The National Academies of
SCIENCES • ENGINEERING • MEDICINE

BOARD ON SCIENCE EDUCATION

Science and Engineering for Grades 6-12: Investigation and Design at the Center

Study Sponsors: Amgen Foundation and Carnegie Corporation of New York

nas.edu/Science-Investigation-and-Design

Overview Webinar
January 31, 2019

The National Academies

- A non-governmental organization (NGO)
- Founded in 1863
- Bring together committees of experts in all areas of scientific and technological endeavor
- Address critical national issues and give advice to the federal government and the public

NATIONAL ACADEMY OF SCIENCES

NATIONAL ACADEMY OF ENGINEERING

NATIONAL ACADEMY OF MEDICINE

The **Board on Science Education** and the **National Academy of Engineering** supported the work of the Committee on Engaging Middle and High School Students in Science and Engineering: New Approaches to Investigation and Design with support from our sponsors.

Study Sponsors:

Carnegie Corporation of New York

AMGEN® Foundation
Inspiring the Scientists of Tomorrow

Committee Members

Brett Moulding *(Co-Chair),* Partnership for Effective Science Teaching and Learning

Nancy Songer *(Co-Chair)*, Drexel University

Juan-Carlos Aguilar, Georgia Department of Education

Anne E. Egger, Central Washington University

Erin Furtak, University of Colorado Boulder

Kenneth L. Huff, Mill Middle School

Joseph Krajcik, Michigan State University

Michael Lach, University of Chicago

Ronald Latanision, Exponent

Mitchell Nathan, University of Wisconsin-Madison

Eileen Parsons, University of North Carolina at Chapel Hill

Cynthia Passmore, University of California, Davis

Helen Quinn, Stanford University

Andrea Tracy, Lawton High School

Committee Charge

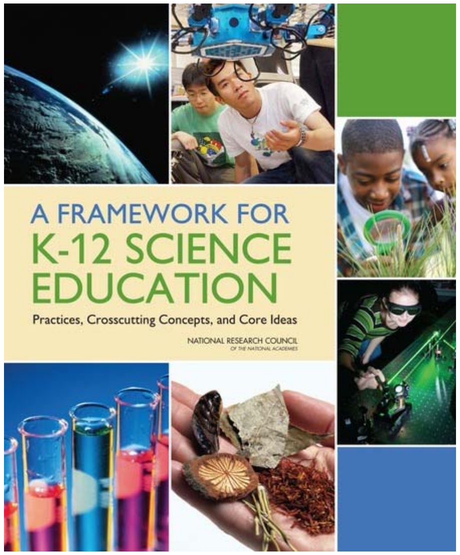
- Review research on science investigation and engineering design for middle and high school students conducted since publication of *America's Lab Report* (National Research Council, 2006)
  - Review will include research and evaluations of innovative approaches, such as computer modeling or use of large on-line data sets that have become more widely available since publication of the original report.

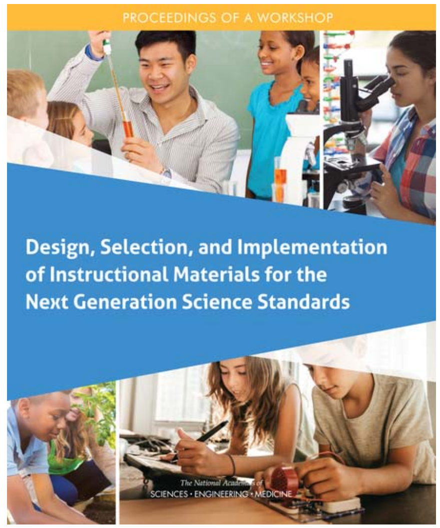
- Provide guidance for designing and implementing science investigation and engineering design for middle and high school students taking into account the new vision for science education embodied in the *Framework for K-12 Science Education* (National Research Council, 2012) and standards based upon it.

