Science for the Next Generation

All students, all (natural) sciences

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Plan for the talk

- I talk about the US
- You think about what of this may be relevant and useful in the Japanese context
- We have a conversation about that at the end.

Context

- Education in US defined by "State Standards" for learning outcomes

- 40+ states adopted "Common Core" standards for math and english language arts.

- What about science?

Next Generation Science Standards

So far 10 states have adopted, more will

Need for new science standards

- Changing student experience
- Changing world
- Changing science knowledge
- Changing understanding of learning

Changing student experience

Children arrive in school with

- Less experience of natural world
  urbanization
- Less experience of mechanical world

electronic devices replacing mechanical

- More experience of technology and media

electronic toys and cell phones everywhere

than prior generations

Changing world

- More jobs require technical and scientific capabilities

- More decisions (both personal and political) require understanding of complex scientific issues

- More data access, data-rich information
need for data interpretation (in daily life).

Changing science

- Disciplinary boundaries diminishing

  (school subjects defined in late 1800's)

- New world issues (climate change; food, energy, and water needs of growing populations; loss of biodiversity)

- Science, engineering, technology and society interconnections pervasive

Changing understandings of cognitive science and learning

- Rote learning (facts and procedures) does not readily transfer to application in new situations.

- Conceptual change vs layering “schooled knowledge” over naïve conceptions

- Building coherent knowledge systems

“Deeper learning”

