

The banner features a blue header with the Next Generation Science Assessment logo on the left and the title "Developing Assessments in Physical Science Across Three Dimensions" in red on the right. Below this is a dark grey section with the text "NSF PI Meeting Tuesday, August 5, 2014" in white. The bottom section is green with logos for UIC Learning Sciences Research Institute, CREATE for STEM Institute, SRI Education, and The Concord Consortium.

Next Generation Science Assessment

Developing Assessments in Physical Science Across Three Dimensions

NSF PI Meeting
Tuesday, August 5, 2014

UIC LEARNING SCIENCES RESEARCH INSTITUTE

CREATE for STEM Institute

SRI Education

The Concord Consortium



This section lists the principal investigators and project team members for the project, along with the technology/curriculum developer. It includes logos for UIC Learning Sciences Research Institute, CREATE for STEM Institute, SRI Education, and The Concord Consortium. A disclaimer at the bottom states that the project is funded by the National Science Foundation and that opinions do not necessarily reflect the views of the NSF.

UIC LEARNING SCIENCES RESEARCH INSTITUTE

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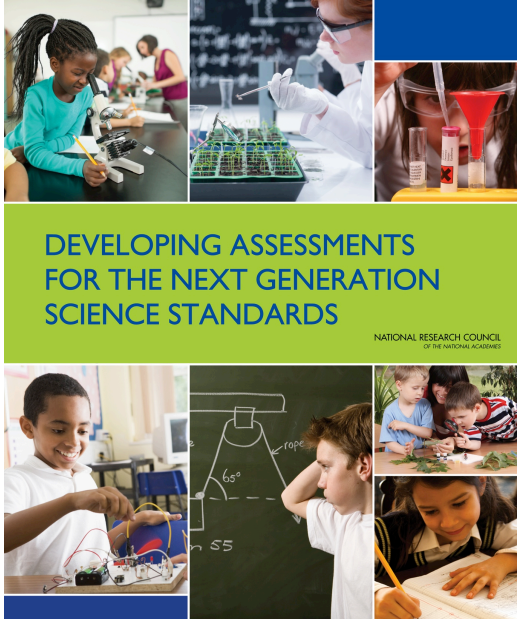
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NGSS Implementation Challenges Addressed by Our Project: Practice & Theory

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**DEVELOPING ASSESSMENTS
FOR THE NEXT GENERATION
SCIENCE STANDARDS**

NATIONAL RESEARCH COUNCIL
OF THE NATIONAL ACADEMIES

**Committee on the
Assessment of
K-12 Science
Proficiency**

Board on Testing and
Assessment
and
Board on Science Education
National Academy of Sciences

Problem of Practice: Assessment Designed to Support Instruction

- To develop the skills and dispositions to use scientific and engineering practices needed to further their learning and to solve problems, students need to experience instruction in which they
 - use multiple practices in developing a particular core idea and
 - apply each practice in the context of multiple core ideas.
- Effective use of the practices will require that they be used in concert with one another, such as in supporting explanation with an argument or using mathematics to analyze data
- Assessments will be critical supports for this instruction.

