinn ([NCER](#)), Megan Vinh (Director, STEM Innovation for Inclusion in Early Education – [STEMIE](#)), Patti Curtis, ([NOYCE](#) fellow)
- On the “Using what works – Translation of STEM pedagogical research into the classrooms” listening session panel: Deborah Ball (University of Michigan and [TeachingWorks](#)), Gillian Roehrig ([NARST](#)), Rachel Dinkes ([Knowledge Alliance](#)), Sylvia Butterfield (AAD, EHR – now EDU), Karen Marongelle (NSF)
- On the “[Albert Einstein Distinguished Educator Fellows](#) Alumni” listening session panel: Gretel von Bargen, Pascale Pinner, Jennifer Kennedy, Doug Hodum, Kellie Taylor, Michael Lach, Channa Comer
- Through one-on-one listening sessions: Camilla Benbow (Vanderbilt) – [link](#); Deborah Ball (University of Michigan and [TeachingWorks](#)); James Moore (EDU Directorate, NSF)

Appendix III

Top actionable items for NSB and NSF

Suggested by listening session participants

All listening session participants were specifically asked what action items they would recommend to NSB (both internally and externally) and to NSF. The following list is a compilation of their answers.

- Paid internships for the last semester of teacher training
- Paid and time-off for professional development
- Increase teacher salaries based on salary differentiation scale – pay teachers in high demand areas more
- Improve educator networks to reduce isolation
- Return of the [Eisenhower program](#)
- Expand [Robert Noyce Teacher Scholarship program \(NOYCE\)](#) and support structures for NOYCE programs at smaller schools
- Use NOYCE and other funded incentives or start a residency program by using already established funding to reduce tuition / loans
- Bring more science assessments and at earlier years
- Encourage collaborative Broader Impacts funding which allows for higher impacts for students and schools that are at higher risk
- Increase funding for STEM alliances
- Loan forgiveness for STEM educators
- Develop short-term programs on distance learning to broaden reach to students and geographically isolated STEM teachers
- Increase tutoring programs to expand touchpoints between teachers and students
- Use labor market need signals – candidates should know what their job prospects are per district and school; districts need to allocate more slots according to need
- Create an applied science route for educators
- Increase teacher portability /teaching credential portability
- Start considering preK-12 teachers as part of the STEM community – not just an auxiliary part
- Develop fellowships / grants to the most excellent teachers (modeled after the [Math for America](#) (MJA) program)
- Create communities of accomplished STEM teachers who work together professionally (again modeled after the MJA program)

- Develop partnerships with districts – high quality educators prepared by high quality mentors who have sustained relationships with their communities
- NSB could be early endorser of inter-state contracts
- NSF needs to invest in the research and development around coherent instructional materials – simply writing a module is not enough
- Engage in the PreK – 5th grade space. It is the most neglected set of years.
- NSF funding that allows teachers to build local partnerships
- Funding cycles that are longer in length so that student progress has time to be measured
- Create opportunities for PreK educators to talk to K educators – create systems to enable that communication
- Integrate STEM content, particularly during the early years – engineering is a natural integrator
- Funding in education that allows for cross-sectional and longitudinal studies needs to be increased – critical for scale and timelines
- Increase funding in understanding how PreK students learn – are we meeting the needs of all the people in this country?
- Increase number of researchers in early STEM education
- Work with faculty at institutions that prepare PreK education students (community colleges and state colleges)
- Increase early education STEM teachers
- Increase PreK-4th grade teacher salaries – currently do not support teacher survival
- Increase STEM content in pre-service
- Capitalize on COVID-19 opportunities to integrate technologies and tools
- Need national “you are brilliant” student campaign
- More after-school opportunities for STEM learning
- Informal learning needs to be increased – “Nothing worth doing is funded at the level of implementation and dissemination”
- Flip science teaching through an engineering, hands-on approach
- Increase partnerships between in-class and out-of-class educators
- Have longitudinal systems and assessment databases
- Different data and different curriculum vendors
- Figure out how to better navigate a data rich yet information poor environment re: outcomes
- Increase interaction with RELs
- Everything we discuss runs through relationships – teaching is not straight implementation but also not just about making it all up. We don’t have a balanced view between those two
- Decrease failure rate to connect with research
- What does it look like to more robustly connect on public education
- Improve communication within the classrooms

References

NSB History in the K-12 STEM Education space

- NSB Retreat Planning Working Group (Memo, 2021)
- [The U.S. Must Improve K-12 STEM Education for All](#) (One-pager, 2021)
- [National Action Plan for Addressing the Critical Needs of the U.S. Science, Technology, Engineering, and Mathematics Education System](#) (NSB Plan, 2007)
- [Educating Americans for the 21st Century](#): A plan of action for improving mathematics, science and technology education for all American elementary and secondary students so that their achievement is the best in the world by 1995 (NSB Plan, 1983)

General Reports

- [Call to Action for Science Education: Building Opportunity for the Future](#) (NASEM, 2022)
- [Progress Report on the Implementation of the Federal STEM Education Strategic Plan](#) (OSTP, 2021)
- [Improving Integrated STEM Education: The Design and Development of a K-12 STEM Observation Protocol](#) (2021)

Pre-K to 3rd grade

- [“Science and Engineering in Preschool Through Elementary Grades: The Brilliance of Children and the Strengths of Educators”](#) (NASEM, 2022)
- [Addressing the Impact of COVID-19 on the Early Care and Education Sector](#) (NASEM, 2022)
- [“Can you help me count these pennies?”: Surfacing preschoolers’ understanding of counting](#) (Megan Franke, 2018)
- Social Policy Report: [PK-3: What Does It Mean for Instruction](#) (DREME, 2017)
- [STEM Starts Early: Grounding science, technology, engineering, and math education in early childhood](#) (New America Report, 2017)

Teacher Shortage

- [A Coming Crisis in Teaching? Teacher Supply, Demand, and Shortages in the U.S.](#) (Learning Policy Institute overview, 2016) – full report [here](#)
- [Characteristics of Public School Teachers](#) (2021)
- [Characteristics of Public School Teachers Who Completed Alternative Route to Certification Programs](#) (2018)
- A Vision and Roadmap for Education Statistics (NASEM, 2022 – Summary Page and Summary of Recommendations only – full report [here](#))
- [NSTA Strategic Plan infographic](#)
- Math for America: [Who We Are](#) and the [M|A Model](#)

Next Generation Science Standards

- Science Education in the 21st Century: [Why K-12 science standards matter](#) – and why the time is right to develop Next Generation Science Standards (2012)
- [NGSS Development Overview](#)
- [Key Takeaways](#) from the Early Years of Transforming Science Education for the Next Generation (2020)

Equity

- [Department of Education Civil Rights Data Collection](#)
- [Girlhood Interrupted: The Erasure of Black Girls' Childhood](#) (2017)