Developments in STEM Education

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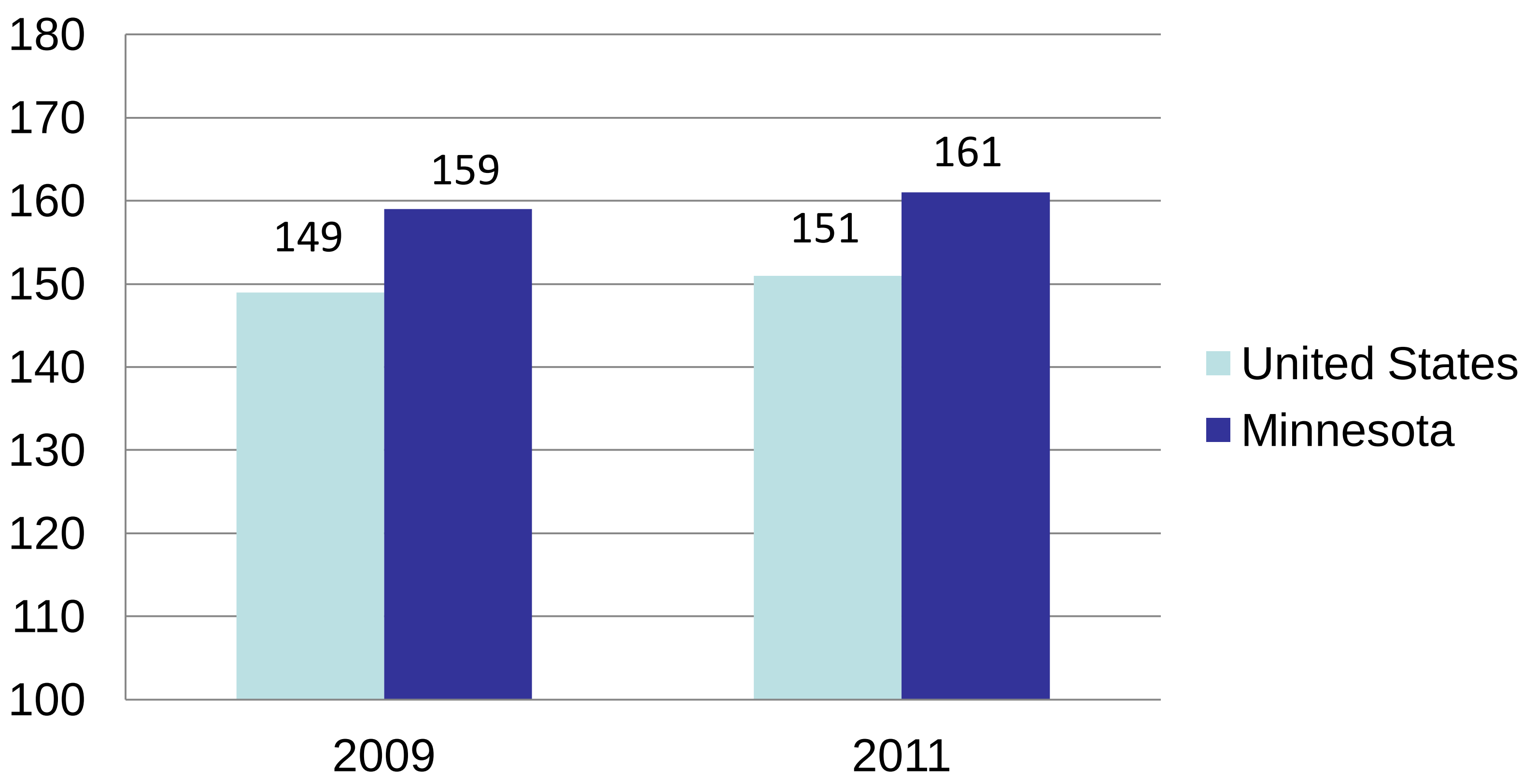
National Research Council

NAEP: The Nation's Report Card

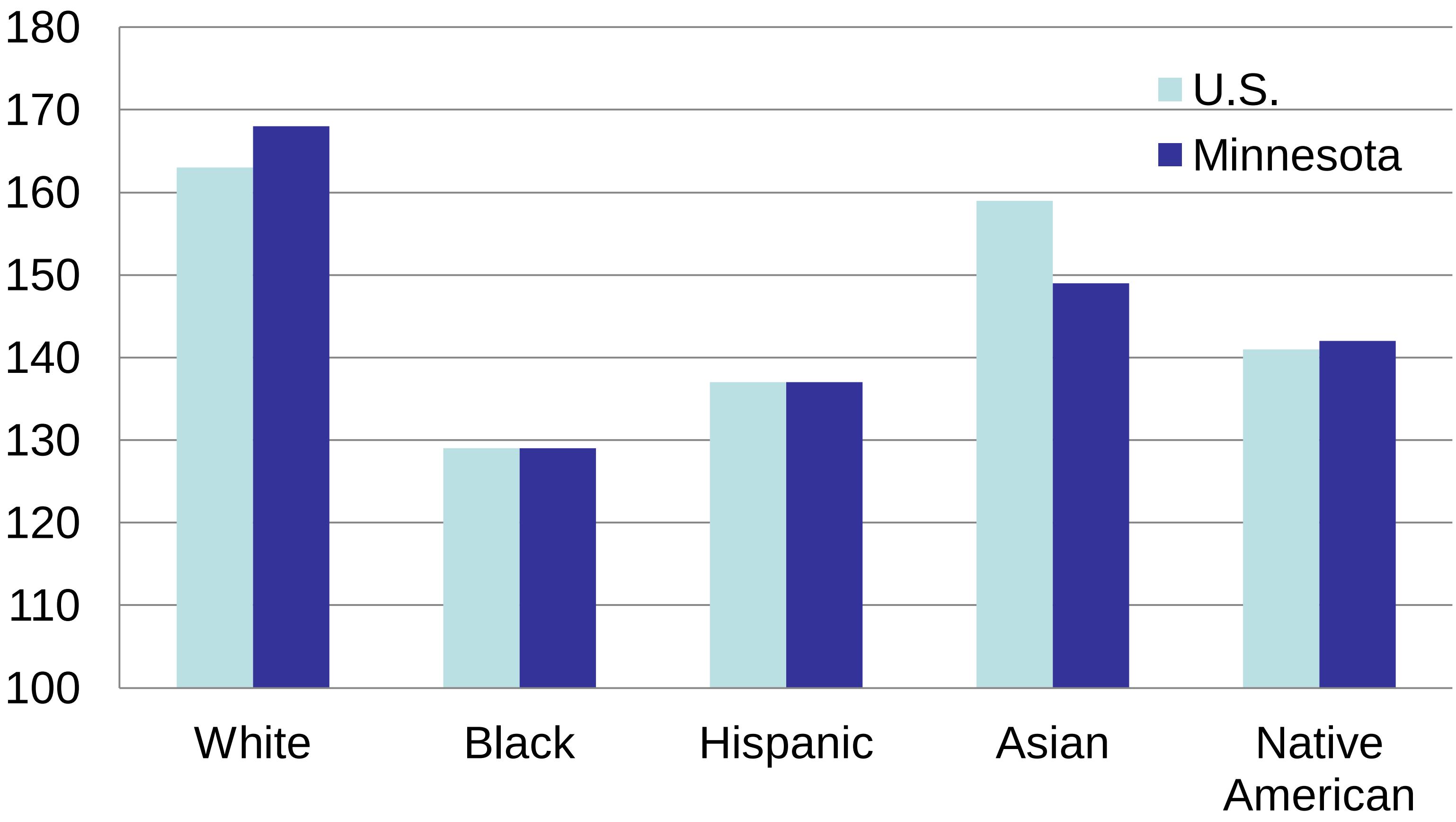
- The National Assessment of Educational Progress (NAEP) -- nationally representative measure of achievement in various subjects (since 1969).

