STEM and the Next Generation Science Standards: The Next Wave of Science Education

By Julie Huffman

The United States has developed as a global leader, in large part, through the genius and hard work of its scientists, engineers, and innovators.

In a world that's becoming increasingly complex, where success is driven not only by *what* you know, but by what you *can do* with what you know, it's more important than ever for our youth to be equipped with the knowledge and skills to solve tough problems, gather and evaluate evidence, and make sense of information.

These are the types of skills that students learn by studying science, technology, engineering, and math—subjects collectively known as STEM.

So what does STEM look like in an NGSS classroom?

Boom

A multi-system approach!
In our classrooms EVERY day.

- Science
- Technology
- Engineering
- Math

Science

1. In November of 2016, the State of California adopted the Next Generation Science Standards (NGSS).

2. State science leadership had already been preparing and training for this. We started that process in September of 2013.

3. We have been running hard with NGSS ever since.

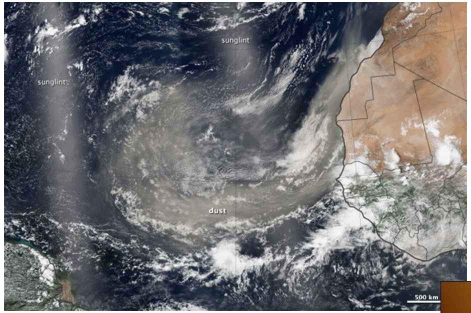
Why new standards?

The Next Generation Science Standards provide students with a brand new way of learning and teachers with a brand new way of teaching.

Inquiry: A seeking or request for truth, information, or knowledge. An investigation.

What do we investigate? Phenomenon

- A ***three-dimensional*** learning approach requires students to use the ***Science and Engineering Practices***, ***Crosscutting Concepts***, and ***Disciplinary Core Ideas*** in concert to explore, investigate, and explain how and why **phenomena** occur.
- Phenomena do not have to be phenomenal. Often simple events, when looking at them through a scientific eye, can elicit curiosity and questions in students and adults. Such wonderment is the beginning of engagement in which answers to questions are sought.
- Check this phenomenon out!