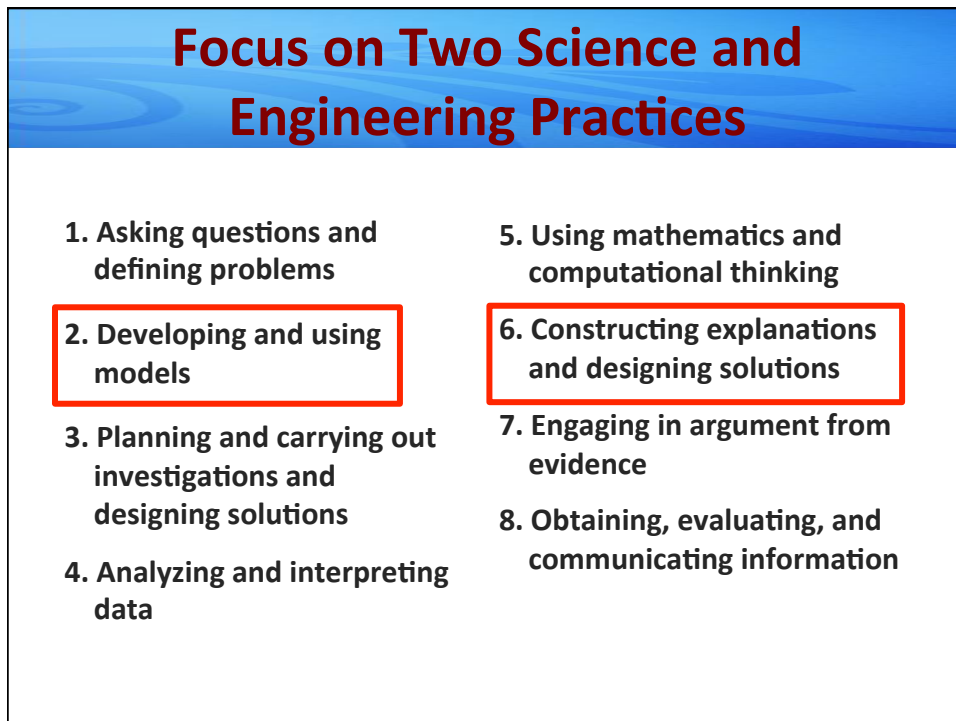
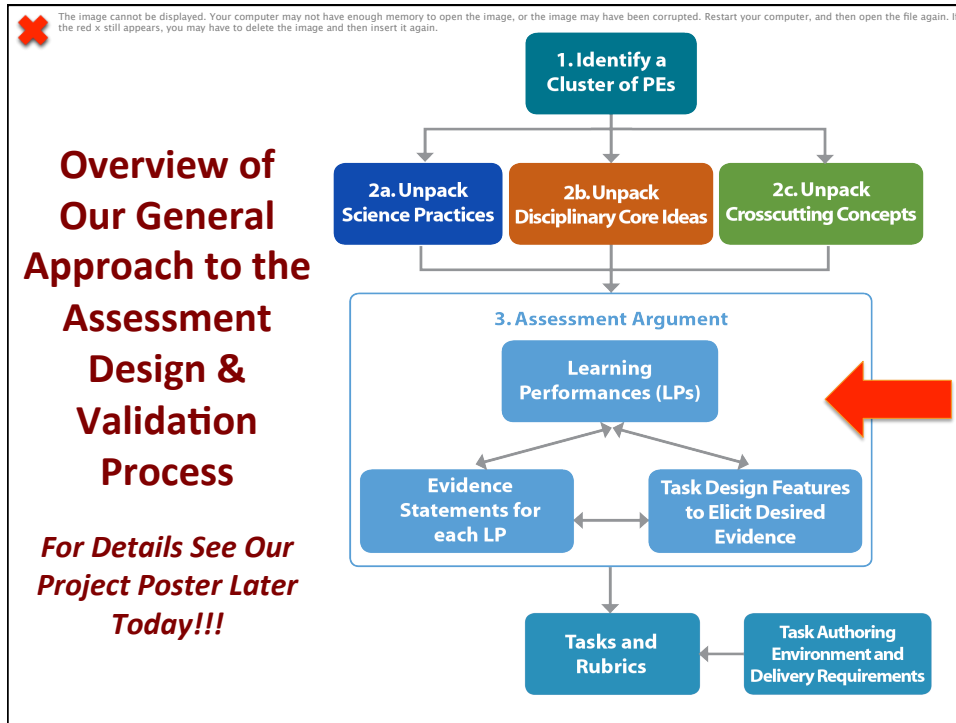
Problem of Theory: Principled Design of Assessment Tasks

- Designing assessment tasks and assembling them into functional instruments will require a careful approach to assessment design.
- Some currently used approaches, such as *evidence-centered design* and *construct modeling*, reflect a principled design process and begin with cognitive research and theory about science knowledge and learning as the starting place of the design process, consistent with core principles from *KWSK*.
- With these approaches, the selection and development of assessment tasks, as well as the scoring rubrics and criteria for scoring, are guided by the construct to be assessed and the best ways of eliciting evidence about student's proficiency with that construct.