- Representative sample of 8th-graders -- measures knowledge and abilities in physical science, life science, and Earth and space sciences.

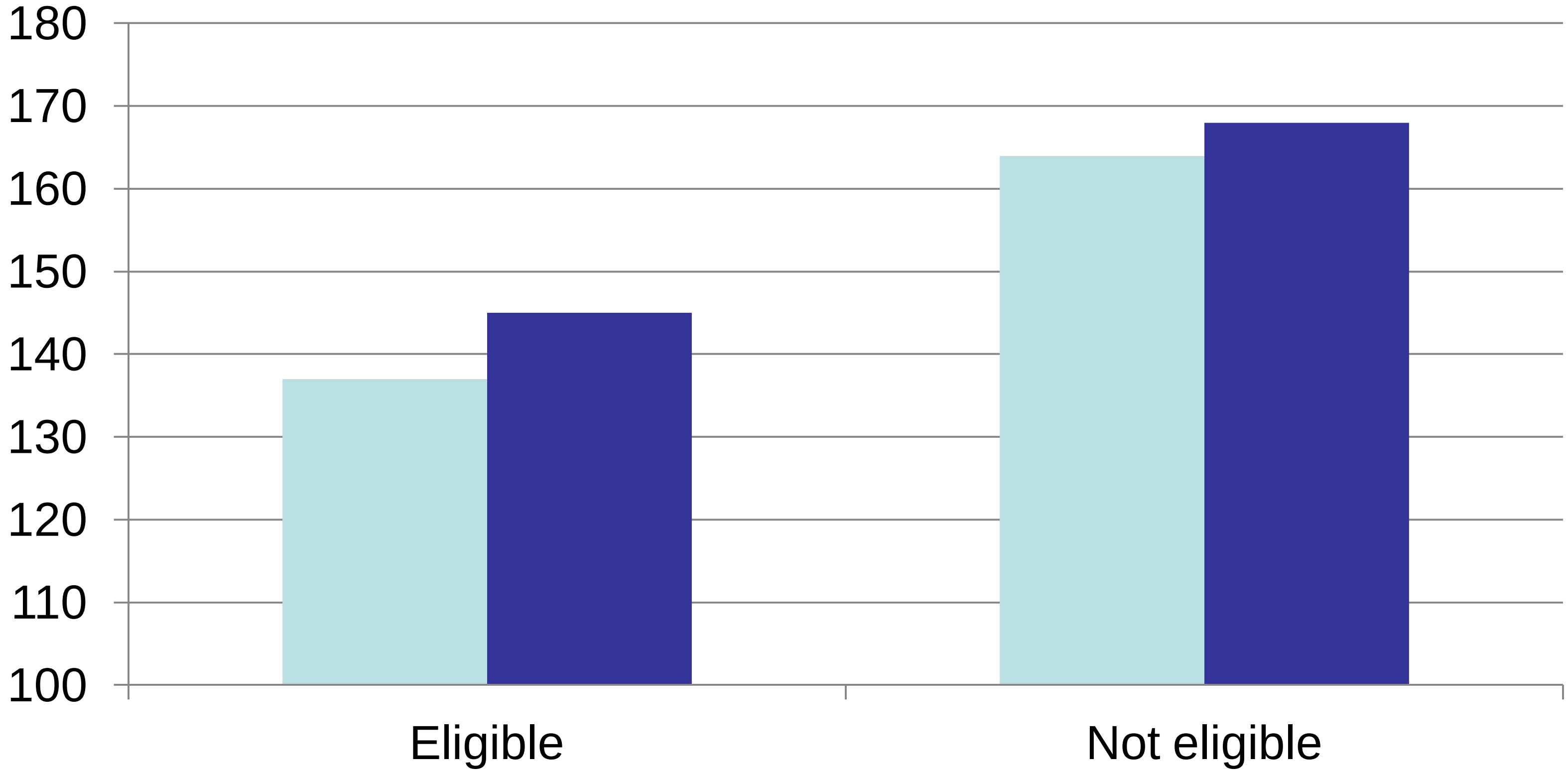
2011 NAEP Science Scores



2011 NAEP Score by Race/Ethnicity



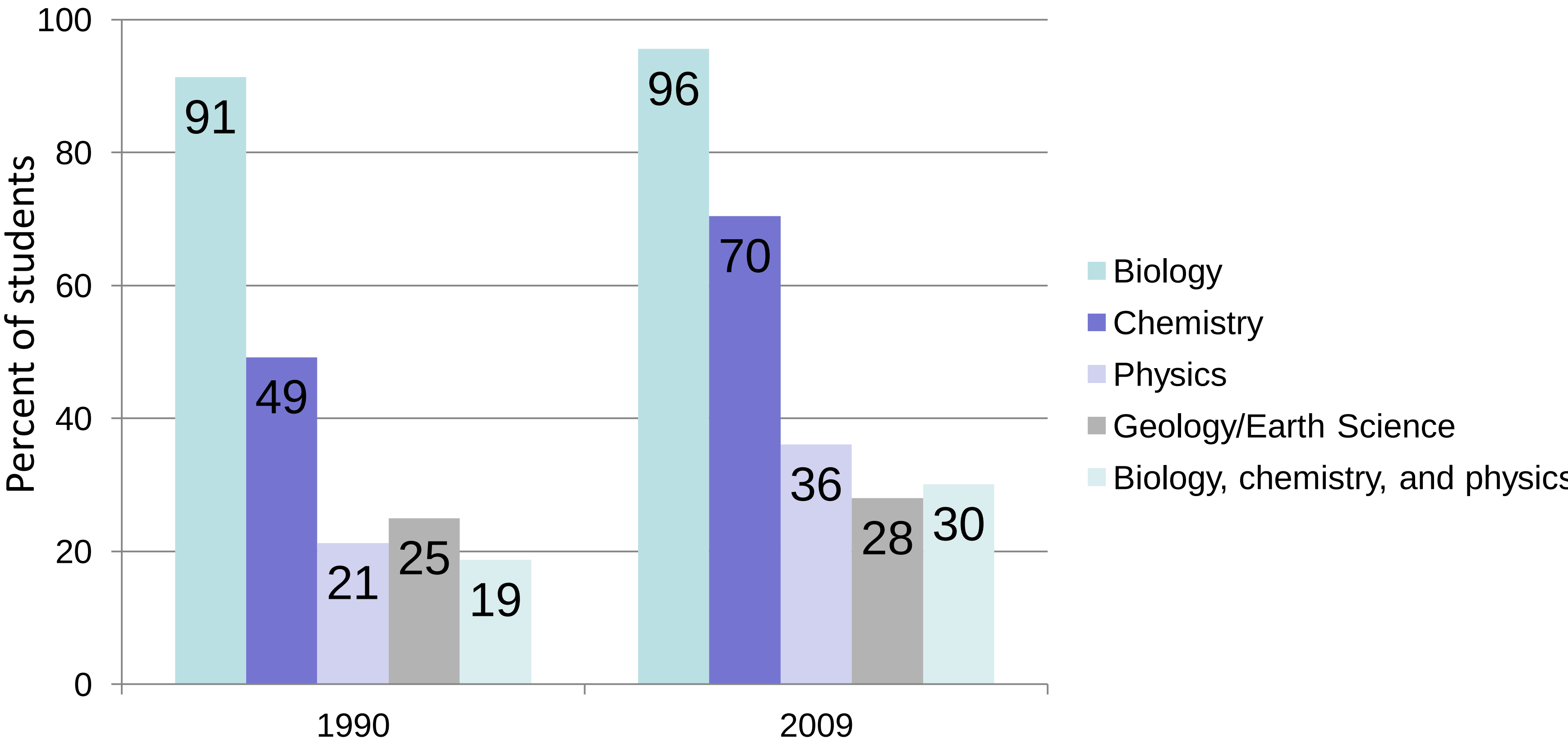
NAEP Scores by Eligibility for free/reduced Lunch



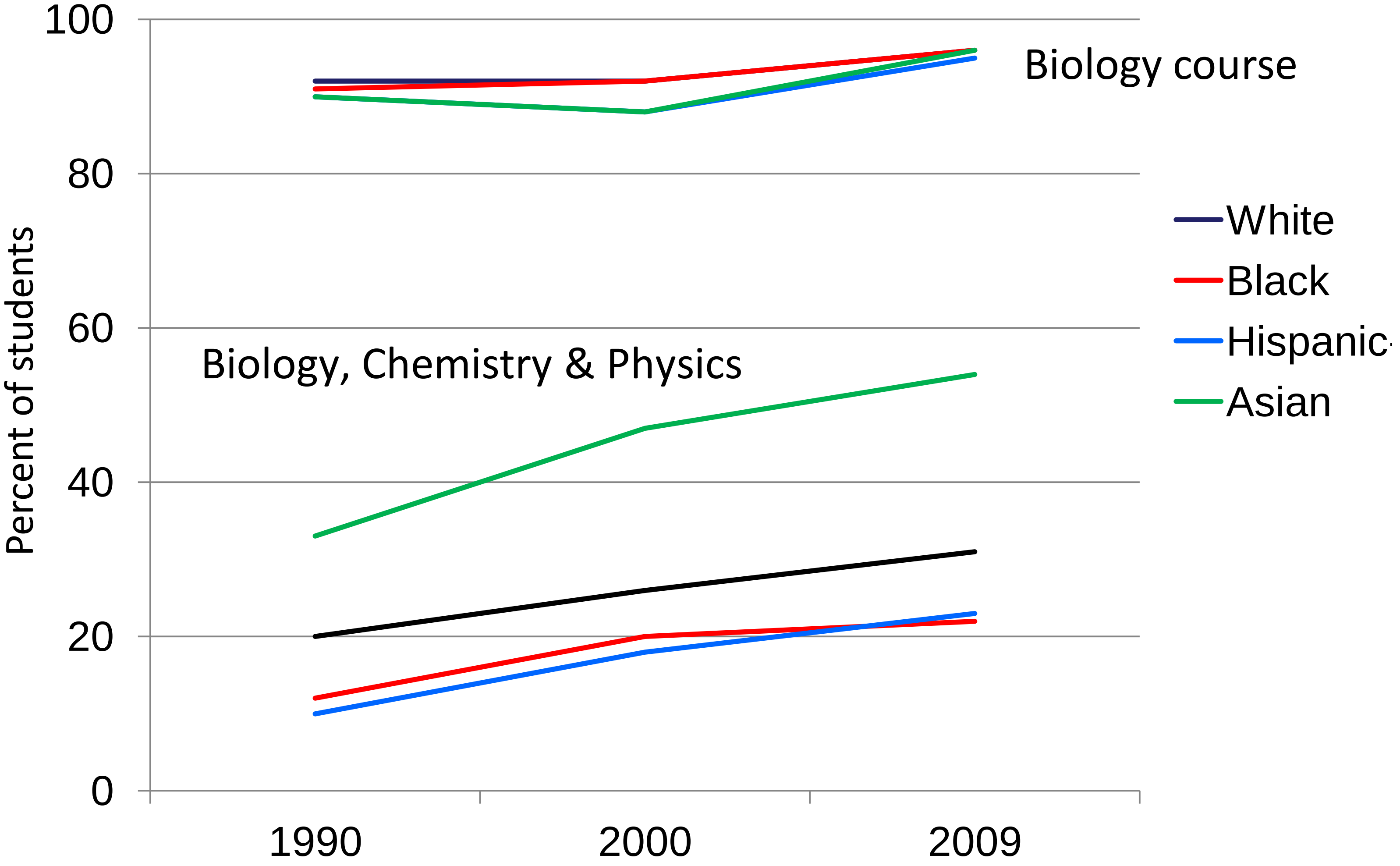
Additional Key Findings (National)

- Students doing hands-on projects or investigations in class more frequently score higher (30% of students do this once or twice a month or less)
- About two-thirds of students work on science projects together at least weekly
- Students who report doing science-related activities that are <u>not</u> for schoolwork score higher