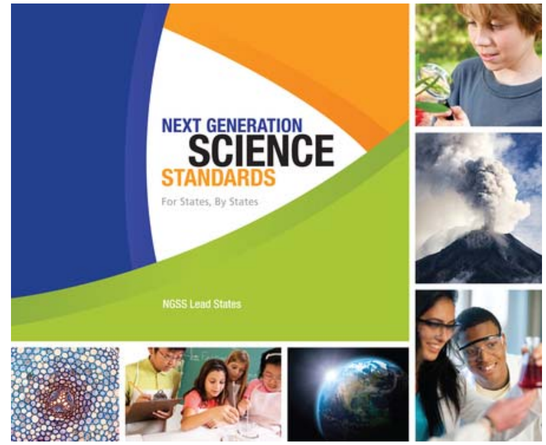
Report Chapters

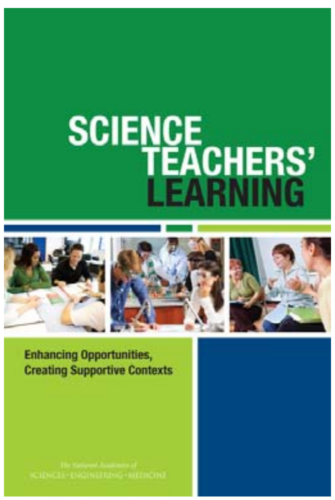
- K-12 Science Education Past and Present
- Learning and Motivation
- How Students Engage with Investigation and Design
- How Teachers Support Investigation and Design
- Instructional Resources for Supporting Investigation and Design
- Preparing and Supporting Teachers to Facilitate Investigation
- Space, Time, and Resources
- The Education System and Investigation and Design
- Conclusions, Recommendations, and Research Questions

