The National Academies of SCIENCES ENGINEERING MEDICINE

BOARD ON SCIENCE EDUCATION

Science and Engineering in Preschool through Elementary Grades:

The Brilliance of Children and the Strengths of Educators

Sponsors:
Carnegie Corporation of New York
Robin Hood Learning + Technology Fund

Charge

Provide guidance on effective approaches to science and engineering instruction in PreK-5 that support success of all students.

- What kinds of **learning experiences prior to entering school** will help prepare children for science and engineering learning in elementary grades?
- What are **promising instructional approaches** for enhancing science and engineering in preK-5? What is necessary in order to implement these approaches? How do these need to be adapted to meet the disparate needs of students?
- How can science and engineering be connected to, or **integrated with**, other subject areas such as mathematics, computer science, and English Language Arts?
- What is the role of **curriculum and instructional materials**?
- What **professional learning opportunities** are needed?
- How do **policies and practices** at the national, state, and local level constrain or facilitate efforts to enhance science and engineering in preK-5? How might policies and practices need to be changed to enhance science and engineering for all students?
- What are the **gaps in the current research base** and what are the key directions for research, both short-term and long-term?

Committee and Study Staff

COMMITTEE

ELIZABETH A. DAVIS (Chair)
University of Michigan

HEIDI CARLONE
Vanderbilt University

JEANANE CHARARA
SOLID Start, Michigan State University

DOUGLAS CLEMENTS
University of Denver

KATIE MCMILLAN CULP
New York Hall of Science

XIMENA DOMÍNGUEZ
Digital Promise

DARYL GREENFIELD
University of Miami

MEGAN HOPKINS
University of California, San Diego

EVE MANZ
Boston University

TIFFANY NEILL
Oklahoma State Board of Education

K. RENAE PULLEN
Caddo Parish Public Schools, Shreveport, LA

WILLIAM SANDOVAL
University of California, Los Angeles

ENRIQUE SUÁREZ
University of Massachusetts

CARRIE TZOU
University of Washington, Bothell

PETER WINZER (NAE)
Nubis Communications

CARLA ZEMBAL-SAUL
Pennsylvania State University

STUDY STAFF

AMY STEPHENS
Study Director

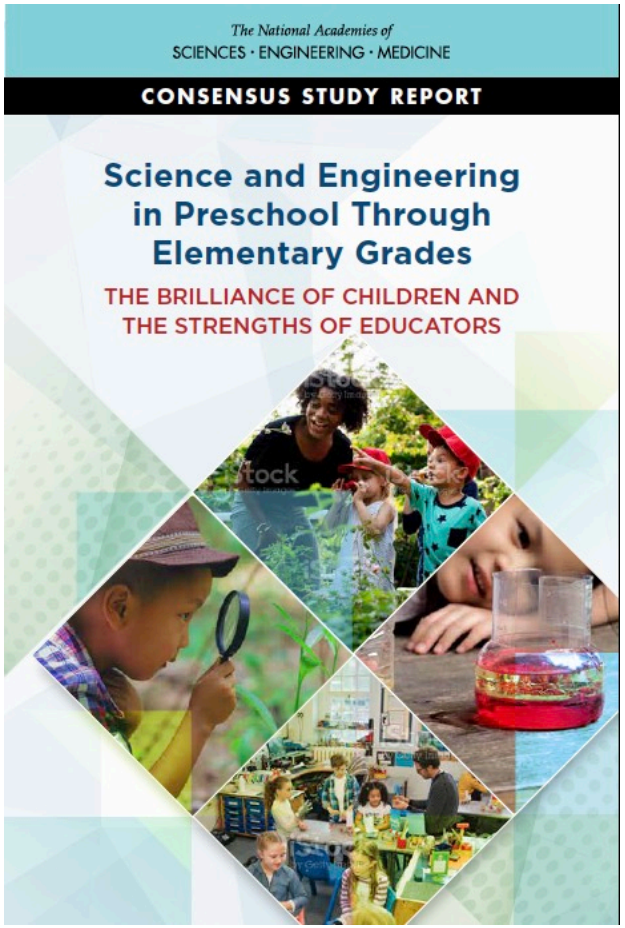
MARGARET KELLY
Senior Project Assistant

TIFFANY TAYLOR
Program Officer

HEIDI SCHWEINGRUBER
Director, Board on Science Education

The National Academies of | SCIENCES ENGINEERING MEDICINE

Report



- Systems and Structures (Ch 2)
- Contextual Nature of Learning (Ch 3)
- Developing Proficiency (Ch 4)
- Learning Environments and Instructional Practices (Ch 5)
- Integrating Across Domains (Ch 6)
- Curriculum and Instructional Materials (Ch 7)
- Supporting Educators (Ch 8)
- Transformative Leadership (Ch 9)