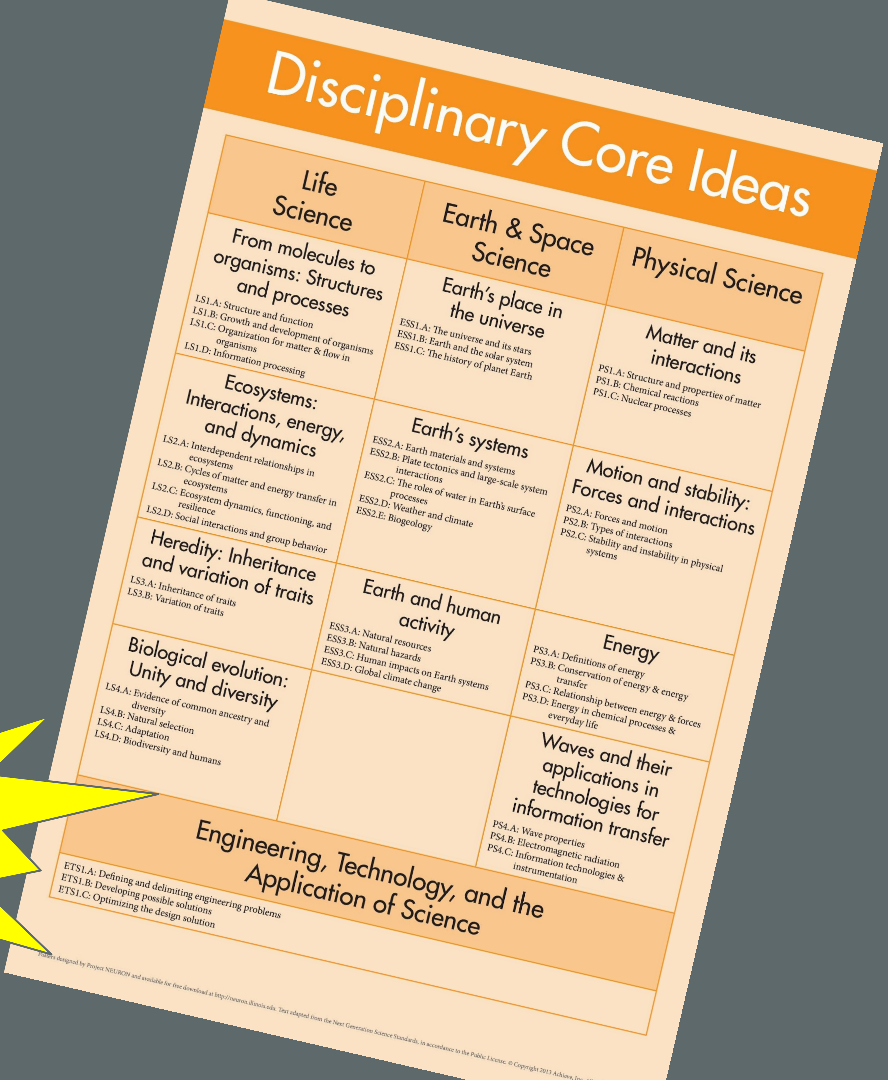

NGSS Instructional Shifts

SCIENCE EDUCATION WILL INVOLVE LESS:	SCIENCE EDUCATION WILL INVOLVE MORE:
Rote memorization of facts and terminology	Facts and terminology learned as needed while developing explanations and designing solutions supported by evidence-based arguments and reasoning.
Learning of ideas disconnected from questions about phenomena	Systems thinking and modeling to explain phenomena and to give a context for the ideas to be learned
Teachers providing information to the whole class	Students conducting investigations, solving problems, and engaging in discussions with teachers' guidance
Teachers posing questions with only one right answer	Students discussing open-ended questions that focus on the strength of the evidence used to generate claims
Students reading textbooks and answering questions at the end of the chapter	Students reading multiple sources, including science-related magazine and journal articles and web-based resources; students developing summaries of information.
Pre-planned outcome for "cookbook" laboratories or hands-on activities	Multiple investigations driven by students' questions with a range of possible outcomes that collectively lead to a deep understanding of established core scientific ideas
Worksheets	Student writing of journals, reports, posters, and media presentations that explain and argue
Oversimplification of activities for students who are perceived to be less able to do science and engineering	Provision of supports so that all students can engage in sophisticated science and engineering practices

What are the 3-dimensions?

The DCI's.

What we want students to know.

