California Math & Science Partnership (CaMSP) Grant:
Implementation in ABCUSD with a Focus on Designing Engineering Lessons

ABC USD
K-12 Alliance/WestEd
CSULB
Anaheim STEM Symposium, CA
October 30, 2015
Primary Goal of the Partnership

- To best prepare secondary science teachers in ABCUSD to deliver high quality, instruction of the NGSS with full integration of the engineering design standards in all of the science disciplines.
Three CaMSP Components

- Science Content-Pedagogy Training (engineering focus) – 54 hrs per year
- **TLC Lesson Studies** - 24 hrs each year
- Engineering Job Shadow – 6 hrs per each year
What's the big idea?
Session Outcomes

• Understand the difference in NGSS between the
  - Science & Engineering Practices
  - Performance Standards (PE’s) for Disciplinary Core Ideas (DCI) that have an engineering focus (have an asterisk*).
  - Middle School Engineering Design Standards

• Learn why an engineering lesson is very unlikely to be a stand alone lesson.

• Learn how an engineering lesson doesn’t have to involve something being constructed.
Science & Engineering Practices

- Asking questions and defining problems
- Developing and using models
- Planning and carrying out investigations
- Analyzing and interpreting data
- Using mathematics and computational thinking
- Constructing explanations and designing solutions
- Engaging in argument from evidence
- Obtaining, evaluating, and communicating information
**MS-PS1 Matter and Its Interactions**

Students who demonstrate understanding can:

**MS-PS1-1.** Develop models to describe the atomic composition of simple molecules and extended structures. [Clarification Statement: Emphasis is on developing models of molecules that vary in complexity. Examples of simple molecules could include ammonia and methanol. Examples of extended structures could include sodium chloride or diamonds. Examples of molecular-level models could include drawings, 3D ball and stick structures, or computer representations showing different molecules with different types of atoms.] [Assessment Boundary: Assessment does not include valence electrons and bonding energy, discussing the ionic nature of subunits of complex structures, or a complete depiction of all individual atoms in a complex molecule or extended structure.]

**MS-PS1-2.** Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred. [Clarification Statement: Examples of reactions could include burning sugar or steel wool, fat reacting with sodium hydroxide, and mixing zinc with hydrogen chloride.] [Assessment Boundary: Assessment is limited to analysis of the following properties: density, melting point, boiling point, solubility, flammability, and odor.]

**MS-PS1-3.** Gather and make sense of information to describe that synthetic materials come from natural resources and impact society. [Clarification Statement: Emphasis is on natural resources that undergo a chemical process to form the synthetic material. Examples of new materials could include new medicine, foods, and alternative fuels.] [Assessment Boundary: Assessment is limited to qualitative information.]

**MS-PS1-4.** Develop a model that predicts and describes changes in particle motion, temperature, and state of a pure substance when thermal energy is added or removed. [Clarification Statement: Emphasis is on qualitative molecular-level models of solids, liquids, and gases to show that adding or removing thermal energy increases or decreases kinetic energy of the particles until a change of state occurs. Examples of models could include drawings and diagrams. Examples of particles could include molecules or inert atoms. Examples of pure substances could include water, carbon dioxide, and helium.]

**MS-PS1-5.** Develop and use a model to describe how the total number of atoms does not change in a chemical reaction and thus mass is conserved. [Clarification Statement: Emphasis is on law of conservation of matter and on physical models or drawings, including digital forms, that represent atoms.] [Assessment Boundary: Assessment does not include the use of atomic masses, balancing symbolic equations, or intermolecular forces.]

**MS-PS1-6.** Undertake a design project to construct, test, and modify a device that either releases or absorbs thermal energy by chemical processes.* [Clarification Statement: Emphasis is on the design, controlling the transfer of energy to the environment, and modification of a device using factors such as type and concentration of a substance. Examples of designs could involve chemical reactions such as dissolving ammonium chloride or calcium chloride.] [Assessment Boundary: Assessment is limited to the criteria of amount, time, and temperature of substance in testing the device.]