Two step development process

A Framework for k-12 Science Education

Produced by BOSE committee,

9 scientists, 9 education experts

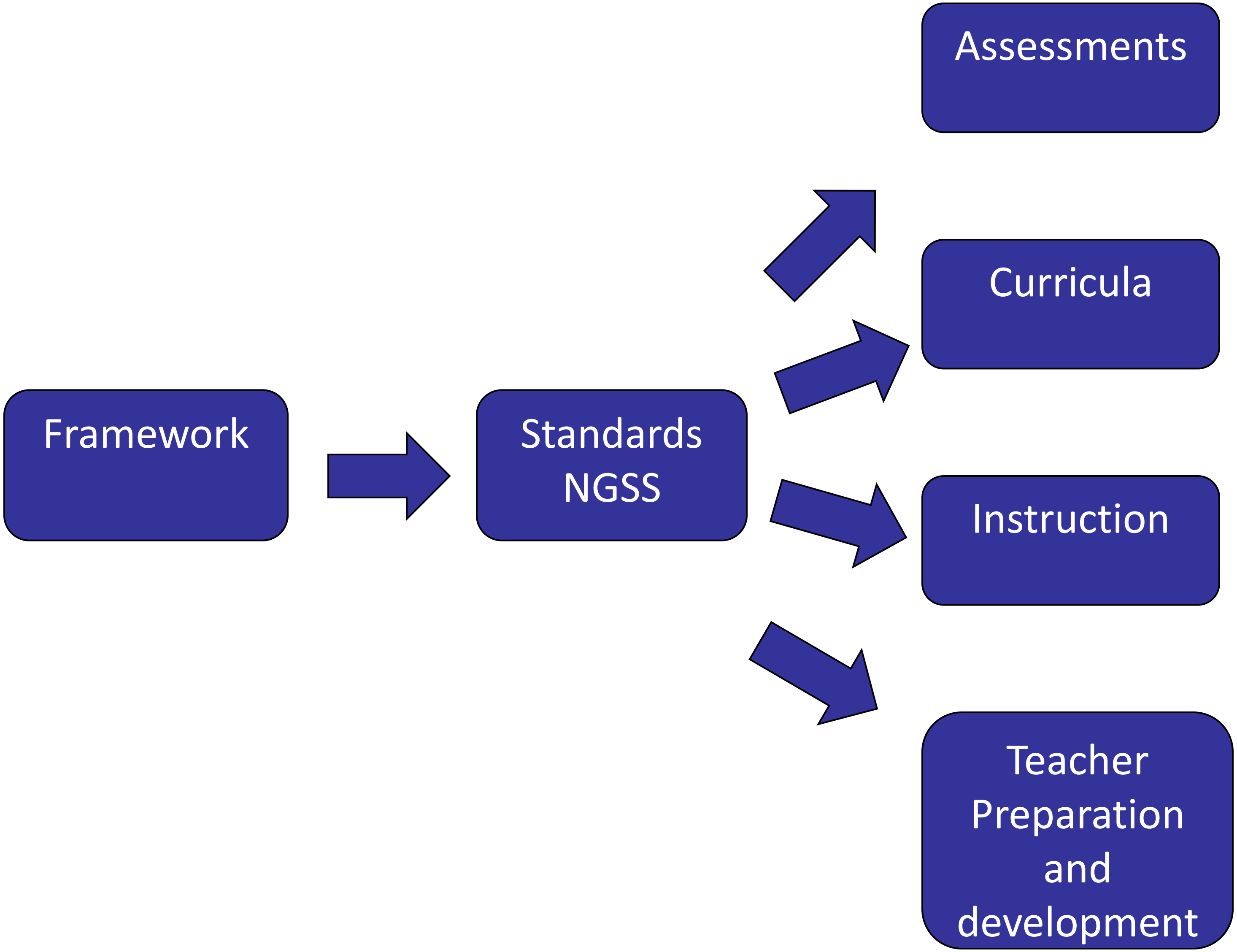
Download at www.nap.edu

Next Generation Science Standards

Produced by a process led by Achieve Inc.

Involving teams from 26 states

www.nextgenscience.edu


Framework
Standards
NGSS
Assessments
Curricula
Instruction
Teacher
Preparation
and
development

Goals of the Framework (shifts)

Science as a coherent body of knowledge and practice

Using results from research on learning to drive more effective science teaching

What do all students need to know and be able to do?

How does this learning build across the years of school?

A new vision of the classroom

- Less teacher talk (maybe 10% of time)

  Teacher role changes to facilitator

  Introducing phenomena

  Orchestrating student work to investigate and explain them

  Providing science ideas via mini-lecture at key moments

  Engaging students in science practices

  Asking questions, rather than giving answers.

Classroom looks different!

Students investigate and explain phenomena

- More student talk and activity
- Work in small groups
- Develop models of system
- Argue about what is observed, how to represent it, what caused it….
- Incorporate science ideas in models
- Use models to support detailed explanations

Framework call for Science in Three Dimensions

- Scientific and engineering practices

--doing what scientists and engineers do

- Crosscutting concepts

-- making connections across sub-disciplines of science

- Disciplinary core ideas

-- learning to use and apply key science ideas,

not just to memorize facts and apply rote procedures

Dimension 1

Science and engineering practices

Scientific and 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 mathematics and computational thinking
6. Developing explanations and designing solutions
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

Red= not common today

Engineering uses all, only 1 and 6 are distinct

Practices used in making sense of phenomena

- Models support explanations
- Argument from evidence to refine models and explanations
- Applying science concepts
- Data analysis turns data to evidence, uses mathematics and computational thinking
- Explanations (or failure of explanation) prompt new questions and investigations
- Need to obtain, evaluate and communicate information at every stage

Students must engage in all practices

- To understand how scientific knowledge is developed (nature of science)
- To support conceptual change by confronting their own models with phenomena
- To be able to apply science and engineering knowledge in new contexts