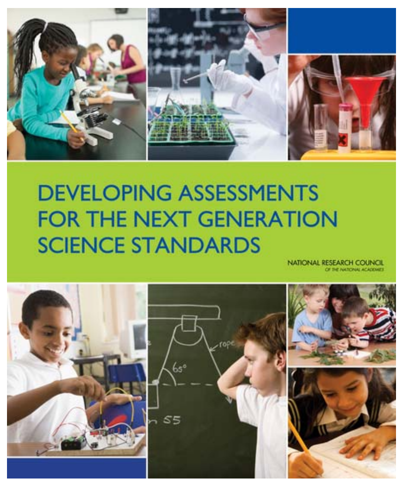
Context of our Study





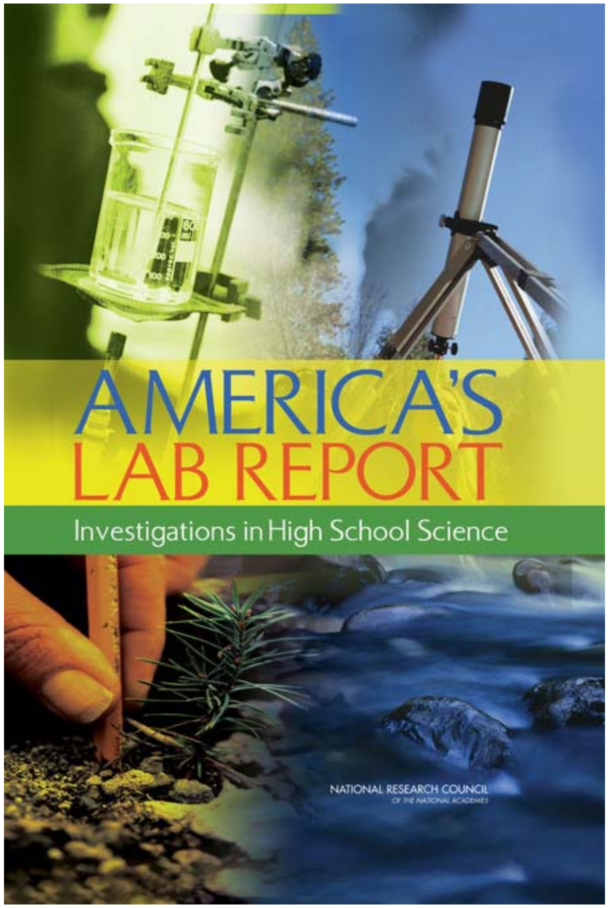




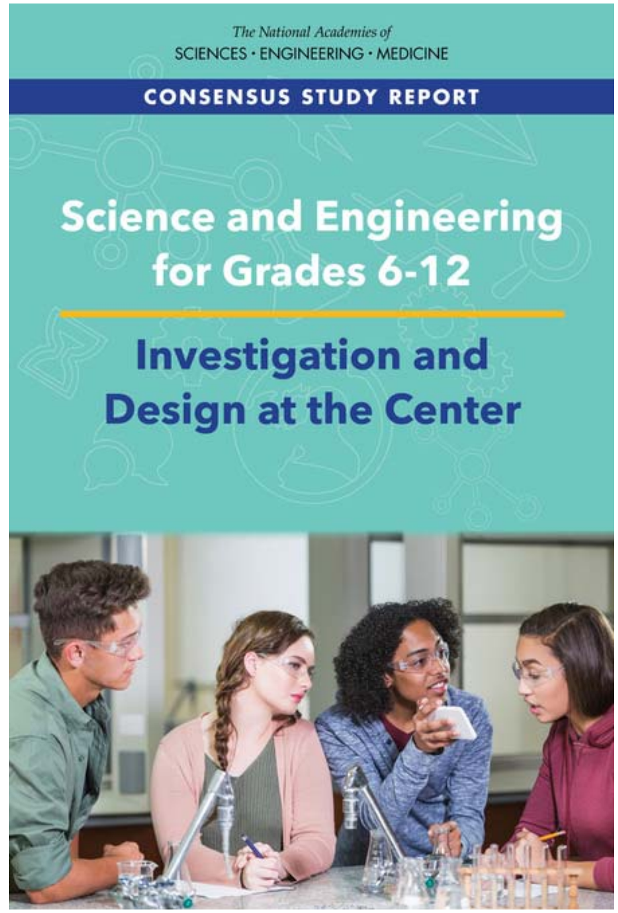


The National Academies of
SCIENCES · ENGINEERING · MEDICINE

Update 2006 Report in this new context



2006



2018


arts of a Plant
plants
flowers
minerals
roots
soil
photosynthesis
SCIENCE
Edition
81
82
84
85
68

Investigation and Design at the Center

- Science investigation and engineering design should be at the CENTER of teaching and learning science. Teachers need to build classes around students investigating phenomena and designing solutions.

- In these classes, students work to make sense of the causes of phenomena or solve challenges in a way that uses all three dimensions of the *Framework* in concert and with increasing depth and sophistication, making connections between ideas and concepts.
  - For example, students **design a solution** (a practice) for a device (crosscutting concept: structure & function) that collects plastics that have made their way to a local waterway and are **causing** native marine life to die prematurely (crosscutting concept: cause/effect).