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 describe, test, and predict more abstract phenomena and design systems.

**Disciplinary Core Ideas**
- **PS1.A: Structure and Properties of Matter**
  - Substances are made from different types of atoms, which combine with one another in various ways. Atoms form molecules that range in size from two to thousands of atoms. (MS-PS1-1)

**Crosscutting Concepts**
- **Patterns**
  - Macroscopic patterns are related to the nature of microscopic and atomic-level structure. (MS-PS1-2)
  - Cause and Effect
Standards (Performance Expectations) for “Matter and Its Interactions”

• **MS-PS1-2**: Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred. *(Energy & Matter/ Patterns)*

• **MS-PS1-6**: Undertake a design project to construct, test, and modify a device that either releases or absorbs thermal energy by chemical processes.*

* (note the asterisk)
Middle School Engineering Design Standards

- **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.

- **MS-ETS1-3**: Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.

- **MS-ETS1-4**: Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.
## 5E Learning Sequence

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Hand Warmer Lesson

How many have heard of hot packs and cold packs?
Specific Disciplinary Core Idea Standards in “Motion and Stability: Forces and Interactions”

• MS-PS2-1: Apply Newton’s Third Law to design a solution to a problem involving the motion of two colliding objects.*
**MS-ETS1 Engineering Design**

Students who demonstrate understanding can:

**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.

**MS-ETS1-3.** Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.

**MS-ETS1-4.** Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.

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### Science and Engineering Practices

**Asking Questions and Defining Problems**
- Asking questions and defining problems in grades 6-8 builds on grades K-5 experiences and progresses to specifying relationships between variables, and clarifying arguments and models.
  - Define a design problem that can be solved through the development of an object, tool, process, or system and includes multiple criteria and constraints, including scientific knowledge that may limit possible solutions. (MS-ETS1-1)

**Developing and Using Models**
- Modeling in 6-8 builds on K-5 experiences and progresses to developing, using, and revising models to describe, test, and predict more abstract phenomena and design systems.
  - Develop a model to generate data to test ideas about designed systems, including those representing inputs and outputs. (MS-ETS1-4)

**Analyzing and Interpreting Data**
- Analyzing data in 6-8 builds on K-5 experiences and progresses to extending quantitative analysis to investigations, distinguishing between correlation and causation, and basic statistical techniques of data and error analysis.
  - Analyze and interpret data to determine similarities and differences in findings. (MS-ETS1-3)

**Engaging in Argument from Evidence**
- Engaging in argument from evidence in 6-8 builds on K-5 experiences and progresses to constructing a convincing argument that supports or refutes claims for either explanations or solutions about the natural and designed world.
  - Evaluate competing design solutions based on joint developed and agreed-upon design criteria. (MS-ETS1-2)

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### Disciplinary Core Ideas

**ETS1.A: Defining and Delimiting Engineering Problems**
- The more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be successful. Specification of constraints includes consideration of scientific principles and other relevant knowledge that are likely to limit possible solutions. (MS-ETS1-1)

**ETS1.B: Developing Possible Solutions**
- A solution needs to be tested and then modified on the basis of the test results, in order to improve it. (MS-ETS1-4)
  - There are systematic processes for evaluating solutions with respect to how well they meet the criterion and constraints of a problem. (MS-ETS1-2, MS-ETS1-3)
  - Sometimes parts of different solutions can be combined to create a solution that is better than any of its predecessors. (MS-ETS1-3)
  - Models of all kinds are important for testing solutions. (MS-ETS1-4)

**ETS1.C: Optimizing the Design Solution**
- Although one design may not perform the best across all tests, identifying the characteristics of the design that performed the best in each test can provide useful information for the redesign process—that is, some of those characteristics may be incorporated into the new design. (MS-ETS1-3)
  - The iterative process of testing the most promising solutions and modifying what is proposed on the basis of the test results leads to greater refinement and ultimately to an optimal solution. (MS-ETS1-4)