Addressing Challenges: Coordinating Contributions to Practice & Theory

Pluses & Minuses of Relying on Performance Expectations

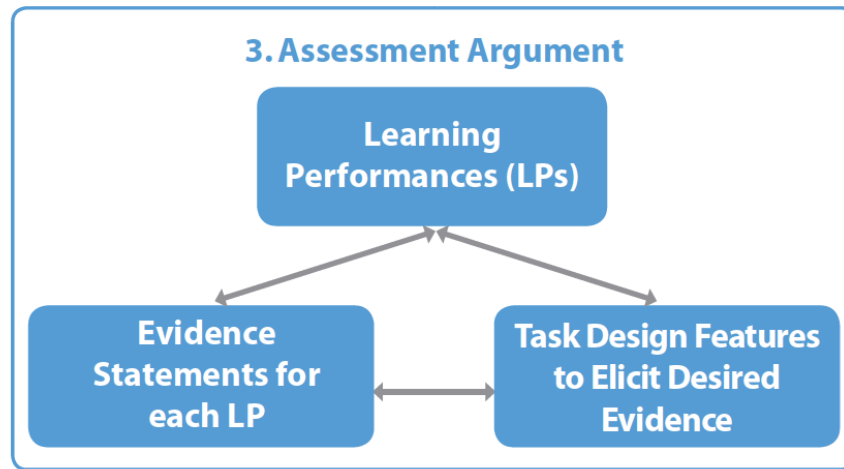
- + Avoid vague cognitive verbs – “know” & “understand”
- + Stated as claims about students in terms of what they are supposed to be able to do to demonstrate their knowledge
- + Identify progressions as part of expectations
- Don't tell us how to get there – curriculum materials and instructional practices
- Need to be “unpacked” in terms of the forms of evidence needed to support the student claim



Focus on Two Physical Science Disciplinary Core Ideas – MS Level	
Life Science	Physical Science
LS1: From Molecules to Organisms: Structures and Processes	PS1: Matter and Its Interactions
LS2: Ecosystems: Interactions, Energy, and Dynamics	PS2: Motion and Stability: Forces and Interactions
LS3: Heredity: Inheritance and Variation of Traits	PS3: Energy
LS4: Biological Evolution: Unity and Diversity	PS4: Waves and Their Applications in Technologies for Information Transfer
Earth & Space Science	Engineering & Technology
ESS1: Earth's Place in the Universe	ETS1: Engineering Design
ESS2: Earth's Systems	ETS2: Links Among Engineering, Technology, Science, and Society
ESS3: Earth and Human Activity	

Progress Made to Date in
Addressing the Challenges of
Practice and Theory

Why Learning Performances?



Qualities of a “Good” Learning Performance

- Blends disciplinary core ideas and practices
- Functions in relation to other learning performances to identify “what it takes” to make progress toward meeting a standard (e.g., NGSS performance expectations)
- Helps to identify an important opportunity that teachers should attend to and assess *before* the end of a unit
- Assessable in a task (likely scenario-based with multiple items)

From a Performance Expectation to Learning Performances

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.]

We determined from unpacking the disciplinary core idea that students need to know that

- Each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it
- “Properties of substances” are the quality or condition of substances that can be observed or measured
- “Characteristic properties” are properties that are independent of the amount of the sample and can be used to identify substances

Example: From a Performance Expectation to Learning Performances

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.]

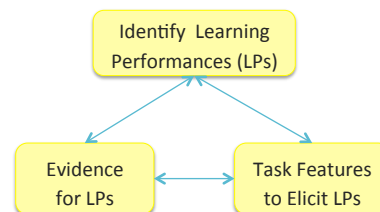
Learning Performance: Students should be able to construct an explanation (including claims, evidence, and reasoning) in which substances are identified based upon characteristic properties

We have developed several such learning performances linked to Performance Expectations for the DCIs in Physical Science

Applying ECD Design Principles: Claims, Evidence and Task Features

ECD in Three Basic Questions

- What **claims** do we want to be able to make about what students know and can do? (Student Model)
- What kinds of **evidence** will students need to provide to demonstrate proficiency? (Evidence Model)
- What kinds of **tasks / task features** will elicit the desired evidence? (Task Model)



When we have logical and coherent answers to these three questions, we have an *assessment argument*.

Assessment Argument Components

<p>Claim</p> <p>Which learning performance are you targeting for your assessment?</p> <p>Evidence</p> <p>What student behaviors will provide evidence of this learning performance?</p>	<p>Students should be able to construct an explanation (including claims, evidence, and reasoning) in which substances are identified based upon characteristic properties</p> <ul style="list-style-type: none"> • Claim: Statement that substances (e.g., Liquid A and B) are the same/different • Evidence: Identification of at least two properties to support claim • Reasoning: Statement that the same substance must have the same set of characteristic properties or that different substances have different characteristic properties
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Assessment Argument Components

<p>Additional Knowledge, Skills and Abilities</p>	
<p>What background knowledge and experiences do students need to respond to the task?</p> <p>Are there ELA or mathematics skills that will be required?</p> <p>What skills do students need to express a correct response?</p>	<ul style="list-style-type: none"> • Knowledge that some properties can be used to identify substances and these properties are called characteristic properties • Knowledge that temperature, volume, and mass cannot be used to identify substances and are not characteristic properties • Ability to identify which data can be used as valid and appropriate evidence • Knowledge that a scientific explanation includes a claim, evidence, and reasoning

Assessment Argument Components

Characteristic Task Features

What features are common across all assessment tasks for this performance expectation?