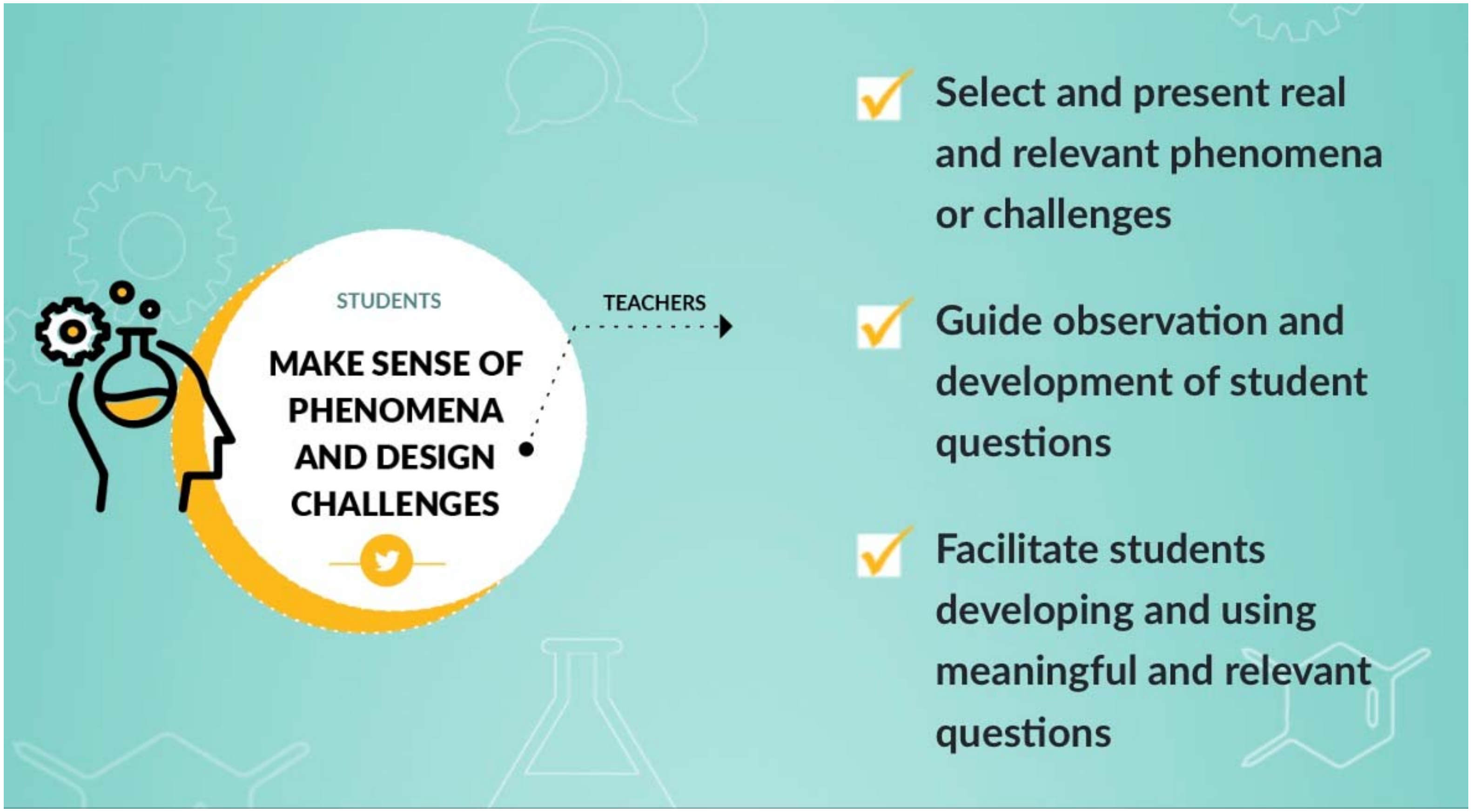
The Power of Investigation and Design

Teachers can use students' curiosity to motivate learning by choosing phenomena and design challenges that are interesting and engaging to students, including those that are locally and/or culturally relevant.

Science investigation and engineering design entail a dramatic shift in the classroom dynamic. Students ask questions, participate in discussions, create artifacts and models to show their reasoning, and continuously reflect and revise their thinking. Teachers guide, frame, and facilitate the learning environment to allow student engagement and learning.

Inclusive pedagogies can support the learning of all students by situating differences as assets, building on students' identities and life experiences.

Make Sense of Phenomena and Design Challenges



https://www.nap.edu/resource/25216/interactive/

Make Sense of Phenomena and Design Challenges

- Need a phenomenon or design challenge that is interesting to students
  - Relevant to their daily lives
  - Connect classroom experiences to learners' communities, culture, experiences, and real world issues
  - Need to be rich enough to promote sustained interest

A high school biology class watched a video about a girl named Addie and her struggle with an antibiotic resistant infection.

