NGSS as Classroom Versions of Scientific Activity

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Purpose of Presentation

- Briefly introduce structural and conceptual vision for science teaching and learning in the newest science standards documents
- Examine activity theory for framing newest U.S. standards documents
- MBL as an example classroom version of scientific activity

Three Dimensions of Science Learning Outlined in NRC Framework/ Used to Frame NGSS

Science and Engineering Practices

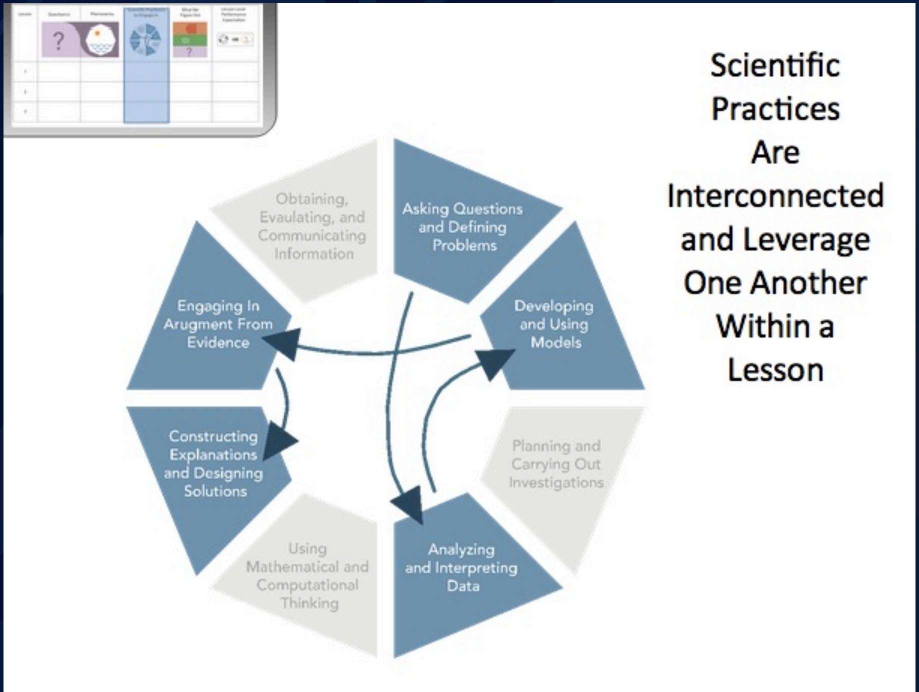
Three-Dimensional Learning to Explain Phenomenon/ Solve Problems

Crosscutting Concepts

Disciplinary Core Ideas

Science & Engineering Practices (SEPs)

Berland (2011) describes practices as the habits of mind and processes undertaken by communities of scientists as they work to develop explanations and arguments for explaining natural phenomena and/or leverage science for making informed decisions as citizens.



Science Studies reveal how practices emerge out of problems scientists have with knowing Gray (2014)

Crosscutting Concepts (CCCs)

1. Patterns
2. Cause and effect
3. Scale, proportion and quantity
4. Systems and system models
5. Energy and matter
6. Structure and function
7. Stability and change

CCCs provide students with connections and intellectual tools that are related across the differing areas of disciplinary content and can enrich their application of practices and their understanding of core ideas. — Framework p. 233

A disciplinary core idea for K-12 science instruction is a scientific idea that:

Has broad importance across multiple science or engineering disciplines or is a key organizing concept of a single discipline

Provides a key tool for understanding or investigating more complex ideas and solving problems

Relates to the interests and life experiences of students or can be connected to societal or personal concerns that require scientific or technical knowledge

Is teachable and learnable over multiple grades at increasing levels of depth and sophistication

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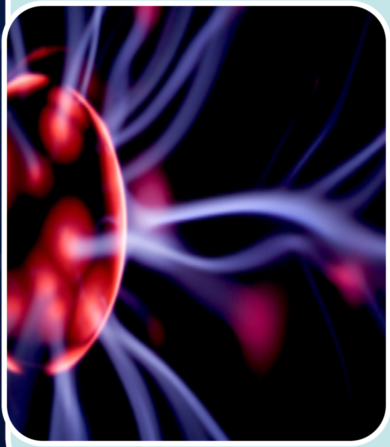
Disciplinary Core Ideas (DCIs)



Physical Science

- PS1: Matter and Its Interactions
- PS2: Motion and Stability: Forces and Interactions
- PS3: Energy
- PS4: Waves and Their Applications in Technologies for Information Transfer