High School Science Course-taking (National)

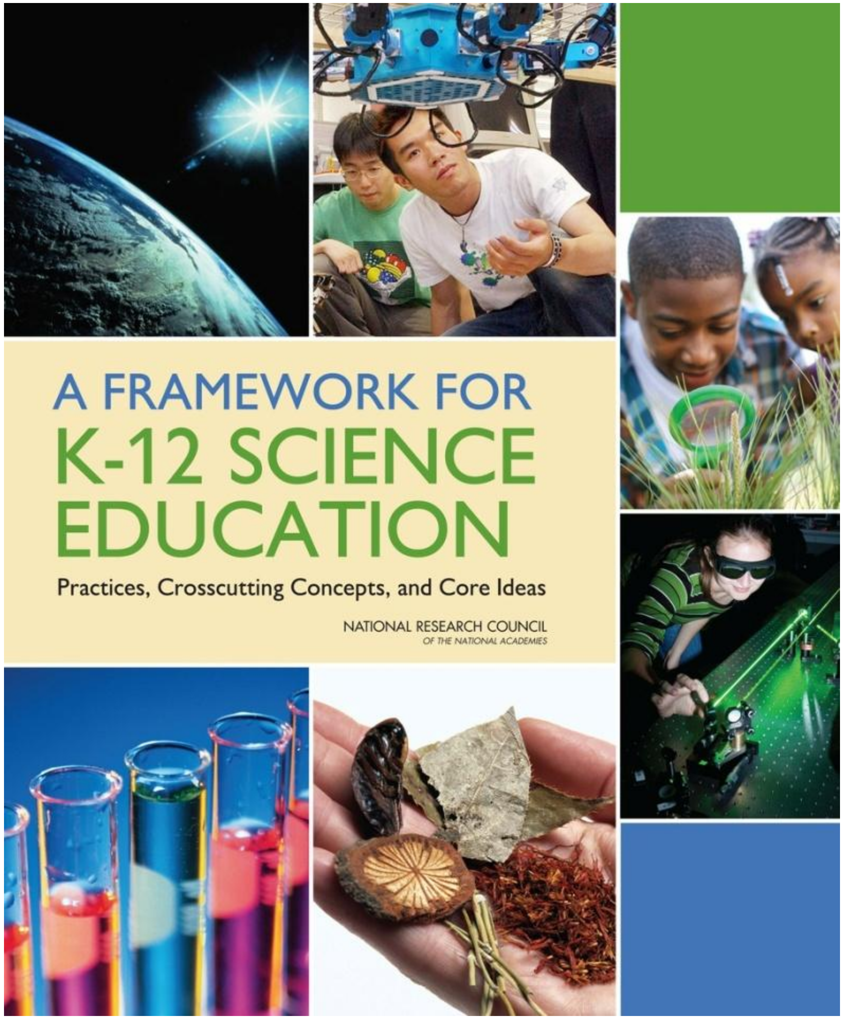


Science course-taking by race/ethnicity



Inequity in Opportunity to Learn

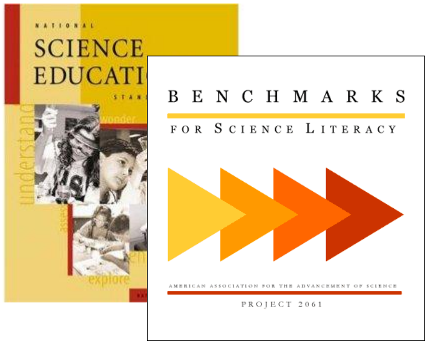
- Students in high schools with lower percentages of non-Asian minority students spent more time with hands-on, manipulative or lab work (NRC, 2006).
- Teachers in high schools with higher percentages of non-Asian minority students were more likely to engage students in individually reading texts or completing worksheets (NRC, 2006).
- Students in high schools with higher concentrations of minority or poor students are more likely to be taught science by a teacher without a major or minor in the subject (US Dept of Ed, 2004).



A Framework for K-12 Science Education

Why new science standards?

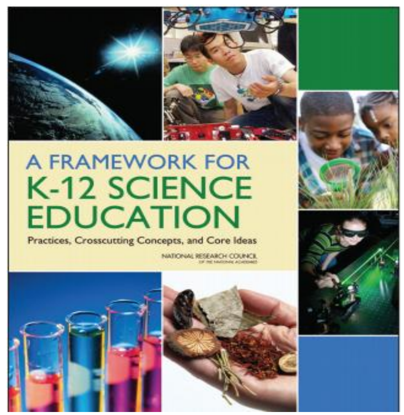
- Improved knowledge about learning and teaching science
- Opportunities to improve current teaching practice
- Shift in focus to reaching ALL students
- A window of opportunity nationally