What are the assessment boundaries to consider?

- Assessment is limited to analysis of the density, melting point, boiling point, solubility, flammability, and odor
- The term “substance” means a pure material (not a mixture)
- Tasks provide data about characteristic properties of substances
- Tasks provide a motivating context

Assessment Argument Components

Variable Task Features

How can you vary contexts for tasks?

How can you vary the complexity of tasks?

How can you increase or reduce demands for ELA and math skills?

- Types of properties included as data/evidence
- State of matter of substances (i.e., solid, liquid, or gas state)
- Inclusion of irrelevant data (e.g., non-characteristic properties)
- Level of scaffolding to develop claim, evidence, and reasoning

Creating a Task and Rubric

Steven found four different bottles filled with unknown pure liquids. He measured the properties of each liquid. The measurements are displayed in the data table below. Steven wonders if any of the liquids are the same substance.

Liquid	Density	Color	Volume	Boiling Point
1	1.0 g/cm ³	Clear	6.1 cm ³	100 C°
2	0.89 g/cm ³	Clear	6.1 cm ³	211 C°
3	0.92 g/cm ³	Clear	10.2 cm ³	298 C°
4	0.89 g/cm ³	Clear	10.2 cm ³	211 C°

Use the data in the table to:

- 1) Write a claim stating whether any of the liquids are the same substance.
- 2) Provide at least two pieces of evidence to support your claim.
- 3) Provide reason(s) that justify why the evidence supports your claim.

Variable Task Features

- Types of properties included as data/evidence – **density and boiling point**
- State of matter of substances – **all liquids**
- Inclusion of irrelevant data – **yes**
- Level of scaffolding to develop claim, evidence, and reasoning – **yes**

Creating a Task and Rubric

For full credit

- **Claim** explicitly states that Liquid 2 and 4 are the same substance.
- **Evidence** includes at least two of the following pieces of evidence: density, boiling point, or color of Liquid 2 and 4 are the same.
- **Reasoning** indicates that density, boiling point, and color are characteristic properties; same substances have the same set of characteristic properties; and Liquid 2 and 4 have the same set of characteristic properties, so they are the same substance.

The Value of ECD

- A systematic process to facilitate consensus about the design principles of tasks (in this case, knowledge-in-use assessments)
- Benefits
 - Developing a shared vision about assessments with colleagues
 - Documentation of design decisions
 - Creating more well-aligned tasks
 - Scalability

Putting Our Ideas and Solutions Out Into Practice

Quick Summary of Project Status

- Identified relevant clusters of Performance Expectations in physical science for middle school students
- Unpacked the Practices, DCIs, and Cross Cutting Concepts
- Identified multiple Learning Performances linked to the multiple Performance Expectations in physical science
- Developed Design Patterns to undergird Task Development
- Developed multiple tasks spanning grades 6-8
- Had teachers review task for relevance to their students
- Implemented tasks in a technology delivery platform
- Collected pilot data on tasks from 50 or more students in each of grades 6, 7 & 8
- Have arrangements in place to collaborate with teachers in CA, MI, and IL on assessment design, interpretation & use

Angela Haydel DeBarger and Christopher J. Harris, SRI International; Joseph Krajcik, Michigan State University; James Pellegrino and Louis DiBella, University of Illinois at Chicago; Daniel Danelin, Concord Consortium

Collaborative Research: Designing Assessments in Physical Science Across Three Dimensions

1 Identify a Cluster of PEs

Performance Expectations related to Energy and Particles of Matter: MS-PS1-1, MS-PS1-4, MS-PS1-4

MS-PS1-4. Develop a model that predicts and describes change in particle motion, temperature, and state as 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 the average kinetic energy of particles and a change of state occurs. Examples of models could include drawing or diagrams. Examples of particles could include molecules or part atoms. Examples of substances could include water, carbon dioxide, and helium.