Life Science

- LS1: From Molecules to Organisms: Structure 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 Science

- ESS1: Earth's Place in the Universe
- ESS2: Earth's Systems
- ESS3: Earth and Human Activity

Engineering, Technology, and Applications of Science

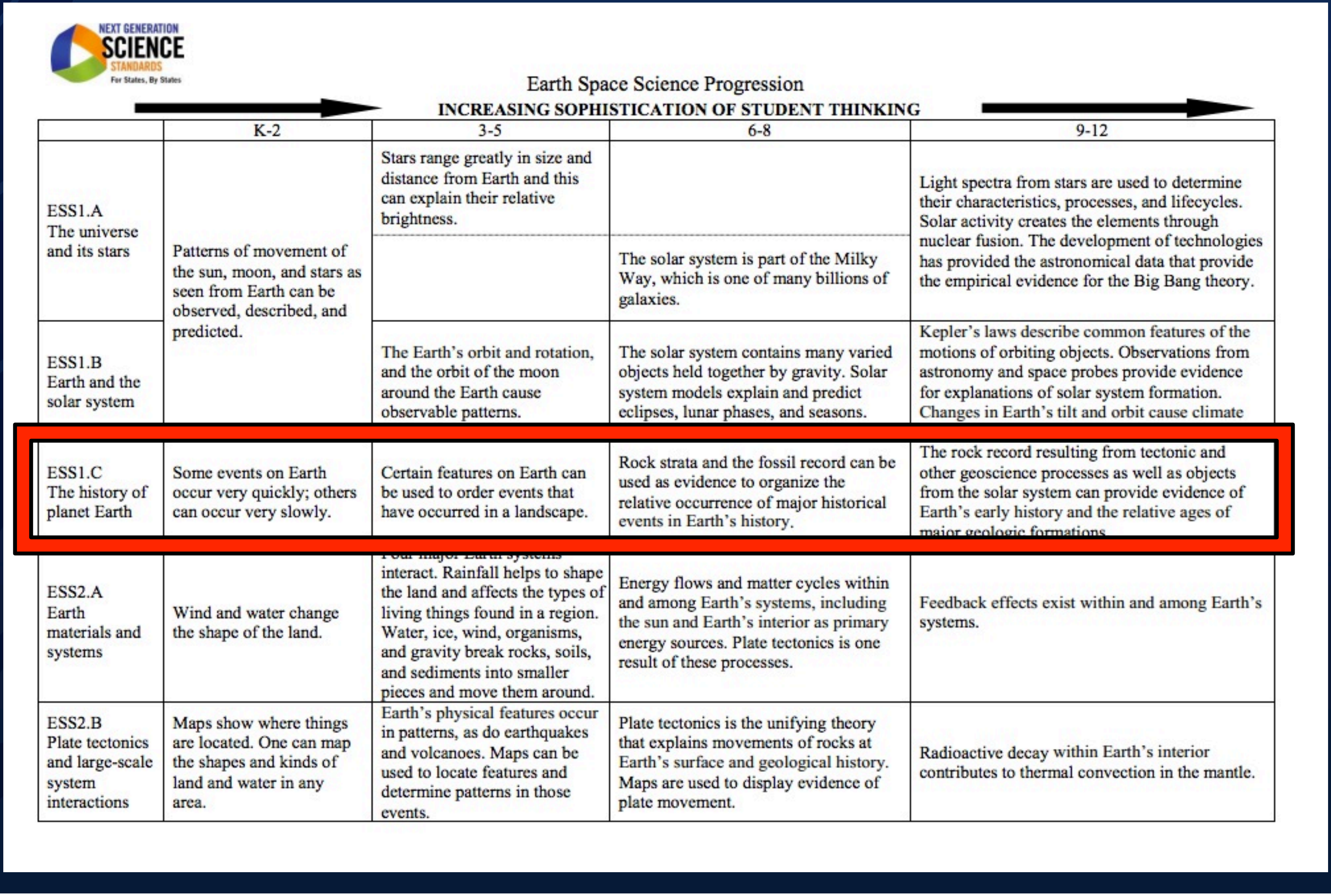
- ETS1: Engineering Design
- ETS2: Links Among Engineering, Technology, Science, and Society

Progressions Across K–12

The framework (and NGSS) emphasizes developing students' proficiency in science coherently across grades K-12 using learning progressions.