1990s

Phase I

Phase II

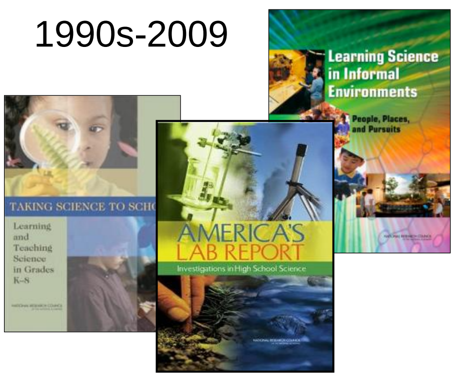


NEXT GENERATION SCIENCE STANDARDS

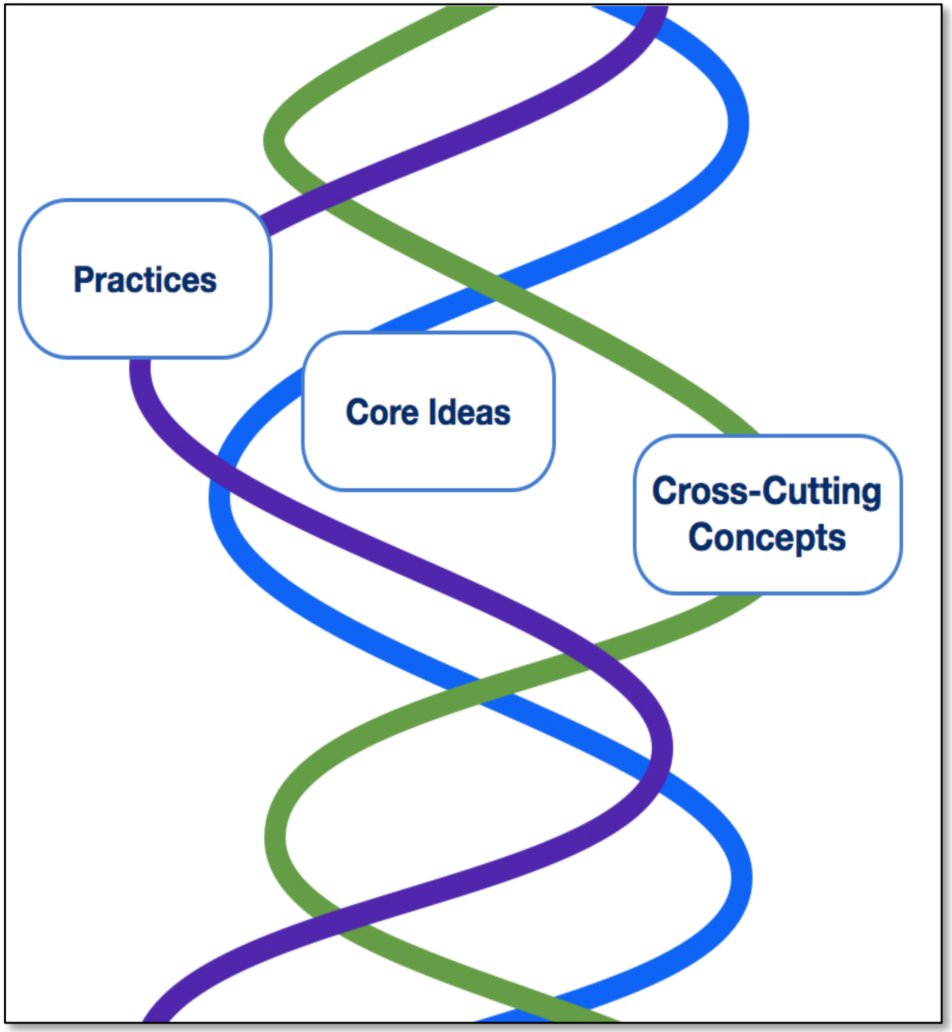
1/2010 - 7/2011

7/2010 – 4/2013

1990s-2009



Framework: Three Dimensions Intertwined



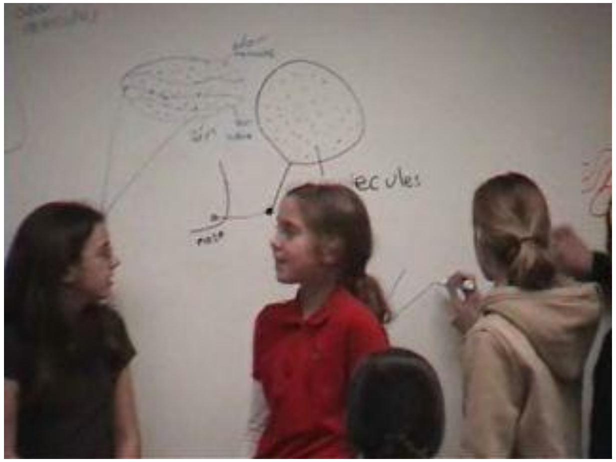
What is new?

1. Central role of scientific practices
2. Organized around crosscutting concepts & core explanatory ideas
3. Organized in learning progressions

Scientific and Engineering Practices

1. Asking questions and defining problems
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Developing explanations and designing solutions
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

Key Role of Scientific and Engineering Practices



- Science is both a body of knowledge AND the process that develops and refines that body of knowledge.

- Developing explanatory core ideas requires engaging in practices. Simply "consuming" information leads to declarative, isolated ideas.

Why Practices?

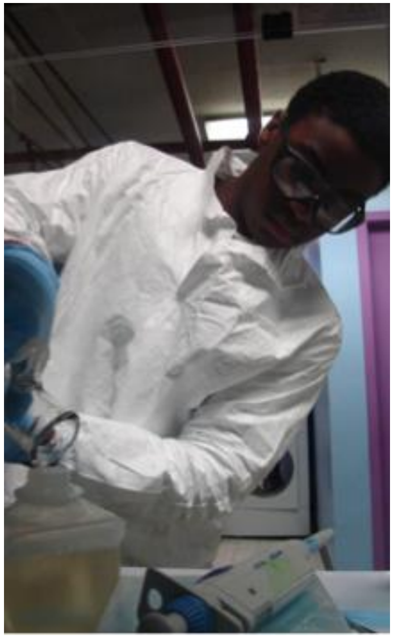
- Practices are central to science and engineering

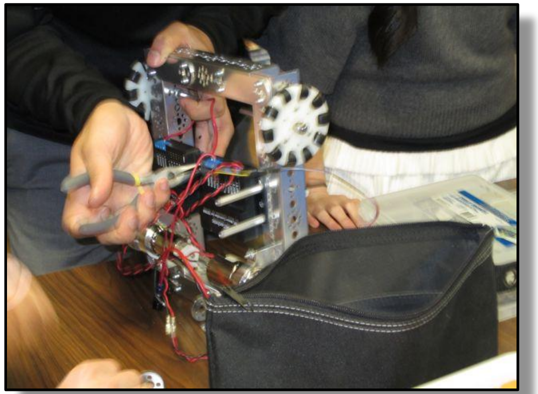
- Practices also advance learning

  - engage students productively in inquiry

  - help students understand aspects of the science and engineering enterprises

  - support important learning processes





Crosscutting Concepts

- Patterns
- Cause and effect: Mechanism and explanation
- Scale, proportion, and quantity
- Systems and system models
- Energy and matter: flows, cycles, conservation
- Structure and function
- Stability and change

Disciplinary Core Ideas
Physical Sciences & Life Sciences

- PS1 Matter and its interactions
- PS2 Motion and stability: Forces and interactions
- PS3 Energy
- PS4 Waves and their applications in technologies for information transfer

- LS1 From molecules to organisms: Structures and processes
- LS2 Ecosystems: Interactions, energy, and dynamics
- LS3 Heredity: Inheritance and variation of traits
- LS4 Biological evolution: Unity and diversity

Disciplinary Core Ideas:
Earth and Space Sciences
Engineering, Technology and Applications of Science

- ESS1 Earth's place in the universe
- ESS2 Earth's systems
- ESS3 Earth and human activity

- ETS1 Engineering design
- ETS2 Links among engineering, technology, science and society

Organized in learning progressions

Learning core explanatory ideas…

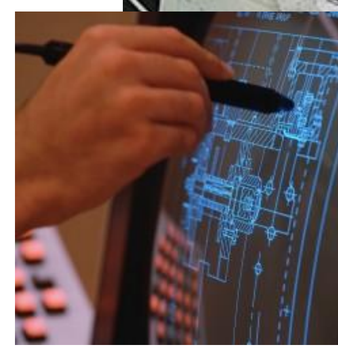
- …unfolds over time
- …requires revisiting ideas in new contexts that force students to extend them
- …requires that students engage in tasks that force them to synthesize and apply ideas

Why this focus on Engineering?