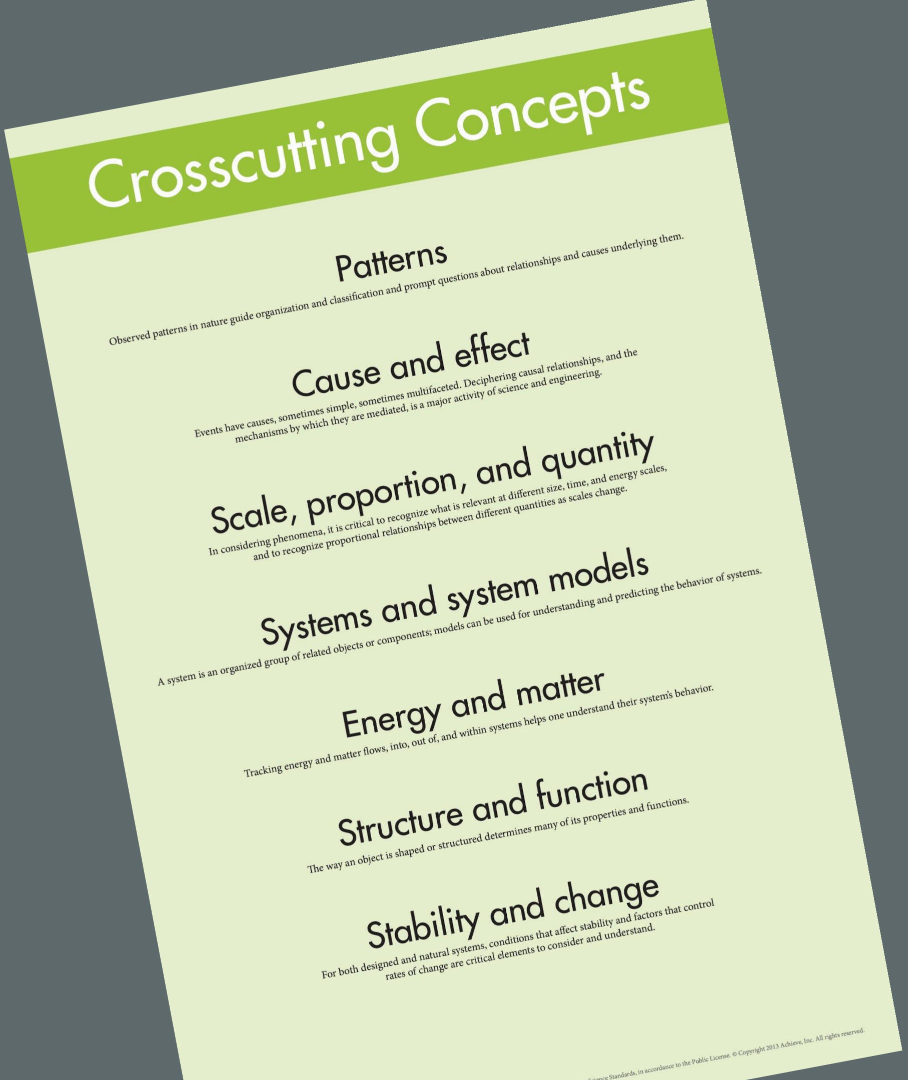


Technology

What are the 3-dimensions?

The CCC’s.

How we want students to think.



What are the 3-dimensions?

The SEP's.

What we want students to do!

Engineering

Science and Engineering Practices

Asking questions and defining problems

A practice of science is to ask and refine questions that lead to descriptions and explanations of how the natural and designed world(s) works and which can be empirically tested.

Developing and using models

A practice of both science and engineering is to use and construct models as helpful tools for representing ideas and explanations. These tools include diagrams, drawings, physical replicas, mathematical representations, analogies, and computer simulations.

Planning and carrying out investigations

Scientists and engineers plan and carry out investigations in the field or laboratory, working collaboratively as well as individually. Their investigations are systematic and require clarifying what counts as data and identifying variables or parameters.

Analyzing and interpreting data

Scientific investigations produce data that must be analyzed in order to derive meaning. Because data patterns and trends are not always obvious, scientists use a range of tools—including tabulation, graphical interpretation, visualization, and statistical analysis—to identify the significant features and patterns in the data. Scientists identify sources of error in the investigations and calculate the degree of certainty in the results.

Using mathematics and computational thinking

In both science and engineering, mathematics and computation are fundamental tools for representing physical variables and their relationships. They are used for a range of tasks such as constructing simulations; solving equations exactly or approximately; and recognizing, expressing, and applying quantitative relationships.