Learning Progressions are pathways for students to learn successively more sophisticated ways of thinking about core concepts of science (i.e., DCIs) from kindergarten through high school.

Progressions Across K-12



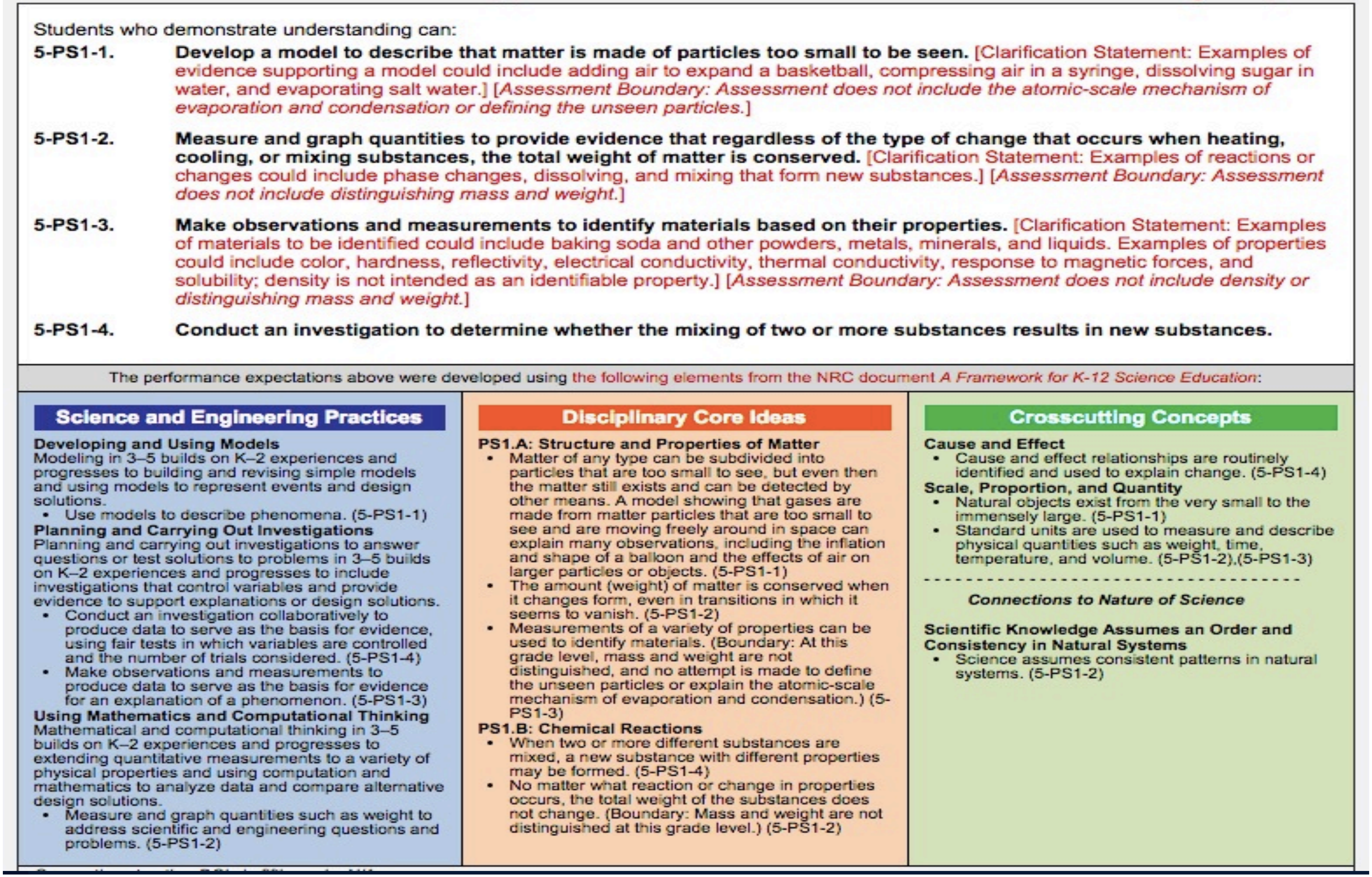
NEXT GENERATION SCIENCE STANDARDS
For States, By States