- “any [science] education that focuses predominantly on the detailed products of scientific labor—the facts of science—without developing an understanding of how those facts were established or that ignores the many important applications of science in the world misrepresents science and marginalizes the importance of engineering.” (NRC Framework, Ch. 3)

- Students should: (1) learn how science is utilized—esp. in the context of engineering design—and (2) come to appreciate the distinctions and relationships between engineering, technology, and applications of science.

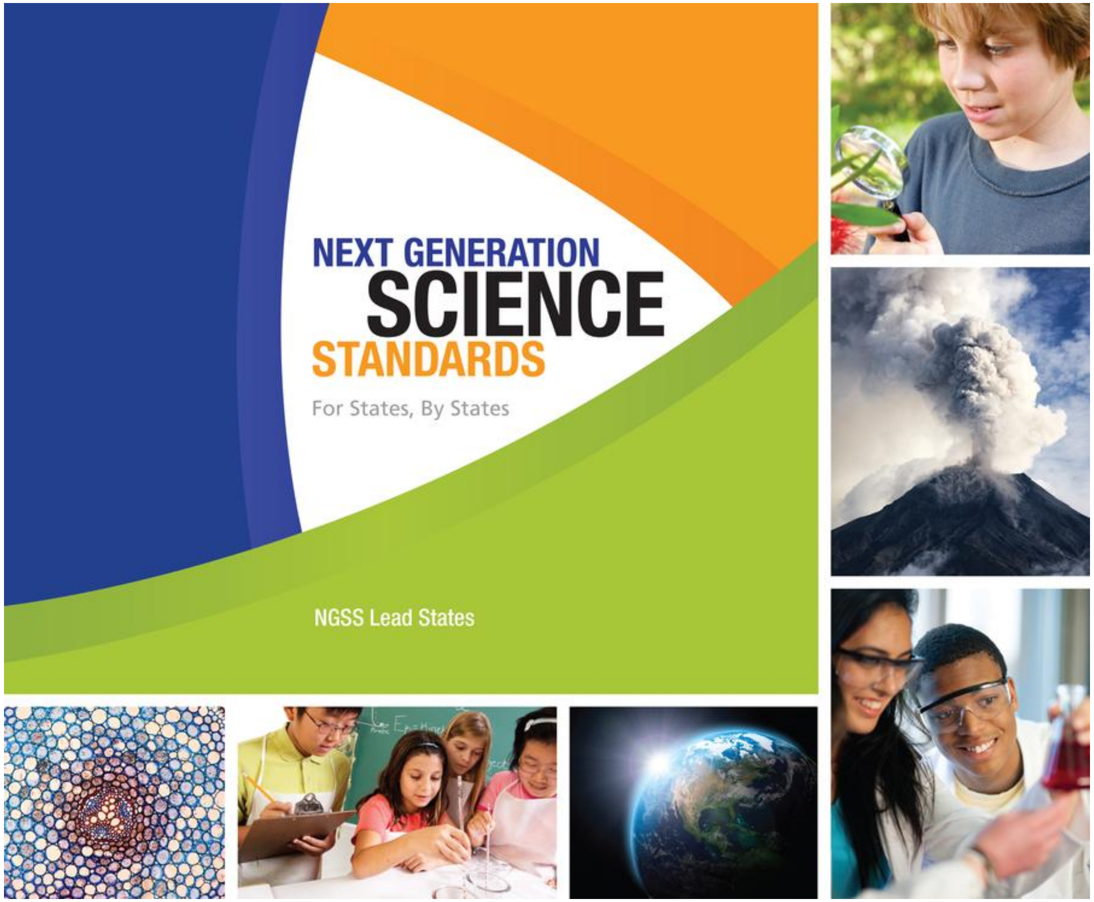
Two youth at the 2008 Scifest festival during a robotics workshop.



There is an increasing demand for citizens who are technologically literate about the built world and who can enter engineering and technology related fields

Engineering Highlights

- Engineering has long been part of science education, but it has been made more visible in the Framework
- Framework outlines two core ideas related to Engineering, Technology & Applications of Science
- Framework outlines a set of engineering practices—many of which are parallel to the scientific practices



Next Generation Science Standards

Process for Development of *Next Generation Science Standards*

Achieve, Inc. engaged states and other key stakeholders in the development and review of the new college and career ready science standards

- State Led Process: 26 lead partner states
- Writing Teams: 41 members from 26 states
- Critical Stakeholder Team: Over 700 members

NGSS – Performance Expectations

- The NGSS describe specific goals for science learning in the form of *performance expectations,* statements about what students should know and be able to do at each grade level.

- Each performance expectation incorporates all three dimensions, and the NGSS emphasize the importance of the connections among scientific concepts.

MS-PS1 Matter and Its Interactions

Students who demonstrate understanding can:

MS-PS1-d. Develop molecular models of reactants and products to support the explanation that atoms, and therefore mass, are conserved in a chemical reaction. [Clarification Statement: Models can include physical models and drawings that represent atoms rather than symbols. The focus is on law of conservation of matter.] [Assessment Boundary: The use of atomic masses is not required. Balancing symbolic equations (e.g. N2 + H2 -> NH3) is not required.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Developing and Using Models
Modeling in 6–8 builds on K–5 and progresses to developing, using and revising models to support explanations, describe, test, and predict more abstract phenomena and design systems.

- Use and/or develop models to predict, describe, support explanation, and/or collect data to test ideas about phenomena in natural or designed systems, including those representing inputs and outputs, and those at unobservable scales. (MS-PS1-a), (MS-PS1-c), (MS-PS1-d)

Connections to Nature of Science

Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena

- Laws are regularities or mathematical descriptions of natural phenomena. (MS-PS1-d)

Disciplinary Core Ideas

PS1.B: Chemical Reactions

- Substances react chemically in characteristic ways. In a chemical process, the atoms that make up the original substances are regrouped into different molecules, and these new substances have different properties from those of the reactants. (MS-PS1-d), (MS-PS1-e), (MS-PS1-f)
- The total number of each type of atom is conserved, and thus the mass does not change. (MS-PS1-d)