Constructing explanations and designing solutions

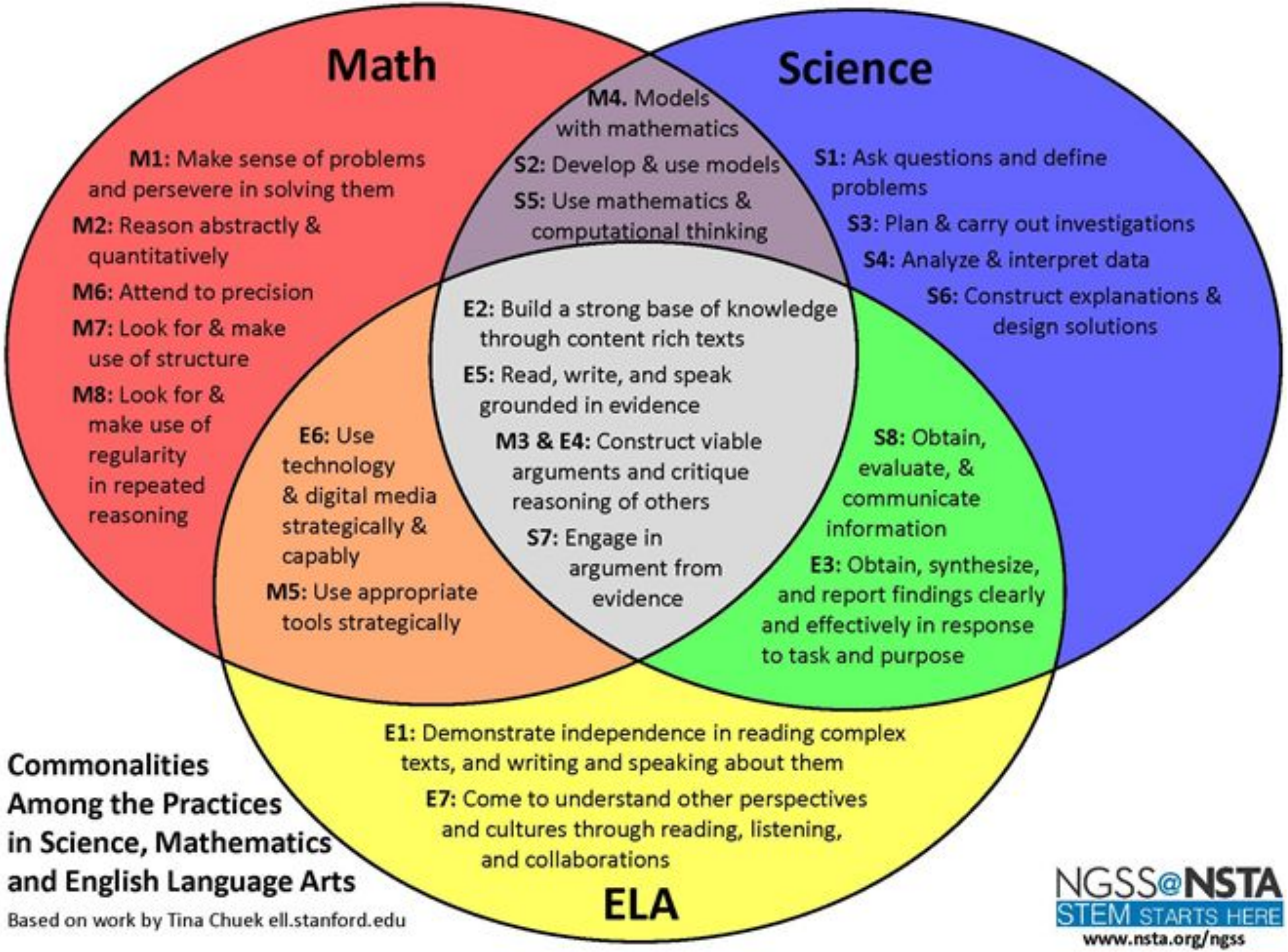
The end-products of science are explanations and the end-products of engineering are solutions. The goal of science is the construction of theories that provide explanatory accounts of the world. A theory becomes accepted when it has multiple lines of empirical evidence and greater explanatory power of phenomena than previous theories.

Engaging in argument from evidence

Argumentation is the process by which evidence-based conclusions and solutions are reached. In science and engineering, reasoning and argument based on evidence are essential to identifying the best explanation for a natural phenomenon or the best solution to a design problem.

Obtaining, evaluating, and communicating information

Scientists and engineers must be able to communicate clearly and persuasively the ideas and methods they generate. Critiquing and communicating ideas individually and in groups is a critical professional activity.