Suggested Prompt: ➔ *Write down a time when you or a family member got really sick, and you went to the doctor and the doctor wrote you a prescription for a medicine to take for several days. Did the medicine help you get better?*

https://www.nextgenscience.org/sites/default/files/Antibiotics%20Unit%20Teacher%20Guide.pdf

Based on
Figures 4-2 A and B

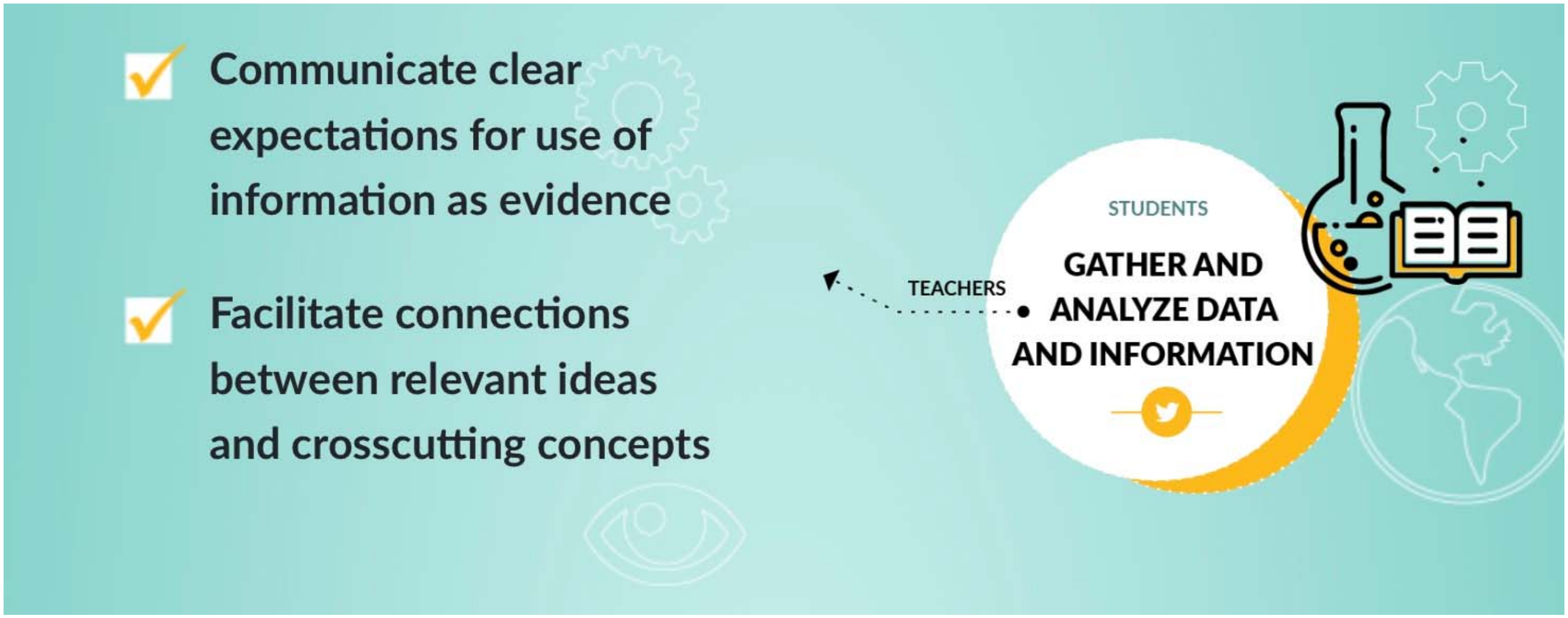
Students engaged in a discussion of questions raised by the video about Addie.

Strategies for this Sharing Initial Questions

- Encourage risk taking with sharing first draft questions we have. If some students raise additional questions later in the lesson or unit that they don't know the answer to, make sure to add those to the initial questions board to validate them and encourage this collective place to share our thinking.