Crosscutting Concepts

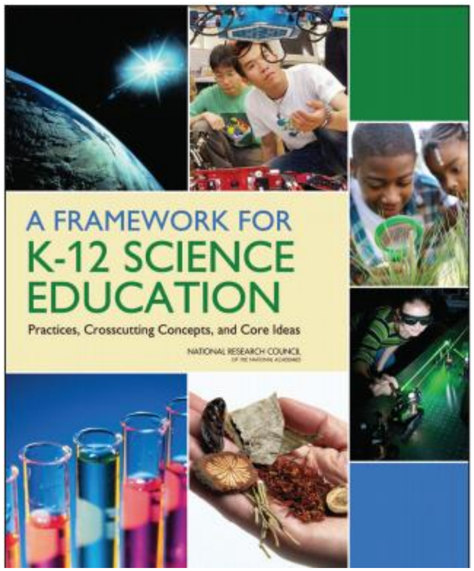
Energy and Matter

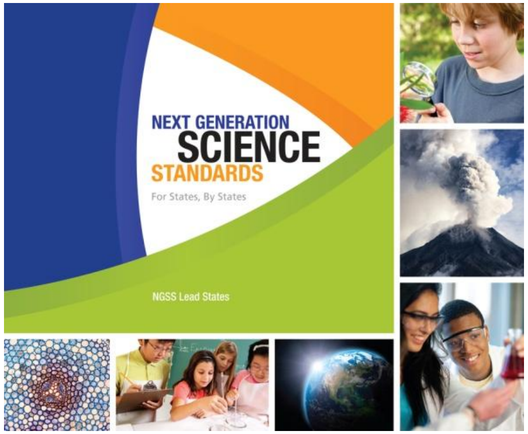
- Matter is conserved because atoms are conserved in physical and chemical processes. (MS-PS1-d)

Note: Performance expectations combine practices, core ideas, and crosscutting concepts into a single statement of ***what is to be assessed***.

They are not instructional strategies or objectives for a lesson.

Implementation





Assessment

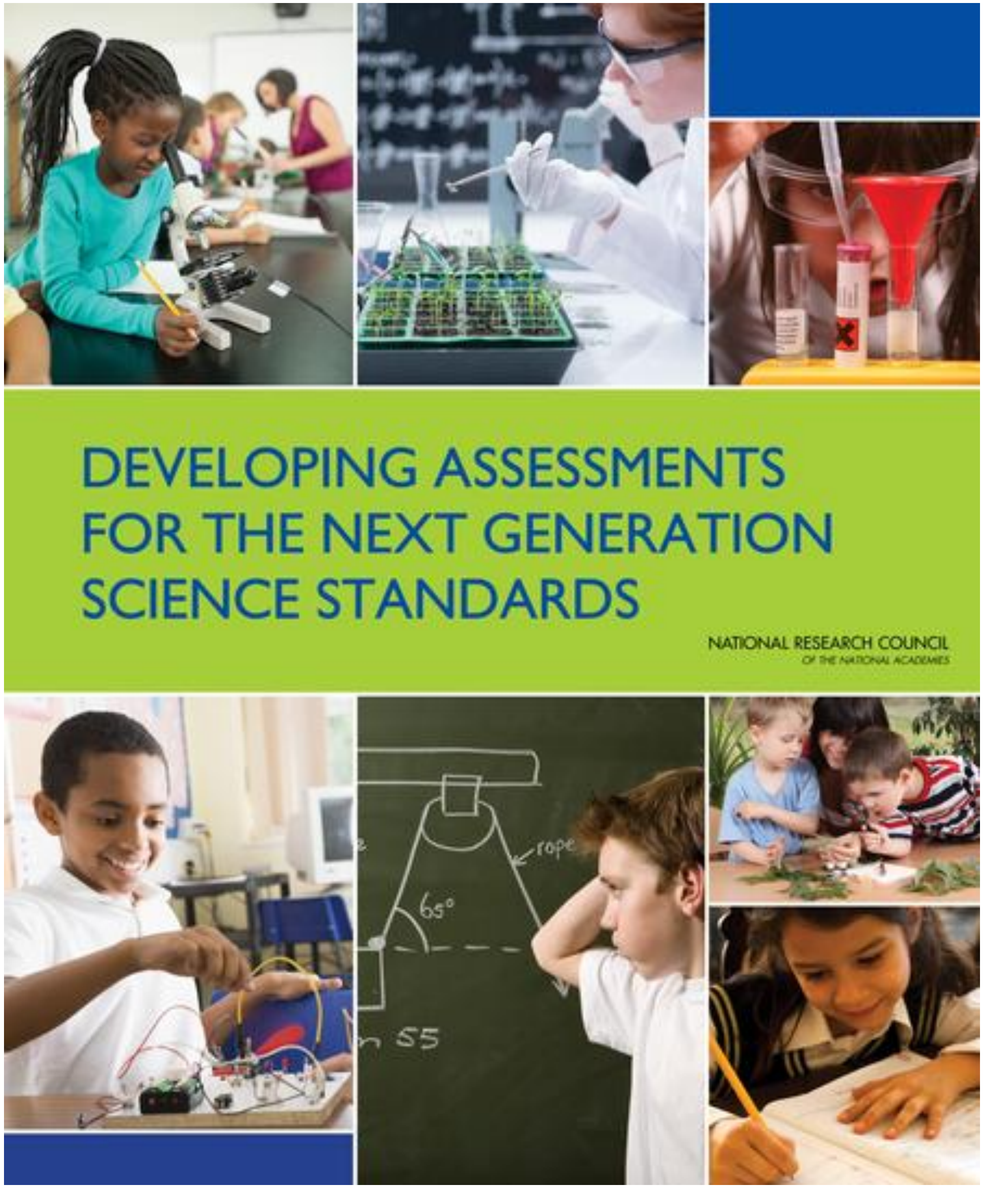
Curricula

Instruction

Teacher learning

Some Challenges for Implementing NGSS

- Lack of time for science in the elementary curriculum
- Teachers’ knowledge & skill
- Lack of curriculum materials aligned to the NGSS
- Large-scale assessments are not aligned to the NGSS



Assessment for the NGSS

Some Assessment Challenges

- Developing rich assessment tasks that evaluate the blending of practices, core ideas, and crosscutting concepts
- Having the platforms and resources to administer these kinds of tasks
- Scoring the tasks
- Developing informative, useful reports of test results
- Creating a system of assessment that satisfies different purposes

Main Messages of NRC Report on Assessment for the NGSS

1. New types of assessment are needed, well designed to address NGSS learning goals

2. State monitoring assessments must move beyond traditional forms; they will NOT suffice.

3. NGSS assessment should start with the needs of classroom teaching and learning

4. States must create coherent systems of assessment to support both classroom learning and policy/monitoring functions.

Main Messages (cont.)

5. Implementation should be gradual, systematic, and carefully prioritized and must attend to equity
6. Professional development and adequate support for teachers will be critical

Not *an* Assessment: Systems of Assessment

- No, single on-demand assessment can well address the depth and breadth of the NGSS nor serve all purposes
- To support NGSS learning, states need to think systemically
  - Assessment to support classroom teaching and learning
  - Assessment for monitoring student learning
  - Indicators of Opportunity-to- learn (OTL)
- OTL indicators should document that students have the opportunity to learn NGSS and that schools have appropriate resources.