Math
Science
M4. Models with mathematics
S2: Develop & use models
S5: Use mathematics & computational thinking
M1: Make sense of problems and persevere in solving them
M2: Reason abstractly & quantitatively
M6: Attend to precision
M7: Look for & make use of structure
M8: Look for & make use of regularity in repeated reasoning
S1: Ask questions and define problems
S3: Plan & carry out investigations
S4: Analyze & interpret data
S6: Construct explanations & design solutions
E2: Build a strong base of knowledge through content rich texts
E5: Read, write, and speak grounded in evidence
M3 & E4: Construct viable arguments and critique reasoning of others
S7: Engage in argument from evidence
E6: Use technology & digital media strategically & capably
M5: Use appropriate tools strategically
S8: Obtain, evaluate, & communicate information
E3: Obtain, synthesize, and report findings clearly and effectively in response to task and purpose
E1: Demonstrate independence in reading complex texts, and writing and speaking about them
E7: Come to understand other perspectives and cultures through reading, listening, and collaborations
ELA
Commonalities Among the Practices in Science, Mathematics and English Language Arts
Based on work by Tina Chuek ell.stanford.edu
NGSS@NSTA
STEM STARTS HERE
www.nsta.org/ngss

Engineering, Technology, and Applications of Science

ETS1.A: Defining and Delimiting Engineering Problems

- A situation that people want to change or create can be approached as a problem to be solved through engineering. (K–2-ETS1-1)
- Asking questions, making observations, and gathering information are helpful in thinking about problems. (K–2-ETS1-1)
- Before beginning to design a solution, it is important to clearly understand the problem. (K–2-ETS1-1)

ETS1.A: Defining and Delimiting Engineering Problems

- Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. (HS-ETS1-1)
- Humanity faces major global challenges today, such as the need for supplies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global challenges also may have manifestations in local communities. (HS-ETS1-1)

Matrix of Connections to Engineering, Technology and Applications of Science in NGSS

NGSS@NSTA
STEM STARTS HERE

K-2	3-5	6-8	9-12
Interdependence of Science, Engineering, and Technology			
• Science and engineering involve the use of tools to observe and measure things.	• Science and technology support each other. • Tools and instruments are used to answer scientific questions, while scientific discoveries lead to the development of new technologies.	• Engineering advances have led to important discoveries in virtually every field of science and scientific discoveries have led to the development of entire industries and engineered systems. • Science and technology drive each other forward.	• Science and engineering complement each other in the cycle known as research and development (R&D). • Many R&D projects may involve scientists, engineers, and others with wide ranges of expertise.
Influence of Engineering, Technology, and Science and the Natural World			
• Every human-made product is designed by applying some knowledge of the natural world and is built by using natural materials. • Taking natural materials to make things impacts the environment.	• People's needs and wants change over time, as do their demands for new and improved technologies. • Engineers improve existing technologies or develop new ones to increase their benefits, decrease known risks, and meet societal demands. • When new technologies become available, they can bring about changes in the way people live and interact with one another.	• All human activity draws on natural resources and has both short and long-term consequences, positive as well as negative, for the health of people and the natural environment. • The uses of technologies and any limitations on their use are driven by individual or societal needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions. • Technology use varies over time and from region to region.	• Modern civilization depends on major technological systems, such as agriculture, health, water, energy, transportation, manufacturing, construction, and communications. • Engineers continuously modify these systems to increase benefits while decreasing costs and risks. • New technologies can have deep impacts on society and the environment, including some that were not anticipated. • Analysis of costs and benefits is a critical aspect of decisions about technology.

Developed by NSTA using information from Appendix J of the *Next Generation Science Standards* © 2011, 2012, 2013 Achieve, Inc.

