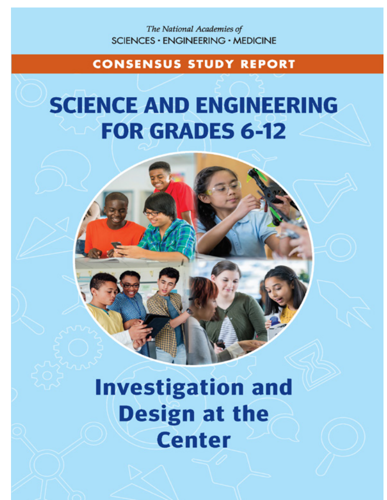
November 2018

Consensus Study Report

HIGHLIGHTS

Science and Engineering for Grades 6-12: Investigation and Design at the Center

The majority of Americans learn most of what they know about science and engineering as middle and high school students. During these years of rapid change for students' knowledge, attitudes, and interests, they can learn science and engineering through schoolwork that piques their curiosity about the phenomena around them.



Education research shows that one effective way to help students learn is to engage them in science investigation and engineering design by asking questions, collecting and analyzing data, and using this evidence to better understand the natural and built world. Science investigation and engineering design are heavily emphasized in *A Framework for K-12 Science Education* and the *Next Generation Science Standards*, which are now guiding the science education of many U.S. students. But this entails a dramatic shift from the traditional classroom dynamic, and teachers will need support and guidance as they implement this approach.

Science and Engineering for Grades 6-12: Investigation and Design at the Center, from the National Academies of Sciences, Engineering, and Medicine, describes evidence-based ways that teaching and learning can shift toward science investigations and engineering design to help realize this new vision in the classroom. The report provides guidance for teachers, administrators, providers of professional development, and creators of instructional materials on how to support students and teachers as they learn and instruct in this way.

THE IMPORTANCE OF SCIENCE INVESTIGATION AND ENGINEERING DESIGN

Research shows that engaging students in learning about natural phenomena and engineering challenges through science investigation and engineering design increases their understanding of how the world works. These approaches are more effective for supporting learning than traditional teaching methods, which rely heavily on teachers providing information and students memorizing it.

Investigation and design entail a dramatic shift in the classroom dynamic: Students ask questions about the causes of phenomena, gather evidence to support explanations of the causes of the phenomena or find solutions to human needs, and communicate their reasoning to themselves and others. Investigation and design may take a number of different paths, but each path would take students in search of finding evidence to support their explanations and/or developing a solution. Meanwhile, teachers focus on structuring the instruction and supporting student learning rather than providing information to the students.

Some examples of student experiences that illustrate investigation or design at the center are

- Students develop a design for a device that collects plastics that have made their way to a local waterway and are causing native marine life to die prematurely.
- Students develop a model to show how the flow of energy into an ecosystem causes change in the seasonal rate of growth of grass.
- Students construct an explanation for how changes in the quantity of grass cause changes in the population of deer mice in the Sandhills of Nebraska.

During experiences like these, students engage simultaneously with three dimensions—science and engineering practices, disciplinary core ideas, and crosscutting concepts—in order to make sense of phenomena and to design solutions, an approach recommended by the *Framework*. For example, in one of the experiences above, the students develop a model (a practice) to show how the flow of energy into an ecosystem (a disciplinary core idea) causes change (a crosscutting concept) in the seasonal rate of growth of grass.

Engaging all students in investigation and design will require an educational system that supports instructional approaches that situate phenomena and design challenges in contexts that are interesting and engaging to students, including contexts that are culturally and locally relevant.

RECOMMENDATIONS

Implementing approaches that put investigation and design at the center of classrooms will require significant and sustained work by teachers, administrators, leaders in professional learning, those designing instructional resources and assessments, and policy makers. The report offers multiple recommendations to guide this work.

Recommendation 1: Science investigation and engineering design should be the central approach for teaching and learning science and engineering in middle and high schools.

- Teachers should arrange their instruction around interesting phenomena or design projects and use their students' curiosity to engage them in learning science and engineering.
- Administrators should support teachers in implementation of science investigation and engineering design. This may include providing teachers with appropriate instructional resources, opportunities to engage in sustained professional learning experiences and work collaboratively to design learning sequences, and choose phenomena with contexts relevant to their students, and time to engage in and learn about inclusive pedagogies to promote equitable participation in science investigation and engineering design.

Recommendation 2: Instruction should provide multiple embedded opportunities for students to engage in three-dimensional science and engineering performances.

- Teachers should monitor student learning through ongoing, embedded and post-instruction assessment as students make sense of phenomena and design solutions to challenges.
- Teachers should use formative assessment tasks and discourse strategies to encourage students to share their ideas, and to develop and revise their ideas with other students.
- Teachers should use evidence from formative assessment to guide instructional choices and guide students to reflect on their own learning.