Classroom Assessment is Priority

- Classroom instruction is the key leverage point for developing *and* assessing students' NGSS learning.
- Formative and summative assessment should be an integral part of classroom instruction and should reinforce and support NGSS learning.
- Compelling examples exist
- Obvious implications for resource development and professional development

Curriculum and Instruction

Standards are not Curriculum

- Curriculum materials designed specifically for the NGSS do not exist currently
- Need for coherent development of ideas over time -- not disconnected lessons
- Need for multiple experiences with each practice
- Formative assessment opportunities need to be embedded

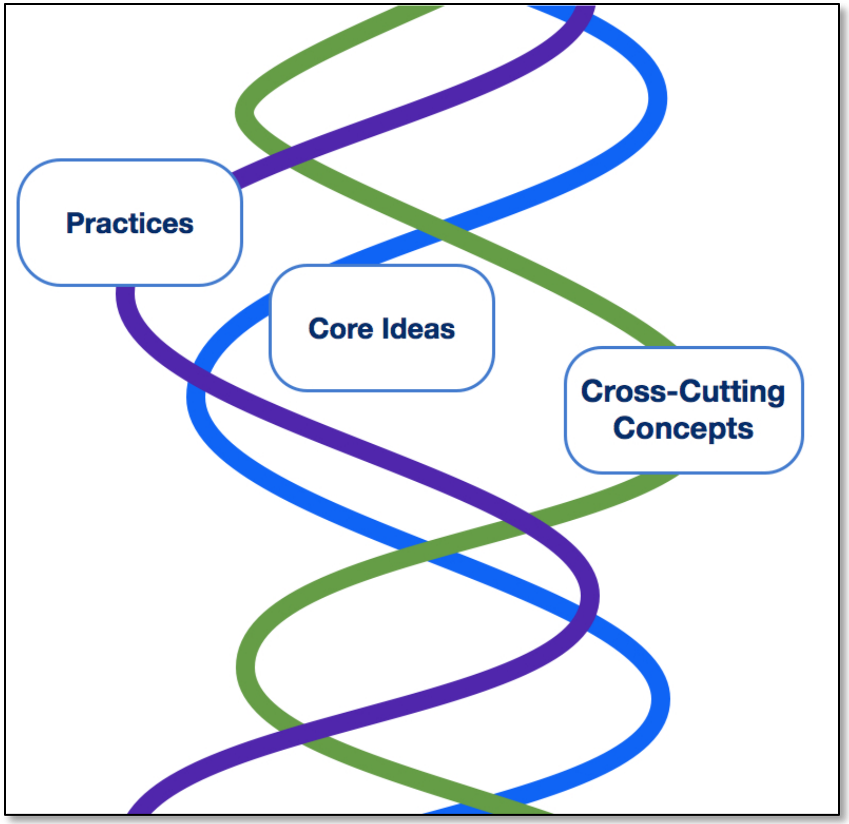
We need thoughtful work to develop and sequence curriculum units of study

Curriculum and Instruction

- Organize curriculum materials around limited number of core ideas: depth and coherence, not breadth of coverage.
- Core ideas should be revisited in increasing depth, and sophistication across years. Focus on connections:
  - help learners build sophisticated ideas from simpler explanations, using evidence.
  - Use cross-cutting concepts to make connections between scientific disciplines
- Curriculum materials should involve learners in practices that develop, use, and refine the scientific ideas, not "explain" the science *for* students.

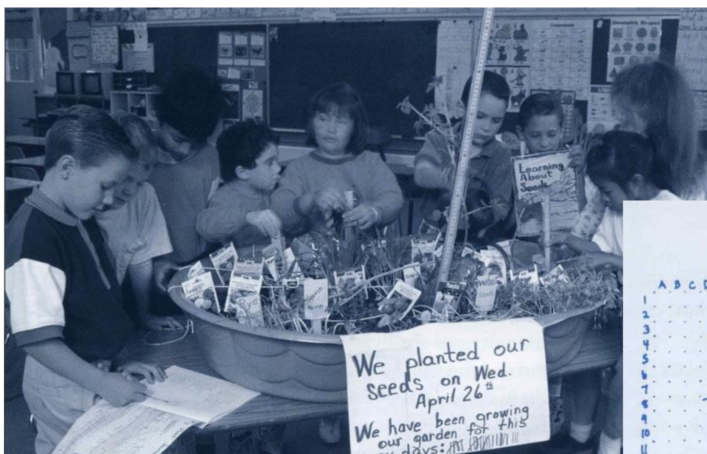
Blending of the Three Dimensions

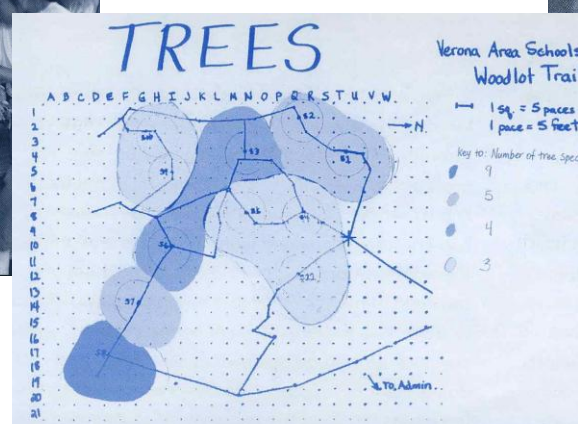
- Not separate treatment of “content” and “inquiry” ***(No “Chapter 1”)***
- Curriculum and instruction needs to do more than present and assess scientific ideas – they need to involve learners in using scientific practices to develop and apply the scientific ideas.



Creating a Scientific Community in the Classroom

- Students carry out investigations, interpret data, discuss findings, create representations and models, argue based on evidence, present at monthly conferences….





Some Challenges for Curriculum and Instruction

- Build coherently in a given grade and across grades
- Provide time for students to engage in the practices and explore ideas in depth
- Provide support for students to become proficient with the practices
- Create opportunities for students to interact with each other in productive ways
- How to integrate engineering
- How to support and include Language Learners

Challenges for Professional Development

- Practices may be unfamiliar to teachers
- Knowledge of crosscutting concepts and some core ideas may be incomplete for some teachers
- Thinking about learning progressions within and across grades
- Some teachers will need to make major changes in instructional approach
- Making connections across disciplines and to mathematics and ELA
- Others……?

To access all NRC reports go to:

www.nap.edu