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UNIVERSITY OF CALIFORNIA, BERKELEY

CENTER ON INSTRUCTION

STEM Overview

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CENTER ON INSTRUCTION

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2011

A Framework for K-12 Science Education

- Released by the National Research Council of the National Academies of Science July 19, 2011
- 1st step in developing Next Generation Science Standards
- **Achieve** will develop Standards within 18 months (January 2013)
- An Evolutionary (not Revolutionary) step forward
  - Builds on Nat'l Science Education Standards, Benchmarks for Science Literacy
  - We've learned a lot about learning and teaching of science
  - There have been advances in scientific knowledge

Notable Features: Content

- Addresses the Mile Wide/Inch Deep Problem
- Fewer Big Ideas arranged as progressions of learning
- Engineering, Technology and Applications of Science is elevated
- Ocean, Climate and Earth Systems Science are IN!

These are good things!

Notable Features: Processes

- "Inquiry" and "Science Processes" are re-defined as Scientific and Engineering Practices
- These Practices represent the intersection and strategic, synergistic integration with ELA and Mathematics Common Core State Standards

Prospects for Impact

- 20 States agreed September 20 to participate in the development of the Standards (AZ, CA, GA, IA, KS, KY, ME, MD, MA, MI, MN, NJ, NY, OH, RI, SD, TN, VT, WA, WV)
- CCSS has some momentum, but implementation has been problematic due to funding constraints and lack of guidance from states to districts

Dimensions of the Framework

- Dimension 1: Scientific and Engineering Practices
- Dimension 2: Crosscutting Concepts
- Dimension 3: Disciplinary Core Ideas

Dimension 1: Scientific & 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 math, information/computer technology, computational thinking
6. Constructing explanations, designing solutions
7. Engaging in argument from evidence
8. Obtaining, evaluating, communicating information

Asking Questions and Defining Problems

Science begins with a question about a phenomenon, such as “Why is the sky blue?” or “What causes cancer?” and seeks to develop theories that can provide explanatory answers to such questions. A basic practice of the scientist is formulating empirically answerable questions about phenomena, establishing what is already known, and determining what questions have yet to be satisfactorily answered.

Constructing Explanations and Designing Solutions

The goal of science is the construction of theories that can provide explanatory accounts of features of the world. A theory becomes accepted when it has been shown to be superior to other explanations both in the breadth of phenomena it accounts for and its explanatory coherence and parsimony. Scientific explanations are explicit applications of theory to a specific situation or phenomenon, perhaps with the intermediary of a theory-based model for the system under study. The goal for students is to construct logically coherent explanations of phenomena that incorporate their current understanding of science or a model that represents it and are consistent with the available evidence.

Engaging in Argument from Evidence

In science, reasoning and argument are essential for identifying the strengths and weaknesses of a scientific claim and for finding the best explanation for a natural phenomenon. Scientists must defend their explanations, formulate evidence based on a solid foundation of data, examine their own understanding in light of the evidence and comments offered by others, and collaborate with peers in searching for the best explanation for the phenomena being investigated.

Obtaining, Evaluating, and Communicating Information

Science cannot advance if scientists are unable to communicate their findings clearly and persuasively or to learn about the findings of others. A major practice of science is thus the communication of ideas and the results of inquiry—**orally, in writing, with the use of tables, diagrams, graphs, and equations, and by engaging in extended discussions with scientific peers. Science requires the ability to derive meaning from scientific texts** (such as papers, the Internet, symposia, and lectures) to evaluate the scientific validity of the information thus acquired and to integrate that information.

English Language Arts Common Core State Standards

- Focus on informational text
- Focus on “Disciplinary Literacy” very similar to Practices of Science
- http://www.corestandards.org/the-standards/english-language-arts-standards
- English Teachers are Science Teachers now!
- Science Teachers are ELA Teachers now!