Equity and Justice

- **Four approaches to equity used in the report**
  1. Increasing opportunity and access to high quality science and engineering learning and instruction
  2. Emphasizing increased achievement, representation, and identification with science and engineering
  3. Expanding what constitutes science and engineering
  4. Seeing science and engineering as part of justice movements

Prioritizing Science and Engineering in Preschool through Elementary Grades

- Children engage in meaningful science and engineering from a very young age, across multiple contexts and settings
- Science and engineering instruction is under-resourced and not highly prioritized in preschool through elementary schools

The National Academies of | SCIENCES ENGINEERING MEDICINE

Prioritizing Science and Engineering in Preschool through Elementary Grades

On average, substantially less instructional time is devoted to science and engineering compared to ELA and mathematics.

Prioritizing Science and Engineering in Preschool through Elementary Grades

- Instructional policies, standards, and teaching practices lack alignment and coherence.
- Limited research on children with learning disabilities and/or learning differences
  - engage in and experience science and engineering
  - forms of support that might be helpful

Prioritizing Science and Engineering in Preschool through Elementary Grades

RECOMMENDATION 1: State policymakers should establish policies that ensure science and engineering is comprehensively, frequently, and consistently taught in all preschool through elementary settings. The policies should also ensure that children are not being pulled out of science and engineering instruction for remediation in other subjects.

Prioritizing Science and Engineering in Preschool through Elementary Grades

RECOMMENDATION 2: District and school leaders in elementary and preschool settings should examine the amount of time and resources allocated to science and engineering instruction and then (a) develop schedules that allow a comprehensive, frequent, and consistent focus on science and engineering, (b) create coherence from preschool through elementary, and (c) allocate the necessary resources (fiscal, material, and human) to support equitable science and engineering learning opportunities.

Prioritizing Science and Engineering in Preschool through Elementary Grades

RECOMMENDATION 3: Preschool and elementary school leaders should evaluate the characteristics of classroom instruction, the qualifications of teachers hired and whether the hiring practices serve to promote educator diversity, and the professional learning opportunities offered to teachers so that adjustments can be made as needed to support and enhance teachers' capacities for teaching science and engineering well.

Prioritizing Science and Engineering in Preschool through Elementary Grades

RECOMMENDATION 4: State leaders, district leaders, and researchers should work together to build connections across preschool and elementary school and to conduct research to investigate how alignment and coherence across preschool through elementary supports children's learning or science and engineering.

The National Academies of SCIENCES ENGINEERING MEDICINE

Supporting Children's Learning, Engagement, and Proficiency in Science and Engineering

- Science and engineering learning experiences provide opportunities for children to identify as people who do and value science and engineering.

- See increases in motivation and disciplinary affiliation when children …
  - are provided opportunities to explore questions that matter to them and
  - are recognized as knowledge-producers and problem solvers.

The National Academies of | SCIENCES ENGINEERING MEDICINE

Supporting Children's Learning, Engagement, and Proficiency in Science and Engineering

RECOMMENDATION 5: To draw on and further develop children's science and engineering proficiencies and identities, teachers should arrange their instruction around interesting and relevant phenomena and design problems that leverage children's natural curiosity and give children opportunities for decision-making, sensemaking, and problem solving.

Supporting Children's Learning, Engagement, and Proficiency in Science and Engineering

- Families (broadly defined) are essential partners.

- Development and expression of proficiencies is related to …
  - knowledge,
  - experiences,
  - cultural and linguistic backgrounds, and
  - characteristics of instructional environment and pedagogical approaches.

Supporting Children's Learning, Engagement, and Proficiency in Science and Engineering

Children's development of ideas and practices is supported by their own intuitive and imaginative ways of investigating and designing as well as by …

- long-term sustained experiences,
- rich settings and materials (including age-appropriate technologies), and
- engagement with peers and knowledgeable others.