Earth Space Science Progression

INCREASING SOPHISTICATION OF STUDENT THINKING

	K-2	3-5	6-8	9-12
ESS1.A The universe and its stars	Patterns of movement of the sun, moon, and stars as seen from Earth can be observed, described, and predicted.	Stars range greatly in size and distance from Earth and this can explain their relative brightness.	The solar system is part of the Milky Way, which is one of many billions of galaxies.	Light spectra from stars are used to determine their characteristics, processes, and lifecycles. Solar activity creates the elements through nuclear fusion. The development of technologies has provided the astronomical data that provide the empirical evidence for the Big Bang theory.
ESS1.B Earth and the solar system		The Earth's orbit and rotation, and the orbit of the moon around the Earth cause observable patterns.	The solar system contains many varied objects held together by gravity. Solar system models explain and predict eclipses, lunar phases, and seasons.	Kepler's laws describe common features of the motions of orbiting objects. Observations from astronomy and space probes provide evidence for explanations of solar system formation. Changes in Earth's tilt and orbit cause climate
ESS1.C The history of planet Earth	Some events on Earth occur very quickly; others can occur very slowly.	Certain features on Earth can be used to order events that have occurred in a landscape.	Rock strata and the fossil record can be used as evidence to organize the relative occurrence of major historical events in Earth's history.	The rock record resulting from tectonic and other geoscience processes as well as objects from the solar system can provide evidence of Earth's early history and the relative ages of major geologic formations
ESS2.A Earth materials and systems	Wind and water change the shape of the land.	Four major Earth systems interact. Rainfall helps to shape the land and affects the types of living things found in a region. Water, ice, wind, organisms, and gravity break rocks, soils, and sediments into smaller pieces and move them around.	Energy flows and matter cycles within and among Earth's systems, including the sun and Earth's interior as primary energy sources. Plate tectonics is one result of these processes.	Feedback effects exist within and among Earth's systems.
ESS2.B Plate tectonics and large-scale system interactions	Maps show where things are located. One can map the shapes and kinds of land and water in any area.	Earth's physical features occur in patterns, as do earthquakes and volcanoes. Maps can be used to locate features and determine patterns in those events.	Plate tectonics is the unifying theory that explains movements of rocks at Earth's surface and geological history. Maps are used to display evidence of plate movement.	Radioactive decay within Earth's interior contributes to thermal convection in the mantle.

Integrating the Three Dimensions and Performance Expectations



Students who demonstrate understanding can:

5-PS1-1. **Develop a model to describe that matter is made of particles too small to be seen.** [Clarification Statement: Examples of evidence supporting a model could include adding air to expand a basketball, compressing air in a syringe, dissolving sugar in water, and evaporating salt water.] [*Assessment Boundary: Assessment does not include the atomic-scale mechanism of evaporation and condensation or defining the unseen particles.*]

5-PS1-2. **Measure and graph quantities to provide evidence that regardless of the type of change that occurs when heating, cooling, or mixing substances, the total weight of matter is conserved.** [Clarification Statement: Examples of reactions or changes could include phase changes, dissolving, and mixing that form new substances.] [*Assessment Boundary: Assessment does not include distinguishing mass and weight.*]

5-PS1-3. **Make observations and measurements to identify materials based on their properties.** [Clarification Statement: Examples of materials to be identified could include baking soda and other powders, metals, minerals, and liquids. Examples of properties could include color, hardness, reflectivity, electrical conductivity, thermal conductivity, response to magnetic forces, and solubility; density is not intended as an identifiable property.] [*Assessment Boundary: Assessment does not include density or distinguishing mass and weight.*]

5-PS1-4. **Conduct an investigation to determine whether the mixing of two or more substances results in new substances.**

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 3–5 builds on K–2 experiences and progresses to building and revising simple models and using models to represent events and design solutions.

- Use models to describe phenomena. (5-PS1-1)

Planning and Carrying Out Investigations
Planning and carrying out investigations to answer questions or test solutions to problems in 3–5 builds on K–2 experiences and progresses to include investigations that control variables and provide evidence to support explanations or design solutions.

- Conduct an investigation collaboratively to produce data to serve as the basis for evidence, using fair tests in which variables are controlled and the number of trials considered. (5-PS1-4)
- Make observations and measurements to produce data to serve as the basis for evidence for an explanation of a phenomenon. (5-PS1-3)

Using Mathematics and Computational Thinking
Mathematical and computational thinking in 3–5 builds on K–2 experiences and progresses to extending quantitative measurements to a variety of physical properties and using computation and mathematics to analyze data and compare alternative design solutions.