K-5 ELA Anchor Standards College & Career Readiness Speaking & Listening

3. Evaluate a speaker's point of view, reasoning, use of evidence and rhetoric. (NGSS Practice: Argumentation)
4. Present information, findings, supporting evidence such that listener can follow line of reasoning and the organization, development, style are appropriate to task, purpose, and audience. (Constructing Explanations)
5. Make strategic use of digital media, visual displays of data to express information and enhance presentations. (Obtaining, Evaluating, Communicating Information)

Grade 3 Reading Informational Text

- RI.3.3. Describe the relationship between a series of scientific ideas, concepts or steps in technical procedures in a text, using language that pertains to time, sequence, cause/effect. (Obtaining, Evaluating, Communicating Information)
- Read and comprehend informational texts including science and technical texts at the high end of grades 2-3 text complexity band independently and proficiently. (Obtaining, Evaluating, Communicating Information)

Grades 6-8 Literacy in Science

- RST.6-8.3. Follow a multistep procedure when carrying out experiments, taking measurements, performing technical tasks. (Planning & Carrying Out Investigations)
- RST.6-8.4. Determine meaning of symbols, key terms, other domain specific words as used in scientific texts. (Obtaining, Evaluating, Communicating Information)
- RST.6-8.7. Integrate quantitative or technical information expressed in words with a version of that information expressed visually in a flowchart, diagram, model, graph or table. (Obtaining, Evaluating, Communicating Information)
- RST.6-8.8. Distinguish among facts, reasoned judgment based on research findings, and speculation in a text. (Argumentation)

Grades 11-12 Literacy in Science

- RST.11-12.7. Integrate, evaluate multiple sources of information presented in diverse formats and media, e.g., quantitative data, video, multimedia, to address a question or solve a problem. (Obtaining, Evaluating, Communicating Information)
- RST.11-12.8. Evaluate hypotheses, data, analysis, and conclusions in a science text, verifying the data when possible and corroborating or challenging conclusions with other sources of information. (Argumentation)
- RST.11-12.9. Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible. (Constructing Explanations)

Common Core State Standards

for Mathematics

Standards for Mathematical Practice

1. Make sense of problems, persevere in solving them. (Planning and carrying out investigations)
2. Reason abstractly and quantitatively. (Mathematical & computational thinking)
3. Construct viable arguments, critique reasoning of others. (Engaging in argument from evidence)
4. Model with mathematics. (Developing and using models)

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Standards for Mathematical Practice

5. Use appropriate tools strategically.
6. Attend to precision. (Communicating information)
7. Look for and make use of structure.
8. Look for, express regularity in reasoning. (Analyzing and interpreting data)

Dimension 2: Cross-Cutting Concepts

- Patterns
- Cause and Effect
- Scale, Proportion and Quantity
- Systems and System Models
- Energy & Matter: Flows, Cycles, Conservation
- Structure and Function
- Stability and Change

Dimension 3: Disciplinary Core Ideas

Organized into Four Domains

- Physical Science
- Life Sciences
- Earth & Space Sciences
- Engineering, Technology and the Applications of Science

Disciplinary Core Ideas

- Broad Explanatory Power
- Each Core Idea is introduced with a question and has description of what students should understand by end Grade 12
- Followed by “Grade Band End Points” (suggestive of Learning Progressions)
- Engineering has new emphasis
- More Ocean, Climate and Earth Systems Science

Our Hope

- Science is Back!
- The dismantling of elementary science is over!
- CCSS and Next Generation Science Standards represent a cultural shift in teaching and learning from an era of memorizing to an era of thinking
- Seamless strategic, synergistic integration of science and language arts and mathematics results in deeper conceptual understanding of complex ideas
- Students use knowledge of science and engineering to improve their lives, solve societal problems and make the world a better place
- Opens the door to STEM…

Important STEM Documents

- Gathering Storm (2005)
- Rising Above the Gathering Storm (2010)
- STEM report from SEDTA (2008)
- Prepare and Inspire: K-12 STEM education for America's future (2010)
- Preparing the next Generation of STEM Innovators (2010)
- Successful K-12 STEM Education (2011)

What is STEM?