Based on Figures 4-2 A and B

Gather and Analyze Data and Information

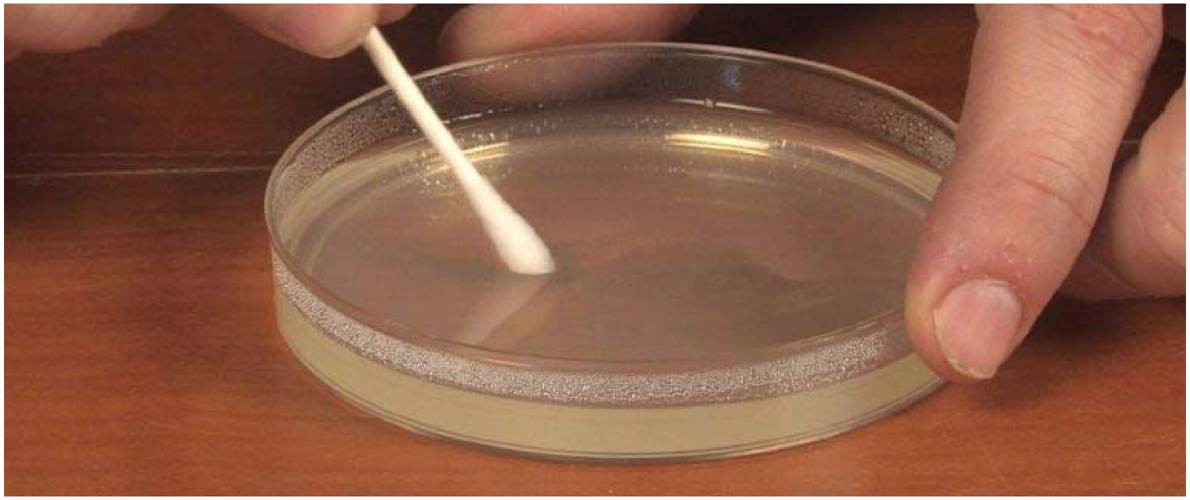


https://www.nap.edu/resource/25216/interactive/

The National Academies of
SCIENCES · ENGINEERING · MEDICINE

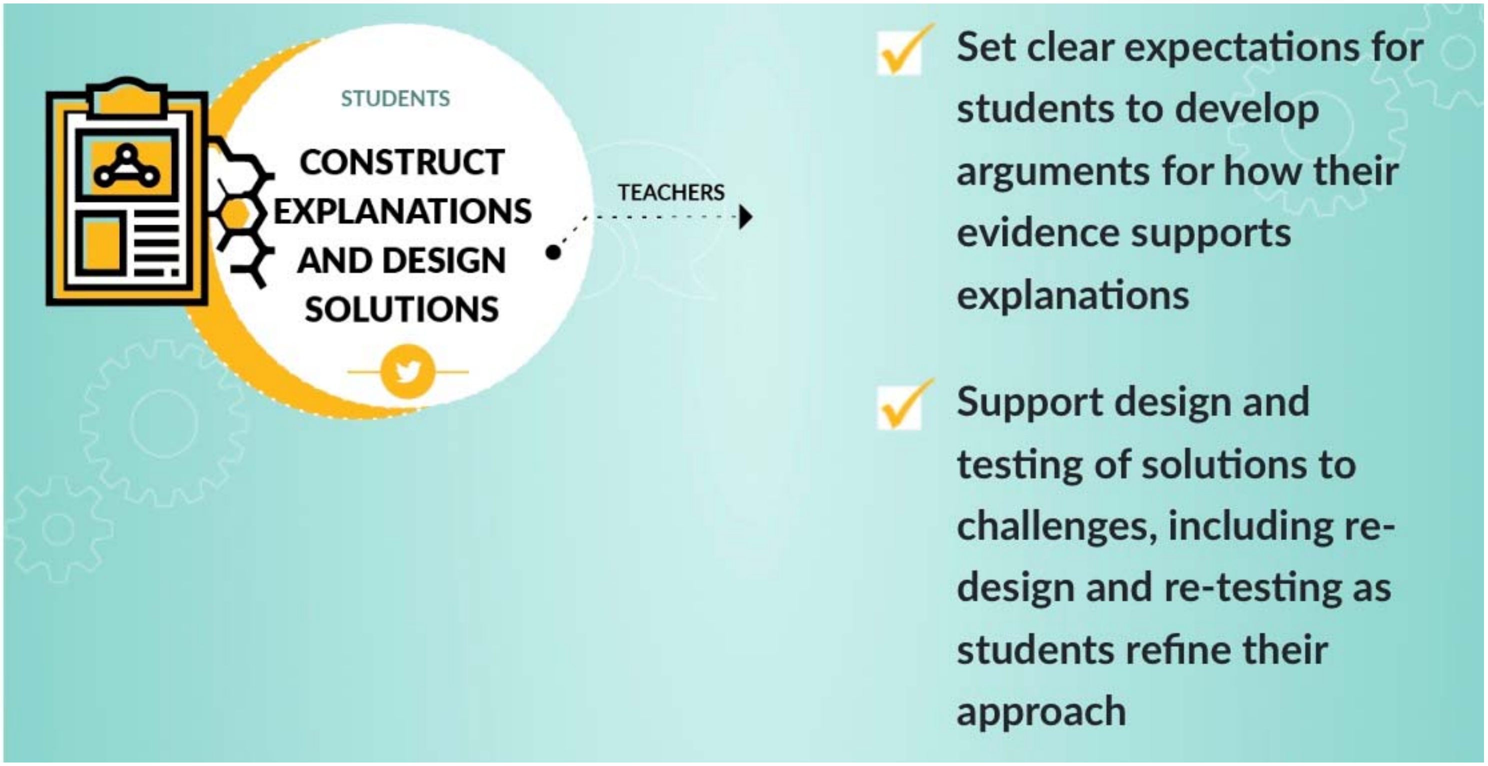
Gather and Analyze Data and Information

To better understand the growth of bacteria making Addie sick, the students begin growing their own bacteria to try to figure out answers to some of their questions about where bacteria come from, how they grow, and how they can be killed.