- Measure and graph quantities such as weight to address scientific and engineering questions and problems. (5-PS1-2)

Disciplinary Core Ideas

PS1.A: Structure and Properties of Matter

- Matter of any type can be subdivided into particles that are too small to see, but even then the matter still exists and can be detected by other means. A model showing that gases are made from matter particles that are too small to see and are moving freely around in space can explain many observations, including the inflation and shape of a balloon and the effects of air on larger particles or objects. (5-PS1-1)
- The amount (weight) of matter is conserved when it changes form, even in transitions in which it seems to vanish. (5-PS1-2)
- Measurements of a variety of properties can be used to identify materials. (Boundary: At this grade level, mass and weight are not distinguished, and no attempt is made to define the unseen particles or explain the atomic-scale mechanism of evaporation and condensation.) (5-PS1-3)

PS1.B: Chemical Reactions

- When two or more different substances are mixed, a new substance with different properties may be formed. (5-PS1-4)
- No matter what reaction or change in properties occurs, the total weight of the substances does not change. (Boundary: Mass and weight are not distinguished at this grade level.) (5-PS1-2)

Crosscutting Concepts

Cause and Effect

- Cause and effect relationships are routinely identified and used to explain change. (5-PS1-4)

Scale, Proportion, and Quantity

- Natural objects exist from the very small to the immensely large. (5-PS1-1)
- Standard units are used to measure and describe physical quantities such as weight, time, temperature, and volume. (5-PS1-2),(5-PS1-3)

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Connections to Nature of Science

Scientific Knowledge Assumes an Order and Consistency in Natural Systems

- Science assumes consistent patterns in natural systems. (5-PS1-2)

Performance Expectations

Performance expectations are "end points" that are assessed at the end.

Teachers role is to design instruction to get students to that end point.

Instruction should engage students in practices.

Three-Dimensional Science Learning

Students engaging in *science and engineering practices* to use *disciplinary core ideas* and *crosscutting concepts* to explain phenomenon or solve problems

Biggest Shifts in NGSS

Three-dimensional learning for the purpose of sensemaking through explaining phenomena or solving problems

Shifting from ‘learning about’ to ‘figuring out’!

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Activity theory for framing newest U.S. standards documents

Activity Theory

The activity in which knowledge is developed and deployed . . . is not separable from or ancillary to learning and cognition. Nor is it neutral. Rather, it is an integral part of what is learned. Situations might be said to co-produce knowledge through activity (Brown, Collins, & Duguid, 1989, p. 32).

Implies that knowledge is deictic, or cannot be fully understood without additional contextual information, since knowledge is as connected to the motivation (*object*) from which it was developed, as it is to the *tools* and *subjects* which produced it.

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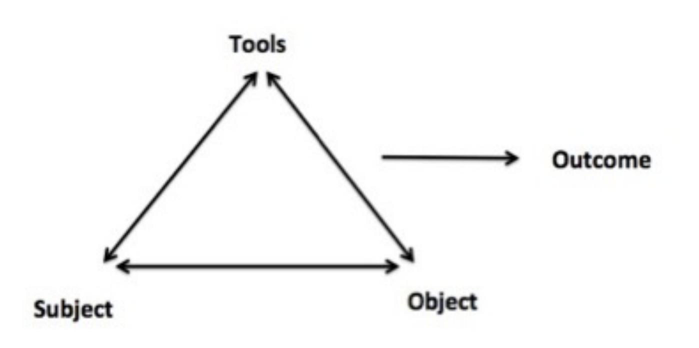
Activity theory for framing newest U.S. standards documents

Activity Theory focuses on *subjects*, *objects*, and *tools* as a framework for understanding "the nature and development of human behaviour" (Lantoff, 2006, p. 8)

Subjects-those engaged in activity

Tools-those resources that are used to mediate the object of activity.

Object-the motivation the subjects have for their engagement.