STEM refers to the areas of science, technology, engineering, and mathematics. STEM initiatives started as a way to promote education in these related areas so that students would be prepared to study STEM fields in college and pursue STEM-related careers. Schools with a strong emphasis on STEM education often integrate science, technology, engineering, and mathematics into the entire curriculum.

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Need for Improved STEM Learning

- demands of the current job market – not just STEM careers
- competing in an increasingly global economy
- individual and societal decisions increasingly require some understanding of STEM

Goals for STEM efforts:

- Expand the number of students who pursue advanced degrees and careers in STEM fields and broaden the participation of women and minorities in those fields.
- Expand the STEM-capable workforce and broaden the participation of women and minorities in that workforce.
- Increase STEM literacy for all students, including those who do not pursue STEM-related careers or additional study in the STEM disciplines.

STEM Goals for Students

- **Career Readiness**

use of technology, applied knowledge, problem solving and communication skills, working in teams

- **College Readiness**

Academic requirements and AP test scores, emphasize pre-requisite knowledge and skills

- **Sci/Tech/Eng/Math Literacy**

improved quality of life, informed decision-making, social and environmental justice

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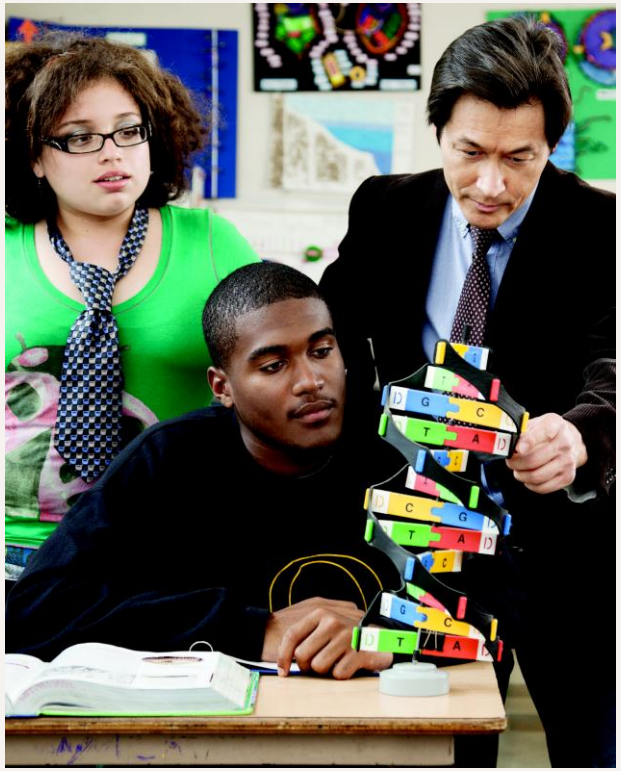
Ways to Organize Thinking About STEM

- Goals for Students
- Approaches to Curriculum
- Instructional Practices



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Successful K-12 STEM Education:

Identifying Effective Approaches in Science Technology, Engineering and Mathematics

(NRC, 2011)

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Criteria for identifying Successful STEM Schools:

- Student STEM Outcomes
- STEM focused schools
- STEM instruction and school-level practices

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STEM Goals/Outcomes for Students

- **Career Readiness**:
  21st Century Skills
- **College Readiness:**
  meeting academic requirements in STEM subjects
- **Sci/Tech/Eng/Math Literacy**:
  informed decision-making, social and environmental justice, community based projects

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Limitations of looking at Student Outcomes

- Test scores don't tell the whole story of success in STEM
- Interest & motivation in STEM are hard to measure
- Don't provide information about the instructional practices and conditions in individual schools

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STEM Focused Schools - (Selective, Inclusive, CTE)

- specific attention to the STEM disciplines
- focus on targeted populations
- rigorous curriculum
- more attention to STEM learning across grades
- more resources
- better prepared teachers

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An example of a Selective STEM school...