Explanations are not science theories

- Student must learn science ideas

- Apply them to understand phenomena or in design projects

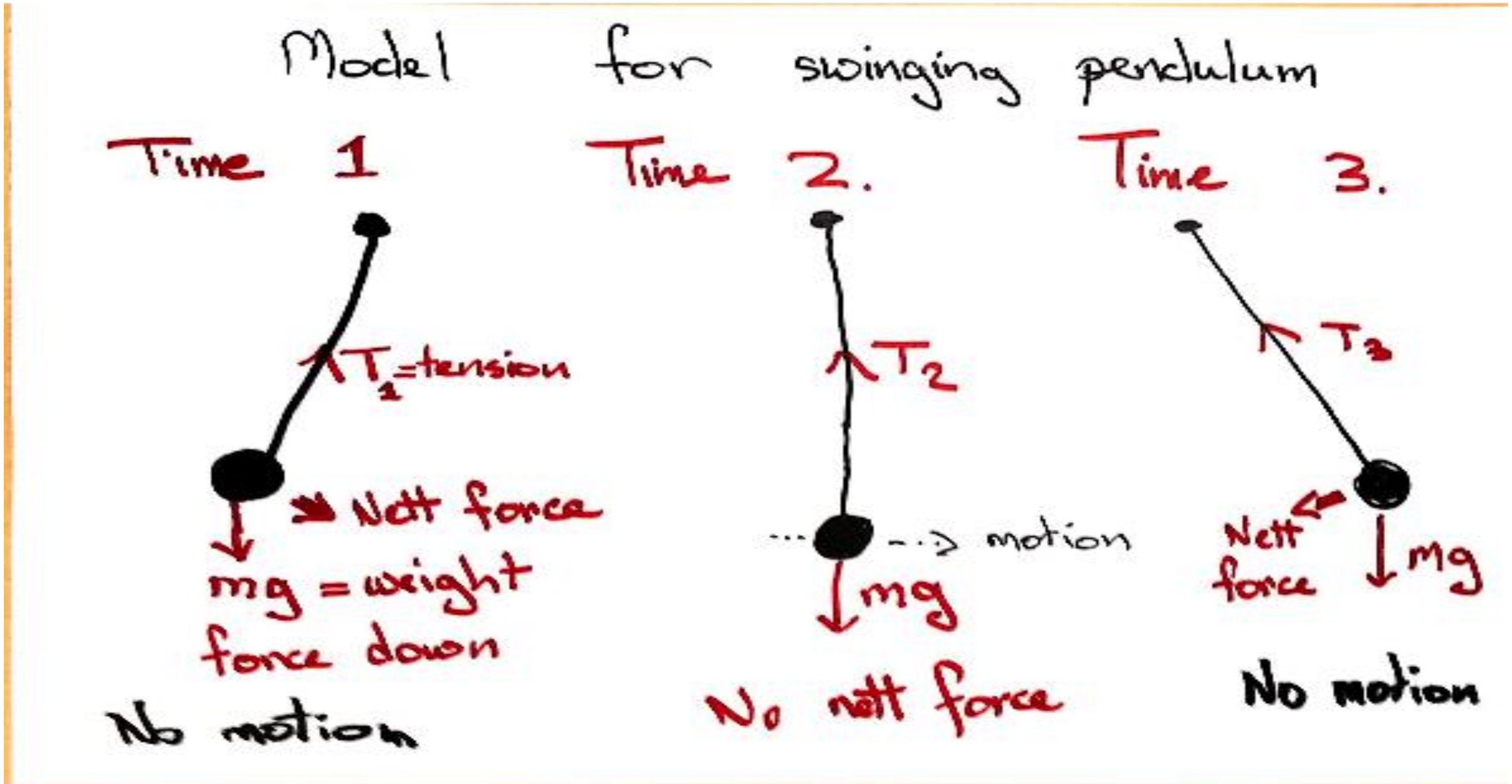
- Phenomenon provides a context to make the learning meaningful

Developing and using models

- Not just learning about models scientists use, but developing your own
- To explain specific phenomena in specific systems
- Incorporate visible and invisible features
- Invisible features represent science ideas

Example– a swinging pendulum

- Abstract diagram --not a picture
- Time sequence of instants
- Invisible forces (and motion) indicated



Model building and observation

As in art, so in science,

the attempt to represent

drives to more careful observation

of what is being represented

Decisions must be made:

what to foreground,

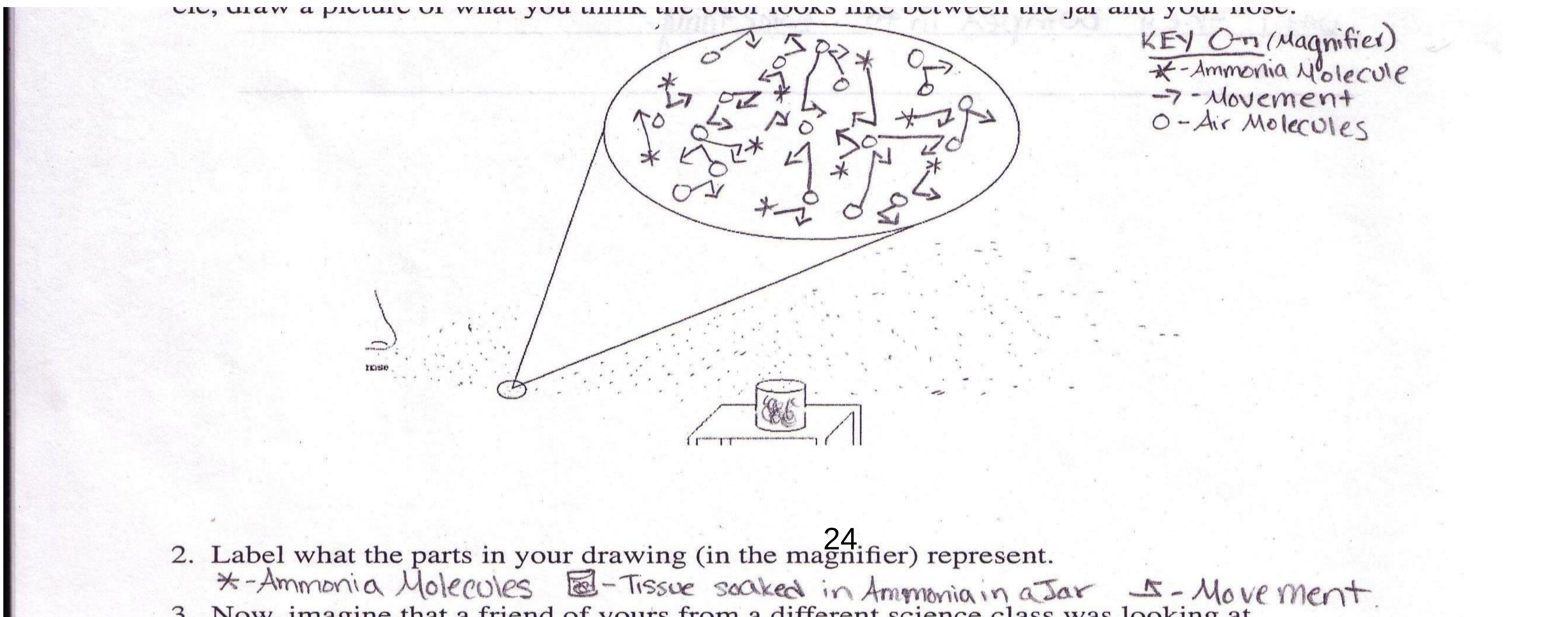
what to leave out

how to revise…

IQWST Assessment: *Modeling Smell*

Your teacher opened a jar that contained a substance that had an odor. Imagine you had a very powerful microscope that allowed to see the odor up really, really close. What would you see?

- 75% of students create a particle model, 25% a mixed model
- 68% of students include odor particles that are moving in straight lines until they collide into each other; 32% include both odor and air



Dimension 2

Cross- cutting concepts

Cross-cutting concepts

- Concepts (or questions) common to all disciplines, but rarely taught or emphasized

- Tools for thinking and analyzing

Scientists see science as interconnected

- Students cannot make connections unless they are supported and encouraged to do so

Cross cutting Concepts

1. Patterns

What patterns (in form, in behavior, repetition over time) do I notice that need explanation?

2. Cause and effect: mechanism and explanation

Can I explain what caused the observed events?

3. Scale, proportion and quantity

What scale, what proportional relationships and what units of measure must I consider?

4. Systems and system models

What is the relevant system, and what is my model for it?

Cross cutting concepts (continued)

5. Energy and matter: flows, cycles and conservation

How do energy and matter flow into, out of, and within this system?

6. Structure and function

How does the shape and structure of this part relate to how it functions?

7. Stability and change

Under what conditions is this system stable?

What makes it change?

Example: energy as a cross cutting idea

How do teachers in one course build on knowledge gained in a different course?

Physicists, chemists, earth scientists and biologists all talk about energy Can students connect the very different usages?

Not as we teach it today!