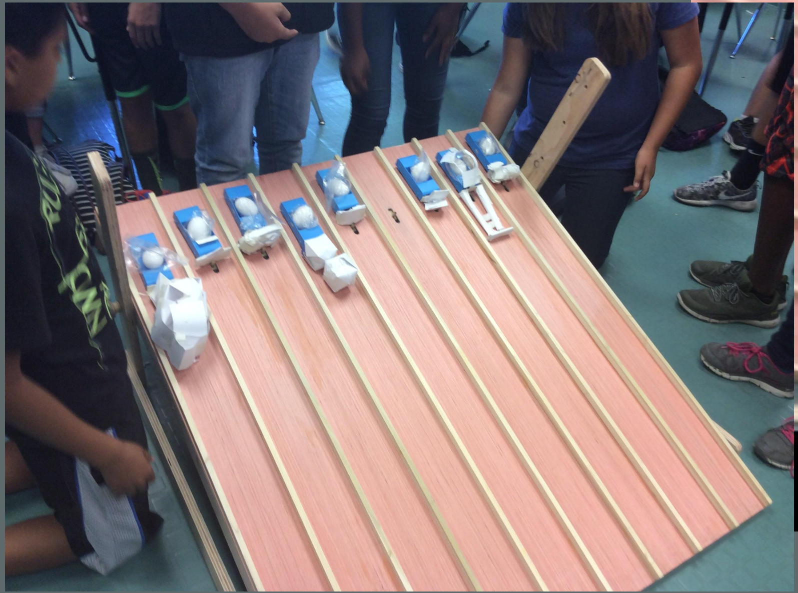
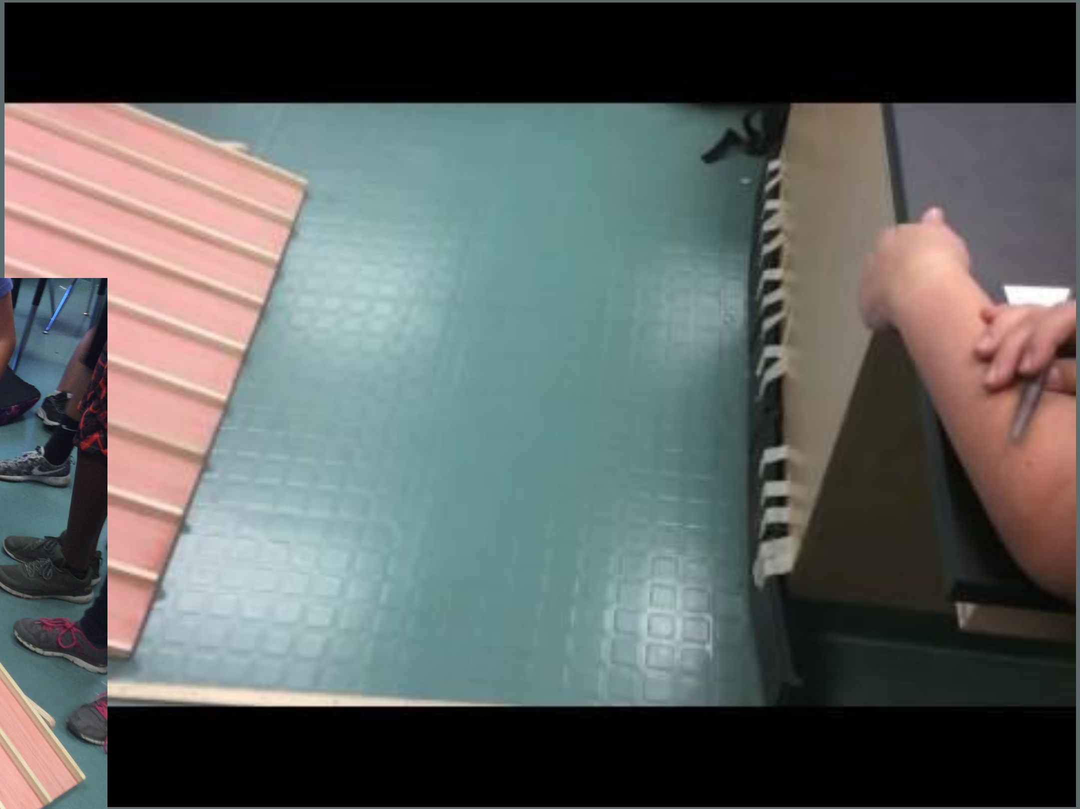
Adapted from: National Research Council (2011). *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*. Committee on a Conceptual Framework for New K-12 Science Education Standards. Board on Science Education, Division of Behavioral and Social Sciences and Education. Washington, DC: The National Academy Press. Chapter 4: Crosscutting Concepts.

Apply Newton's Third Law to design a solution to a problem involving the motion of two colliding objects.