The North Carolina School of Science and Mathematics (NCSSM)

680 residential students:

- White, 64 percent
- Black, 11 percent
- Hispanic, 1 percent
- Asian Pacific Islander, 22 percent
- Native American, < 1 percent

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An Inclusive STEM school...

Manor New Technology High School, Austin, TX

315 students (2009-2010):

- White, 32 percent
- Black, 22 percent
- Hispanic, 44 percent
- Asian/Pacific Islander, 2 percent

56 percent of students considered economically disadvantaged

5 percent - special education

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A STEM-focused Career and Technical Education school...

Dozier-Libbey Medical High School
Antioch, CA

343 students:

- White, 29 percent
- Black, 15 percent
- Hispanic, 35 percent
- Asian/Pacific Islander, 17 percent

45 percent in 2009-2010 eligible for free or reduced-price lunch

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STEM in Comprehensive Schools...

Christa McAuliffe School, Jersey City, New Jersey

900 students:

- White, 12 percent
- Black, 6 percent
- Hispanic, 76 percent
- Asian/Pacific Islanders, 6 percent
- Native American, < 1 percent

84 percent in 2008-2009 were eligible for free or reduced-price lunch.

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STEM instruction and school practices as Criteria for Success

Key aspects of practice in successful schools:

- Instruction captures student interest and involves them in STEM practices
- School conditions are supportive to effective STEM instruction

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High Quality STEM Instructional Practices

- Capitalize on students early interest and experiences
- Actively engage students in science, engineering and math practices throughout schooling
- Teachers use what they know about student learning to help students apply practices
- Students successively deepen understanding of core STEM ideas and of the concepts that are shared across Science, Math & Engineering
- Pedagogy is student-centered and focuses on experiential learning

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Approaches to STEM Curriculum

- Complete integration/immersion
  (across STEM/across other disciplines)
- Strategic Integration
- Disciplinary focus on Science and Mathematics and expanded curriculum to Engineering and Technology

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Project Based Learning

In Project Based Learning (PBL), students go through an extended process of inquiry in response to a complex question, problem, or challenge. Rigorous projects help students learn key academic content and practice 21st Century Skills (such as collaboration, communication & critical thinking).

(source: http://www.bie.org)

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Rigorous and in-depth Project Based Learning

- is organized around an open-ended Driving Question or Challenge.
- creates a need to know essential content and skills.
- requires inquiry to learn and/or create something new.
- requires critical thinking, problem solving, collaboration, and various forms of communication.
- allows some degree of student voice and choice.
- incorporates feedback and revision.

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Ohio STEM Learning Network

http://www.osln.org/

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Project Lead the Way

http://www.pltw.org/

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Implementing High Quality Science and Math Instructional Programs

Science: FOSS, SEPUP

Sci/Lit: Seeds of Science Roots of Reading

Math: Interactive Math Programs, Investigations

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Barriers to improving STEM Education

- Curriculum and credit issues
- Schools lack of funding
- Lack of qualified teachers
- Difficult to recruit and retain STEM-Educated Teachers
- Societal and cultural beliefs about STEM
- Hard to attract Students to STEM

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Key Elements needed for supporting STEM education

- Coherent standards & curriculum
- Build teacher capacity thru PD and Pre-service, and recruitment of STEM
- Supportive system of Assessment and Accountability
- Adequate Instructional Time
- Equal access to high-quality STEM learning opportunities and materials
- School/district conditions and culture

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School Conditions & Cultures

- District/School leadership as the driver for change
- Strong parent and community ties
- Student-centered learning climate
- Instructional guidance for teachers

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National STEM Initiatives

- Educate to Innovate
- Connect a Million Minds
- National Lab Day
- Tapping America's Potential
- National Math and Science Initiative
- National Instruments
- US Dept. of Education

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Center on Instruction Website:

- http://www.centeroninstruction.org
- See the STEM resources section under Professional Development events