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Three-Dimensional Science Learning Examined with Activity Theory

Framing for classroom versions of scientific activity

Students (*subjects*) engaging in *science and engineering practices* to use *disciplinary core ideas* and *crosscutting concepts* (*all tools*) to explain phenomenon or solve problems (*objects*)

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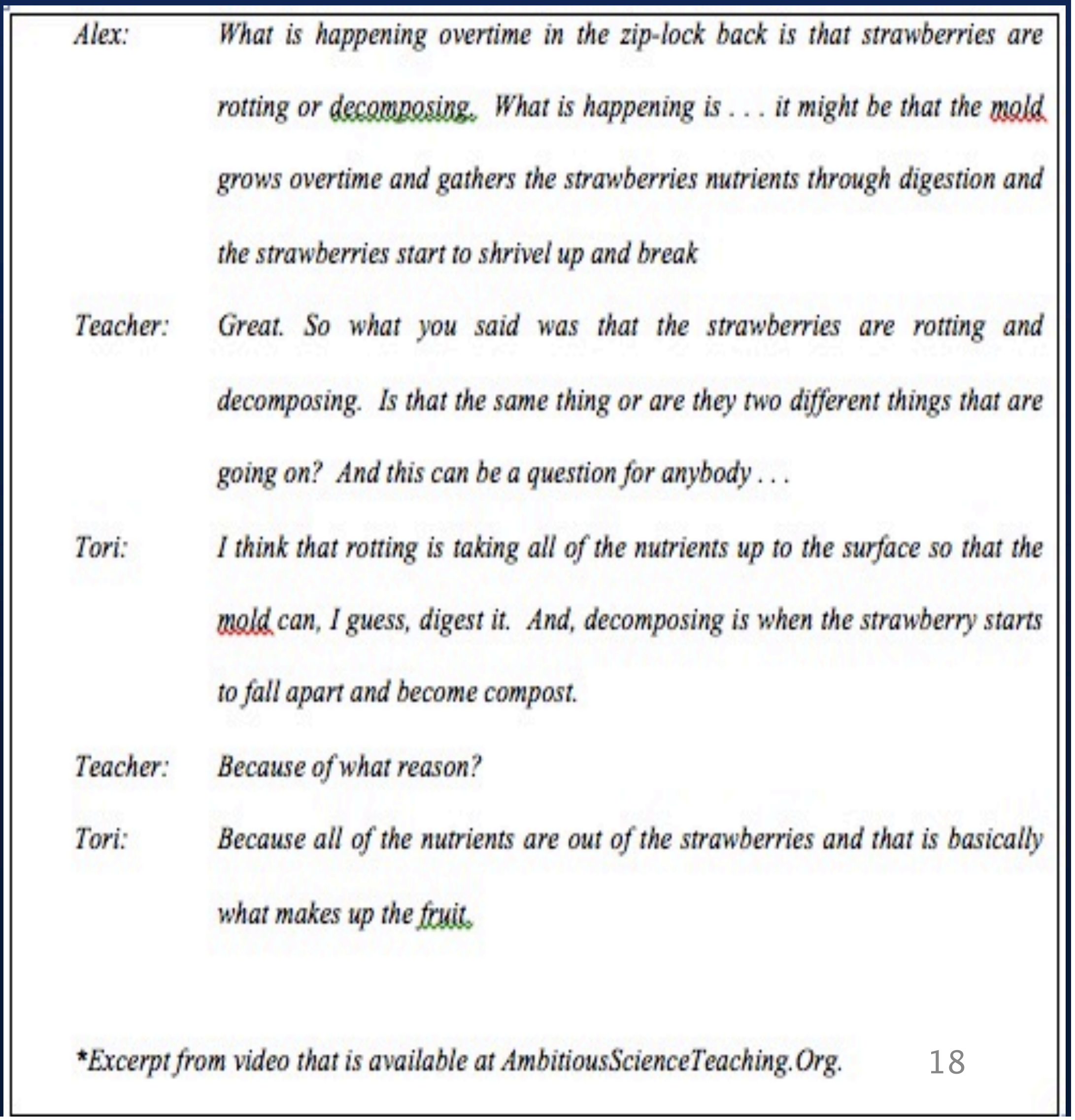
A Classroom Example of Activty

In the example the students' [*subjects*] *object* of the activity is to explain the phenomenon (i.e., what is happening to strawberries in a zip-lock bag at room temperature after twenty days).

In this, students use *tools* like partial understandings about DCIs like digestion, nutrients, and mould growth in concert with *tools* like developing scientific practices of constructing explanations to achieve the *object* of classroom activity.