The National Academies of SCIENCES ENGINEERING MEDICINE

Supporting Children's Learning, Engagement, and Proficiency in Science and Engineering

- Children can share, use, connect, and develop their understanding of big conceptual ideas in science and engineering when instruction…
  1) is anchored in design problems and phenomena that are conceptually rich, accessible, and meaningful to children and
  2) provides supports for children to iteratively refine their explanations and solutions.

- Science and engineering learning are social endeavors.

Supporting Children's Learning, Engagement, and Proficiency in Science and Engineering

- When teachers elicit, notice, value, and build on ideas, experiences, and communicative resources children bring, they can support children in making sense of the natural and designed world.

- Robust formative assessment approach…
  - provides appropriate supports,
  - includes multiple modalities, and
  - specifies a way of making inferences about children's understanding.

Supporting Children's Learning, Engagement, and Proficiency in Science and Engineering

RECOMMENDATION 6: Teachers should enact science and engineering learning experiences that establish norms for a caring, collective culture and position children as active thinkers and doers while also providing opportunities to support collaboration and collective thinking.

RECOMMENDATION 7: Teachers should include formative assessment processes that gather multiple forms of evidence at multiple timepoints, with the goal of informing instruction.

Supporting Children's Learning, Engagement, and Proficiency in Science and Engineering

RECOMMENDATION 8: Teachers should seek out opportunities to continue to build their expertise in working toward equity and justice in their science and engineering teaching.

The National Academies of SCIENCES ENGINEERING MEDICINE

Supporting Children's Learning, Engagement, and Proficiency in Science and Engineering

RECOMMENDATION 9: Preschool and elementary school leaders and teachers should engage and collaborate with families and local community leaders to mutually support children's opportunities for engaging in science and engineering. Such collaboration allows for leaders and teachers to design learning experiences that are meaningful and relevant to children and helps families to better support their children's learning outside of school.

Curriculum and Content Integration

- Integration has the potential to
  - enhance connections between subjects (e.g., ELA, math, computational thinking) and
  - effectively increase amount of instructional time for science and engineering.

- Integration can benefit all domains if design…
  - respects unique content and disciplinary practices of all domains,
  - leverages meaningful and mutually supportive connections among subject areas, and
  - is developmentally, culturally, & linguistically appropriate.

Curriculum and Content Integration

- High-quality instruction requires curriculum materials that ...
  - build toward the vision of the *Framework*;
  - are grounded in investigation and design;
  - are coherent, flexible, adaptable, equitable, responsive; and
  - have evidence supporting their effectiveness.

Curriculum and Content Integration

RECOMMENDATION 10: Curriculum developers should work in partnership with researchers, teachers, school or district leaders, and families and community leaders to develop preschool through elementary science and engineering curriculum materials that are coherent and equitable, that build toward the vision of the *Framework* and that:

- provide opportunities for children's sensemaking around investigation and design;
- build on children's interests and repertoires of practice;
- provide educative supports for teachers;
- provide opportunities for teachers to make productive adaptations to meet contextual needs;
- provide supports for teachers to make meaningful connections to communities and families;
- explore integrating science and engineering with other domains in ways that benefit children's learning and use instructional time effectively;
- are manageable for use in preschool and elementary settings;
- align preschool and elementary instruction; and
- show evidence of effectiveness.

Curriculum and Content Integration

RECOMMENDATION 11: State and district leaders should rely on a robust evidence-based review, selection, and implementation process when making decision about preschool through elementary curricular programs to adopt to ensure that the science and engineering units build toward the vision of the *Framework* and are grounded in investigation and design, coherent, flexible, adaptable, and equitable.

Curriculum and Content Integration

- Educators' use and adaptation of science and engineering curriculum materials is influenced by
  - knowledge, beliefs, and attitudes about the disciplines, teaching science and engineering, and learners;
  - characteristics of the materials themselves;
  - school and classroom contexts in which materials are used.

Curriculum and Content Integration

RECOMMENDATION 12: State and district leaders should provide teachers with sustained professional learning opportunities for using and adapting curriculum materials, and should ensure that they have adequate access to materials, equipment, and other physical and digital resources needed for children to engage in investigation and design.

RECOMMENDATION 13: As materials become available, state and district leaders should ensure that every school has the curriculum materials and instructional resources needed for engaging in science and engineering teaching that works toward equity and justice.