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### Crosscutting Concepts

**Influence of Science, Engineering, and Technology on Society and the Natural World**
- 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. (MS-ETS1-1)
- The uses of technologies and limitations on their use are driven by both societal or individual needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions. (MS-ETS1-1)

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### Connections to MS-ETS1

**Science:** MS-PS3-3

**Science:** MS-PS1-6, MS-PS3-3, Life Science: MS-L.C-5

**Science:** MS-PS1-6, MS-PS3-3, Life Science: MS-L.C-5

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### Articulation of DCIs across grade bands

**3-ETS1.A (MS-ETS1-1), (MS-ETS1-2), (MS-ETS1-3); 3-5.ETS1.B (MS-ETS1-2), (MS-ETS1-3), (MS-ETS1-4); 3-5.ETS1.C (MS-ETS1-1), (MS-ETS1-2), (MS-ETS1-3), (MS-ETS1-4); HS-ETS1.A (MS-ETS1-1), (MS-ETS1-2), (MS-ETS1-3), (MS-ETS1-4); HS-ETS1.B (MS-ETS1-2), (MS-ETS1-3), (MS-ETS1-4), (MS-ETS1-5); HS-ETS1.C (MS-ETS1-1), (MS-ETS1-2), (MS-ETS1-3), (MS-ETS1-4)

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### Common Core State Standards Connections

**ELA/Literacy –**

RST.6-8.1 Cite specific textual evidence to support analysis of science and technical texts. (MS-ETS1-1, (MS-ETS1-2), (MS-ETS1-3)

RST.6-8.7 Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table). (MS-ETS1-3)

RST.6-8.9 Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text on the same topic. (MS-ETS1-2, (MS-ETS1-3)

WHST.6-8.7 Conduct short research projects to answer a question (including a self-generated question), drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration. (MS-ETS1-2)

WHST.6-8.8 Gather relevant information from multiple print and digital sources; assess the credibility of each source; and quote or paraphrase the data and conclusions of others while avoiding plagiarism and providing basic bibliographic information for sources. (MS-ETS1-1)

WHST.6-8.9 Draw evidence from informational texts to support analysis, reflection, and research. (MS-ETS1-2)

SL.6.5 Include multimedia components and visual displays in presentations to clarify claims and findings and emphasize salient points. (MS-ETS1-4)

**Mathematics –**

MP.2 Reason abstractly and quantitatively. (MS-ETS1-1), (MS-ETS1-2), (MS-ETS1-3), (MS-ETS1-4)

7.EE.3 Solve multi-step real-life and mathematical problems posed with positive and negative rational numbers in any form (whole numbers, fractions, and decimals), using tools strategically. Apply properties of operations to calculate with numbers in any form; convert between forms as appropriate; and assess the reasonableness of answers using mental computation and estimation strategies. (MS-ETS1-1), (MS-ETS1-2), (MS-ETS1-3)

7.SP Develop a probability model and use it to find probabilities of events. Compare probabilities from a model to observed frequencies; if the agreement is not good, explain possible sources of the discrepancy. (MS-ETS1-4)

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The section entitled "Disciplinary Core Ideas" is reproduced verbatim from A Framework for K-12 Science Education: Practices, Cross-Cutting Concepts, and Core Ideas. Integrated and reprinted with permission from the National Academy of Sciences.
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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 describe, test, and predict more abstract phenomena and design systems.
  - Develop a model to predict and/or describe phenomena. (MS-PS1-1), (MS-PS1-4)
  - Develop a model to describe unobservable mechanisms. (MS-PS1-5)

*Analyzing and Interpreting Data*
- Analyzing data in 6-8 builds on K-5 and progresses to extending quantitative analysis to investigations, distinguishing between correlation and causation, and basic statistical techniques of data and error analysis.
  - Analyze and interpret data to determine similarities and differences in findings. (MS-PS1-2)