2a Unpack Science Practices

Developing Models

Component	Evidence
Model elements	Specifies only the appropriate and necessary elements and their attributes in the model
Relationships among elements	Represents only the appropriate relationships and/or interactions among the elements in the model
Consequence	Represents the consequence between model elements and the real world phenomenon or available data
Limitations	Specifies the appropriate limitations of the model

Using Models

Component	Evidence
Model elements	Identifies the appropriate and necessary elements and their attributes in the model
Relationships among elements	Describes the appropriate relationships and/or interactions among the elements in the model
Consequence	Describes the consequence between model elements and the real world phenomenon or available data
Limitations	Identifies the appropriate limitations of the model
Explanation/justification	Explains or predicts phenomena using the model

2b Unpack Disciplinary Core Ideas

PS1.A Structure and Properties of Matter

Identify and further elaborate major ideas

- Substances can be in the form of simple molecules or extended structures. The atoms that join together can be the same or different types of atoms.
- Simple molecules are composed of two or more atoms joined together as a group of atoms, and we know the actual number of atoms in the molecule (examples: CO₂, C₂H₆, CH₄, O₂, O₃, C₆₀).
- Matter is made of atoms and molecules. These atoms and molecules are constantly in motion. All particles of matter have kinetic energy because they are in motion.

Define boundary conditions

- Students are not expected to know the relationship between heat and temperature.
- Students are not expected to compare situations where both the number of particles and the temperature of the objects vary.

Discipline prior knowledge

PS1.1. Develop a model to describe that matter is made of particles too small to be seen.

Student challenges

- Particle sizes of substances and increased mass when changing states from liquid to gas (Phase 6 & Phase 7, WI, Conitt & Preston, 1986).

A Design Process for Developing Next Generation Science Assessments

High-quality assessments of student learning that are aligned with standards are critical to developing a coherent and consistent approach to K-12 science education. Here we describe our design process for creating high-quality science assessments that facilitate the process with the performance expectation related to energy and matter at the middle school level. This design process incorporates principles of evidence-centered design and state-of-the-art psychometric research within an integral validity framework to develop valid and reliable discipline-based assessments that address science practice and crosscutting concepts in the area of physical science. A range of classroom and curriculum developers involved in the research, including classroom using a student curriculum designed to help students learn the scientific practice and connect together in Next Generation Science Standards. A range of data of the research is the inclusion of teachers in co-developing measures for formative use of the assessments. The design framework and the assessments will serve as timely models for next-generation science assessments.

2c Unpack Crosscutting Concepts

Patterns

Important components

- Identification: Identifying patterns in phenomena or data
- Characterization: Characterizing the strength, direction, and/or nature of patterns in phenomena or data
- Organization: Organizing and classifying objects or relationships into types according to similarities or differences

Essential questions to consider

- Construct explanations about how and why particular patterns occur
- Develop and use models to describe observed patterns or predict patterns
- Analyze data to identify characteristic patterns
- Plan investigations to discover patterns
- Construct arguments about the validity of observed patterns

Patterns for Science and the PS Crosscutting Concepts

Specify the boundary conditions for the PS crosscutting concepts

- Students are not expected to know the relationship between heat and temperature.
- Students are not expected to compare situations where both the number of particles and the temperature of the objects vary.

3 Develop the Assessment Argument

Learning performance

Students are able to develop a model to describe how particle motion changes when thermal energy is added and removed.

Evidence

Model elements: Model includes two or more atoms in motion, addition and/or removal of thermal energy, and organization of molecular kinetic energy.

Relationships among elements: Model shows that particles move faster (slower) if thermal energy is added (removed).

Consequence: Model elements corresponds to real world phenomena (e.g., describe how matter expands/contracts when heated/cooled).

Additional CSAs:

- Knowledge matter is made of particles too small to be seen
- Knowledge of atoms and common simple molecules
- Knowledge that model describes how thermal energy rates
- Ability to construct a paper-pencil drawing or use a technology-based drawing tool

Discipline task features

- Task presents real-world phenomenon
- Task includes qualitative where thermal energy rates
- Models do not need to include components of sub-particles, shells, and bonds.
- The relative size of different types of atoms and states is not considered for the middle school level

Variable task features

- Types of models/drawing 3D ball-and-stick/molecular space model or computer simulation
- Types of substances
- State of matter of substances (i.e., solid, liquid or gas state)
- Level of scaffolding to develop models

The Next Generation Science Assessment project is a collaboration among Michigan State University, SRI International and the University of Illinois at Chicago with Concord Consortium and is funded by the National Science Foundation under Grants 1119601, 1156468, and 1116474. Any opinions, findings, and conclusions or recommendations expressed in this document and those of the authors are not necessarily those of the funder or the National Science Foundation.