Alex: *What is happening overtime in the zip-lock back is that strawberries are rotting or decomposing. What is happening is . . . it might be that the mold grows overtime and gathers the strawberries nutrients through digestion and the strawberries start to shrivel up and break*

Teacher: *Great. So what you said was that the strawberries are rotting and decomposing. Is that the same thing or are they two different things that are going on? And this can be a question for anybody . . .*

Tori: *I think that rotting is taking all of the nutrients up to the surface so that the mold can, I guess, digest it. And, decomposing is when the strawberry starts to fall apart and become compost.*

Teacher: *Because of what reason?*

Tori: *Because all of the nutrients are out of the strawberries and that is basically what makes up the fruit.*

**Excerpt from video that is available at AmbitiousScienceTeaching.Org.*

Tool Work

Engeström and Middleton (1996)-*tools* are not conveniently handed to the *subject*, they are invented, refined, discarded and replaced in the activity, according to how functionally useful they are found to be in meeting the *object* of the activity.

Tools are sharpened and honed, and even changed, as they are applied to different contexts

As seen in the episode, *tools* find their usefulness in how they support the *subject-object* dialectic (e.g., how helpful they are for explaining what happens to strawberries)

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Scientific Activity and Tools

Tools identified as SEPs-referred to, as tools scientists developed within scientific activity over time to work at problems with knowing (Gray, 2014).

Accounts of scientific activity explicated in the science studies literature as researchers examine the behaviour of scientists engaged in their day-to-day activity (c.f., Giere, 1999; Knorr Cetina, 1999; Nersessian, 1999).

Accounts of scientific activity have been used to represent classroom versions of these activities, so that, these representative versions are true to the disciplinary activity

Contesting Final Form Tools

Basing NGSS on scientific activity has led to what might be perceived of as finished products represented as SEPs, DCIs, and CCCs in *NGSS*.

However, activity theory posits that there are no finished products, only *tools* that develop overtime that lend themselves as promising candidates for meeting future *objects* identified by future *subjects*.

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New Tools for New Activity

This suggests that the SEPs, DCIs, and CCCs of the *NGSS*, all *object*-mediating *tools* envisioned for use in classroom representations of scientific activity, not learned as much as they are taken up, strategically used, and uniquely constituted within the contexts within which they are activated

Also suggests that additional *tools* (e.g., localized practices developed by students to work at knowing) might also be constituted that help localized communities of practice work toward defensible knowledge claims.

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Implications for Teaching and Learning

At its very essence, activity has a functional role for the subjects (Passmore, Gouvea, Giere, 2014). This role is what defines activity and helps us conceptualize *tools* in ways that may be dramatically different than they are traditionally framed in science classrooms.

Reframing classrooms as activity systems allows teachers to see their students' work as more than learning finalized forms of knowledge and practices identified as SEPs, DCIs, and CCCs in the *NGSS* in context independent forms without application.

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Implications for Teaching and Learning

With activity theory, <u>student work</u> can be seen as <u>the taking-up, creating, and refining tools in powerful context dependent ways that are functionally important to them as *subjects* in activity for accomplishing *objects*</u>

Modeling Based Learning As an Example of a Classroom Version of Scientific Activity