Recommendation 3: Instructional resources to support science investigation and engineering design need to use approaches consistent with knowledge about how students learn and consistent with the *Framework* to provide a selection of options suitable for many local conditions.

- Teachers and designers of instructional resources should work in teams to develop coherent sequences of lessons that include phenomena carefully chosen to engage students in the science or engineering to be learned. Instructional resources should include information on strategies and options teachers can use to craft and implement lessons relevant to their students' backgrounds, cultures, and place.

- Administrators should provide teachers with access to high-quality instructional resources, space, equipment, and supplies that support the use of *Framework*-aligned approaches to science investigation and engineering design.

Recommendation 4: High-quality, sustained, professional learning opportunities are needed to engage teachers as professionals with effective evidence-based instructional practices and models for instruction in science and engineering. Administrators should identify and encourage participation in sustained and meaningful professional learning opportunities for teachers to learn and develop successful approaches to effective science and engineering teaching and learning.

- Professional development leaders should provide teachers with the opportunity to learn in the manner in which they are expected to teach, by using *Framework*-aligned methods during professional learning experiences. Teachers should receive feedback from peers and other experts while working throughout their career to improve their skills, knowledge, and dispositions with these instructional approaches.
- Professional development leaders should prepare and empower teachers to make informed and professional decisions about adapting lessons to their students and the local environment.
- Administrators and education leaders should provide opportunities for teachers to implement and reflect on the use of *Framework*-aligned approaches to teaching and learning.

Recommendation 5: Undergraduate learning experiences need to serve as models for prospective teachers, in which they experience investigation and design as learners.

- College and university faculty should design and teach science classes that model the use of evidence-based principles for learning and immerse students in *Framework*-aligned approaches to science and engineering learning.
- Faculty should design and teach courses on pedagogy of science and engineering that use instructional strategies consistent with the *Framework*.
- College and university administrators should support and incentivize design of new courses or redesign of existing courses that use evidence-based principles and align with the ideas of the *Framework*.

Recommendation 6: Administrators should take steps to address the deep history of inequities in which not all students have been offered a full and rigorous sequence of science and engineering learning opportunities, by implementing science investigation and engineering design approaches in all science courses for all students.

- Teachers and designers of instructional resources should work in teams to develop coherent sequences of lessons that include phenomena carefully chosen to engage students in the science or engineering to be learned. Instructional resources should include information on strategies and options teachers can use to craft and implement lessons relevant to their students' backgrounds, cultures, and place.
- Administrators should provide teachers with access to high-quality instructional resources, space, equipment, and supplies that support the use of *Framework*-aligned approaches to science investigation and engineering design.
- School and district staff should systematically review policies that impact the ability to offer science investigation and engineering design opportunities to all students. They should monitor and analyze differences in course offerings and content between schools, as well as patterns of enrollment and success in science and engineering courses at all schools. This effort should include particular attention to differential student outcomes, especially in areas in which inequality and inequity have been well documented (e.g., gender, socioeconomic status, race, and culture). Administrators should use this information to construct specific, concrete, and positive plans to address the disparities.
- State and national legislatures and departments of education should provide additional resources to schools with significant populations of underserved students to broaden access/opportunity and allow all students to participate in science investigations and engineering design.

Recommendation 7: For all students to engage in meaningful science investigation and engineering design, the many components of the system must become better aligned. This will require changes to existing policies and procedures. As policies and procedures are revised, care must be taken not to exacerbate existing inequities.

- State, regional, and district leaders should commission and use valid and reliable summative assessment tools that mirror how teachers measure three-dimensional learning.
- States, regions, and districts should provide resources to support the implementation of investigation and engineering design-based approaches to science and engineering instruction across all grades and in all schools, and should track and manage progress towards full implementation. State, regional, and district leaders should ensure that the staff in their own offices who oversee science instruction or science educators have a deep knowledge of *Framework*-aligned approaches to teaching and learning.

COMMITTEE ON SCIENCE INVESTIGATIONS AND ENGINEERING DESIGN EXPERIENCES IN GRADES 6-12

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For More Information . . . This Consensus Study Report Highlights was prepared by the Board on Science Education based on the Consensus Study Report *Science and Engineering for Grades 6-12: Investigation and Design at the Center* (2018). The study was sponsored by the Amgen Foundation and the Carnegie Corporation of New York. Any opinions, findings, conclusions, or recommendations expressed in this publication do not necessarily reflect the views of any organization or agency that provided support for the project. Copies of the Consensus Study Report are available from the National Academies Press, (800) 624-6242; http://www.nas.edu/Science-Investigation-and-Design.

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