Supporting Educators

- Multiple kinds of supports are needed to provide effective, engaging science and engineering learning opportunities:
  - strong teacher preparation,
  - curriculum materials,
  - physical and digital resources,
  - coherent professional learning opportunities, and
  - supportive school leadership.
- Supports provide opportunities to expand on teachers' strengths.

Supporting Educators

- Preservice early childhood and elementary teachers demonstrate positive shifts in beliefs, knowledge, and practice related to science and engineering teaching when have opportunities …
  - to engage in science and engineering practices and
  - to support children in engaging in these practices.

Supporting Educators

RECOMMENDATION 14: Teacher educators (in and outside of schools of education), facilitators of professional learning experiences, and school and district leaders should:

- Help preschool through elementary teachers to recognize importance and value of teaching science and engineering
- Understand and address the needs and goals of classroom teachers
- Support teachers in connecting their professional learning with their classroom practice
- Foreground authentic and equitable science and engineering content and disciplinary practice
- Allow for meaningful integration of science and/or engineering with other subjects
- Support teachers' effective use and adaptation of science and engineering curriculum materials

Supporting Educators

- Demographics of preschool/elementary teacher workforce starkly different from demographics of children being taught, resulting in cultural mismatch.
- Support needed in enacting science and engineering instruction that is responsive to and supportive of children's cultural and linguistic backgrounds.

Supporting Educators

- Research highlights the importance of:
  - diversifying workforce
  - placing preservice teachers in mentored and supportive field placements
  - using sustained professional learning experiences synergistically with educative curriculum materials

The National Academies of | SCIENCES ENGINEERING MEDICINE

Supporting Educators

- With respect to supporting the development of teachers' knowledge, attitudes, beliefs, and practices, professional learning experiences are beneficial when they engage preschool through elementary teachers in …
  - Collaboratively analyzing practice and children's thinking
  - Making connections among professional learning opportunities (educative curriculum materials and workshops to their classrooms)
  - Engaging in instructional co-design
  - Working with supportive coaches or facilitators

Supporting Educators

RECOMMENDATION 15: Designers and facilitators of professional learning opportunities should ensure that sustained opportunities to work on science and engineering teaching that works toward equity and justice, in conjunction with supportive curriculum materials, are offered. These experiences should support teachers in developing the ability to recognize and value their learners' conceptual, linguistic, and cultural resources, such as funds of knowledge stemming from their families and communities and their sensemaking repertoires.

Supporting Educators

RECOMMENDATION 16: Schools of education should provide professional learning opportunities for science teacher education faculty on how to work toward equity and justice in teacher education.

The National Academies of SCIENCES ENGINEERING MEDICINE

Supporting Educators

RECOMMENDATION 17: Federal agencies should reassess how funds are allocated for research and development efforts to enhance teaching and learning of science and engineering within preschool through elementary classrooms and prioritize efforts that:

- Diversify the preschool through elementary teacher workforce
- Recognize unique character of preschool through elementary teachers and teaching
- Develop teachers as leaders
- Support research and development that works across content areas to support teacher educators, teachers, and children in making meaningful connections,
- Elevate the study of equitable curricular resources and initial and ongoing teacher professional learning experiences that support teachers in working toward equity and justice in preschool and elementary science and engineering

District and School Leadership

- Science and engineering instruction is included as a strong part of curriculum when preschool and elementary school and district leaders
  - emphasize importance of science and engineering education
  - foster shared responsibility among teachers
  - allocate time and resources and
  - provide professional learning opportunities.

District and School Leadership

- Specialists can provide preschool and elementary science and engineering instruction
- Have greatest impact when …
  - school and district administrators and other leaders are involved in science education and
  - overall district and school culture places value on science and provides resources to support it.

District and School Leadership

RECOMMENDATION 18: District leaders should provide professional learning opportunities for principals, center directors, and other school leaders to enhance leaders' capacity for providing instructional leadership for science and engineering. These professional learning opportunities should focus on science and engineering practices and support leaders in seeing multiple ways science and engineering are valuable for children.

Questions and Discussion

Thank you for your engagement!

If you're interested in reading the report, you can obtain a PDF (for free!) or order the book at nap.edu — search for Science and Engineering in Preschool through Elementary