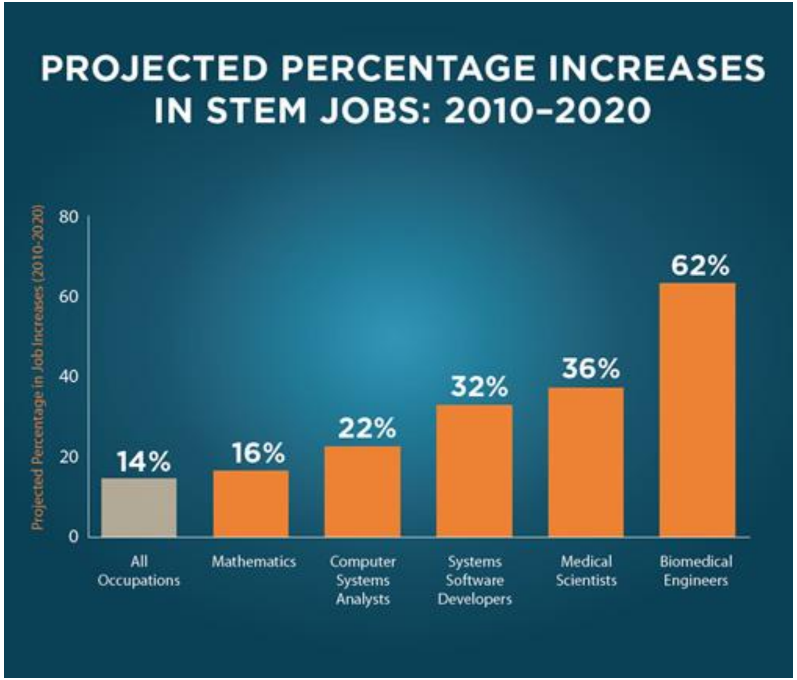
"When two objects collide, push, or pull on one another, each one exerts a force on the other that can cause energy to be exchanged. Students design bumpers to minimize the effect of a collision and then conduct investigations to understand the physical processes that allowed their bumpers to work."

MS-ETS1-1. Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.

MS-ETS1-2. Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

Why STEM?



The average median hourly wage for STEM jobs is $37.44. Compared to the median for all other types of jobs in the US, $18.68, STEM-related jobs pay exceptionally well.

Compared to the rest of the world, the US ranks 27th in math. The US has fallen behind the rest of the world at an alarming rate. US students recently finished 27th in math and 20th in science in the ranking of 34 countries.

21 INSTRUCTIONAL SHIFTS FOR THE 21ST CENTURY

Individual ➡ Collaborative
Knowledge-based ➡ Skills-Based
Teacher-centered ➡ Student-centered
Single-source ➡ Crowd-sourced
Excluding technological tools ➡ Embracing technological tools
Students learn from authorities ➡ Students learn from experience
Occurs in a classroom at a school ➡ Any time, any place
Defined by standards ➡ Defined by student needs
Artificial products ➡ Authentic products
Students and teachers isolated ➡ Students and teachers collaborating world-wide
Points-based grading ➡ Standards-based grading
Assessed by seat time ➡ Assessed by student mastery
Students re-creating or repeating ➡ Students creating
Information scarcity ➡ Information abundance
Externally directed ➡ Self directed
Passive learning ➡ Active learning
Lecture ➡ Inquiry
Consuming ➡ Creating (including coding)
Turn it in ➡ Publish it
Discipline specific ➡ Multidisciplinary
Students given information sources ➡ Students find sources themselves

College and Career Readiness in WSHUHSD

Agriculture and Natural Resources
Arts, Media, and Entertainment *(Film and Video Production, Stage Technology, Visual and Commercial Art)*
Building and Construction Trades *(Residential and Commercial Construction*
Engineering and Architecture (Aerospace, Civil Engineering)
Health Science and Medical Technology *(Allied Health, Dental, Emergency Medicine, Medical Technology, Sports Medicine)*
Hospitality, Tourism, and Recreation *(Food Service, Tourism and Recreation)*
Information and Communication Technologies *(Network, Software and Systems Development)*
Manufacturing and Product Development *(Product Innovation and Design)*
Marketing, Sales and Service
Public Services *(Emergency Response, Legal Practices, Criminal Justice)*
Transportation *(Systems Diagnostics, Service, and Repair)*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Science Literacy

Science
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