Teachers in all disciplines need to adjust their language around energy toward a more common conception

and need to discuss the disciplinary differences in usage and the reasons for them.

Dimension 3

Disciplinary core ideas

Criteria: A 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

Core ideas

- Physical Sciences (matter, forces and interactions, energy, waves and information)
- Life Sciences (molecules to organisms, ecosystems, heredity and variation, evolution and biodiversity)
- Earth and space sciences

(earth in space, earth systems science, human interactions)

purple => not emphasized in current curriculum

More core ideas

- Engineering Technology and Applications of Science (engineering design; interactions of science, engineering technology and society)

This is new!

If not in science then where in school do students meet these ideas?

Applications make science meaningful to many students

Engineering

- 8 practices and 2 core ideas
- Designing solutions to real world problems requires students to apply (and develop) their understanding of science
- Knowing design principles helps inform effective design practice

Integrating the Dimensions

- To facilitate students’ learning the three dimensions must be built together in standards, assessments, curriculum and instruction

- Students should explore a core idea by engaging in the practices and making connections to crosscutting concepts.

Next Generation Science Standards

- Based in detail on Framework
- Standards as “performance expectations”
- Each demands a practice and possibly also a cross-cutting connection as well as particular disciplinary knowledge
- Adopted by 11 states so far, more coming

Barriers to change

- Political – Evolution and Climate change (seen by some in US as political rather than scientific issues)
- Practical: Classroom space and time,

  Teacher knowledge,

  Resources for professional development

  Resources for classroom investigation and design activity

  Student and parent expectations

Engaging Girls

Careers for Women (US)

(late '60's) vs Today

- Women PhDs in physics

  2% recent PhD 13-15%

- Women doctors

  7-8% ~30% (all ages)

  (today >50% of med school applicants)

- Women Lawyers

  4-5% ~30% (all ages)

  (close to 50% of law students)

Math linked careers (engineering, physical science, computer science) lag others, look more like physics.

Contributing factors

- Parental expectations of interest
- Peer pressure
- Social norms impacting math self image
- Teacher and mentor expectations
- Stereotypes

Parental expectations

“I must take my son to the science museum”

“My daughter would love that ”

- a doll, a craft project, toy cooking pots and stove

“My son would love that”

A robot, a toy weapon, sports equipment, a building toy

Gender stereotypes send strong social messages!

Peer pressure

- The pressure to “fit in” by doing what others do
- Pervasive and powerful in schools,

  outliers are often bullied
- Media (particularly advertizing) reinforce the social norms
- Even when in the same school,

  girls and boys live separated and different experiences

I believe this is particularly potent in Japan

–how does it define you and your choices?

Teacher and Adviser expectations

- Embody gender norms of prior generation

  insults and messages are often inadvertent

- Transmit low expectations for girls careers

  (both explicitly and implicitly)

- Less inclined to push girls to achieve

Will support you when you make it clear you know what you want and are willing to work for it.

Engaging girls
(not an issue for biosciences)

- Science as useful knowledge
  vs knowledge for its own sake

- Design experience makes engineering an option, not a mysterious male domain

- Engaging in practices
  builds confidence in one’s own thinking

Some evidence suggests these approaches help

(Mis)perceptions about the life

- Too demanding, no way I could enjoy life and succeed

  --all rewarding careers are demanding!

- Only for nerds (ie male and socially challenged)

  -- you'll meet many interesting people

- I am not smart enough

  --you'll never know unless you go for it

Other under-represented students

- Doing science is broadly engaging

- Supports language learning and “code switching”

- Supports and motivates

  reading and math learning

Why consider language learning in science?

Increasing fraction of students whose home language is not English

(in CA 43%, 22% classified as English learners ie not yet English competent)

Large differences by social class in language level (in home language) at school entry (factor of 10 in vocabulary)

Poor language development is a major barrier to school success

Science demands & supports language growth

Undergraduate science

- Same learning theory (and more) implies need for change
- Early research experience
- Prospective science teachers need to experience science practices in college science

And in Japan?

- Is any of this relevant for Japanese schools?
- What strikes you as most interesting?
- Most challenging?