*Constructing Explanations and Designing Solutions*
- Constructing explanations and designing solutions in 6-8 builds on K-5 experiences and progressively to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific knowledge, principles, and theories.
  - Undertake a design project, engaging in the design cycle, to construct and/or implement a solution that meets specific design criteria and constraints. (MS-PS1-6)

*Obtaining, Evaluating, and Communicating Information*
- Obtaining, evaluating, and communicating information in 6-8 builds on K-5 and progresses to evaluating the merit and validity of ideas and methods.
  - Read and evaluate information from multiple appropriate sources and assess the credibility, accuracy, and possible bias of each publication and methods used, and describe how they are supported or not supported by evidence. (MS-PS1-3)

Connections to Nature of Science

*Scientific Knowledge is Based on Empirical Evidence*
- Science knowledge is based upon logical and conceptual connections between evidence and

Disciplinary Core Ideas

PSL.A: Structure and Properties of Matter
- Substances are made from different types of atoms, which combine with one another in various ways. Atoms form molecules that range in size from two to thousands of atoms. (MS-PS1-1)
- Each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it. (MS-PS1-2), (MS-PS1-3)
- Gases and liquids are made of molecules or atoms that are moving about relative to each other. (MS-PS1-4)
- In a liquid, the molecules are constantly in contact with others; in a gas, they are widely spaced except when they happen to collide. In a solid, atoms are closely spaced and may vibrate in position but do not change relative locations. (MS-PS1-4)
- Solids may be formed from molecules, or they may be extended structures with repeating subunits (e.g., crystals). (MS-PS1-1)
- The changes of state that occur with variations in temperature or pressure can be described and predicted using these models of matter. (MS-PS1-4)

PSL.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-PS1-2), (MS-PS1-3), (MS-PS1-5)
- The total number of each type of atom is conserved, and thus the mass does not change. (MS-PS1-5)
- Some chemical reactions release energy, others store energy. (MS-PS1-5)

PSL.D: Definitions of Energy
- The term "heat" as used in everyday language refers both to thermal energy (the motion of atoms or molecules within a substance) and the transfer of thermal energy from one object to another. In science, heat is used only for this second meaning; it refers to the energy transferred due to the temperature difference between two objects. (secondary to MS-PS1-4)
- The temperature of a system is proportional to the average internal kinetic energy and potential energy per atom or molecule (whichever is the appropriate building block for the system's material). The details of that relationship depend on the type of atom or molecule and the interactions among the atoms in the material. Temperature is not a direct measure of a system's total thermal energy. The total thermal energy (sometimes called the total internal energy) of a system depends

Crosscutting Concepts

Patterns
- Macroscopic patterns are related to the nature of microscopic and atomic-level systems. (MS-PS1-2)

Cause and Effect
- Cause and effect relationships may be used to predict phenomena in natural or designed systems. (MS-PS1-4)

Scale, Proportion, and Quantity
- Time, space, and energy phenomena can be observed at various scales using models to study systems that are large or small. (MS-PS1-1)
- The transfer of energy can be tracked as energy flows through a designed or natural system. (MS-PS1-5)

Structure and Function
- Structures can be designed to serve particular functions by taking into account properties of different materials, and how materials can be shaped and used. (MS-PS1-6)

Connections to Engineering, Technology, and Applications of Science

Interdependence of Science, Engineering, and Technology
- 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. (MS-PS1-3)

Influence of Science, Engineering and Technology on Society and the Natural World
- 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

*The performance expectations marked with an asterisk (*) were integrated into the text content with this document using a practice of Crosscutting Concepts and Core Ideas. Integrated and reprinted with permission from the National Academy of Sciences.
**Explain:** Design a safe and effective (time & temperature) hand warmer that can be used to heat Mrs. Song's hand for the longest time period. Which ingredients would be best for this hand warmer, and why?

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Circle one: Exothermic  Endothermic
How could you tell?

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Circle one: Exothermic  Endothermic
How could you tell?

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#1 Calcium Chloride (CaCl₂) and Water

#2 Vinegar and Baking Soda

#4 Hydrochloric Acid (HCl) and Magnesium

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