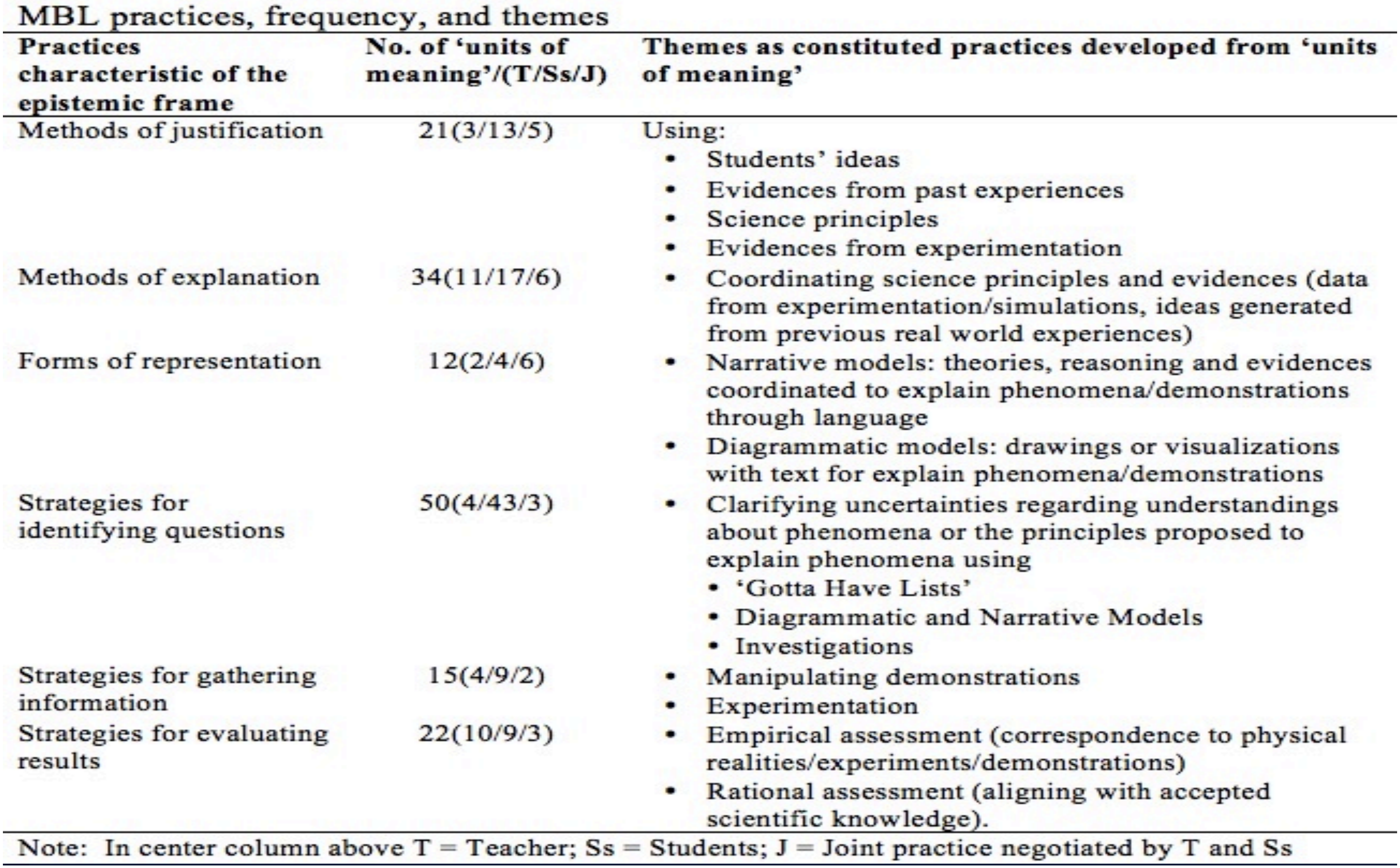
Typical MBL experience

- Students introduced to complex anchoring phenomenon
- Ask what ideas might explain it (Gotta Have Lists)
- Ask to create an initial model (their sets of ideas for explaining the phenomenon)
- Complete investigations or activity that will offer them more evidence or additional ideas to think with
- Revisions of initial models

Modeling Based Learning As an Example of a Classroom Version of Scientific Activity

Ex. To help students understand buoyancy, especially through reasoning with Newton's laws, students were asked to explain the following three phenomena:

Emergent Practices from MBL Buoyancy



MBL practices, frequency, and themes

Practices characteristic of the epistemic frame	No. of 'units of meaning'/(T/Ss/J)	Themes as constituted practices developed from 'units of meaning'
Methods of justification	21(3/13/5)	Using: • Students' ideas • Evidences from past experiences • Science principles • Evidences from experimentation
Methods of explanation	34(11/17/6)	• Coordinating science principles and evidences (data from experimentation/simulations, ideas generated from previous real world experiences)
Forms of representation	12(2/4/6)	• Narrative models: theories, reasoning and evidences coordinated to explain phenomena/demonstrations through language • Diagrammatic models: drawings or visualizations with text for explain phenomena/demonstrations

Strategies for identifying questions	50(4/43/3)	• Clarifying uncertainties regarding understandings about phenomena or the principles proposed to explain phenomena using
		  • 'Gotta Have Lists'
		  • Diagrammatic and Narrative Models
		  • Investigations

Strategies for gathering information	15(4/9/2)	• Manipulating demonstrations • Experimentation
Strategies for evaluating results	22(10/9/3)	• Empirical assessment (correspondence to physical realities/experiments/demonstrations) • Rational assessment (aligning with accepted scientific knowledge).

Note: In center column above T = Teacher; Ss = Students; J = Joint practice negotiated by T and Ss

Ways MBL Represents Scientific Activity

- A persistent *object* of activity
- The taking-up, sharpening, and honing of *object*-mediating *tools* (e.g., partial understandings, ideas, practices)
- Students (*subjects*) engaging in practices (*tools*) to use ideas (*tools*) to explain phenomena (*object*)

Thank you!

For references or any other resources/questions:

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