They create plans and protocols for data collection, and draw sketches and diagrams showing what happens to bacteria under different conditions over time.

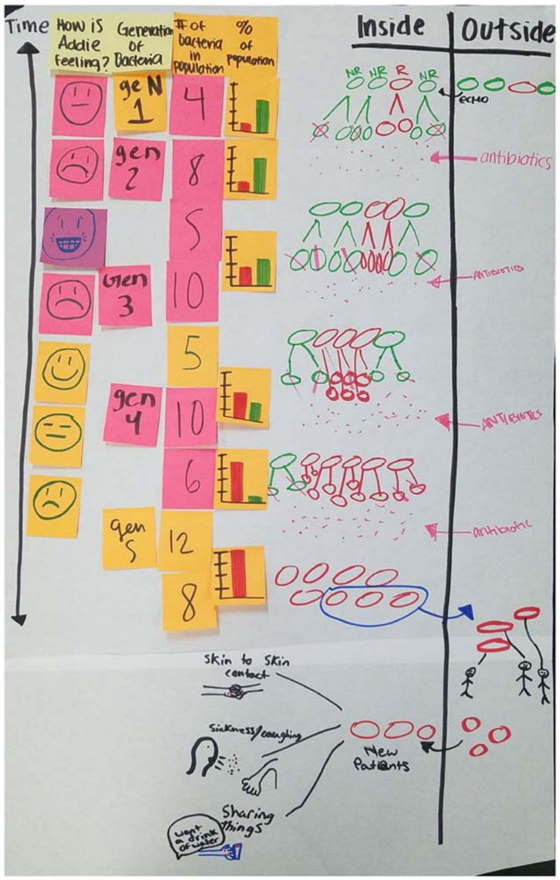
Construct Explanations and Design Solutions



https://www.nap.edu/resource/25216/interactive/

Construct Explanations and Design Solutions

Students developed models to help explain Addies's illness and treatment.



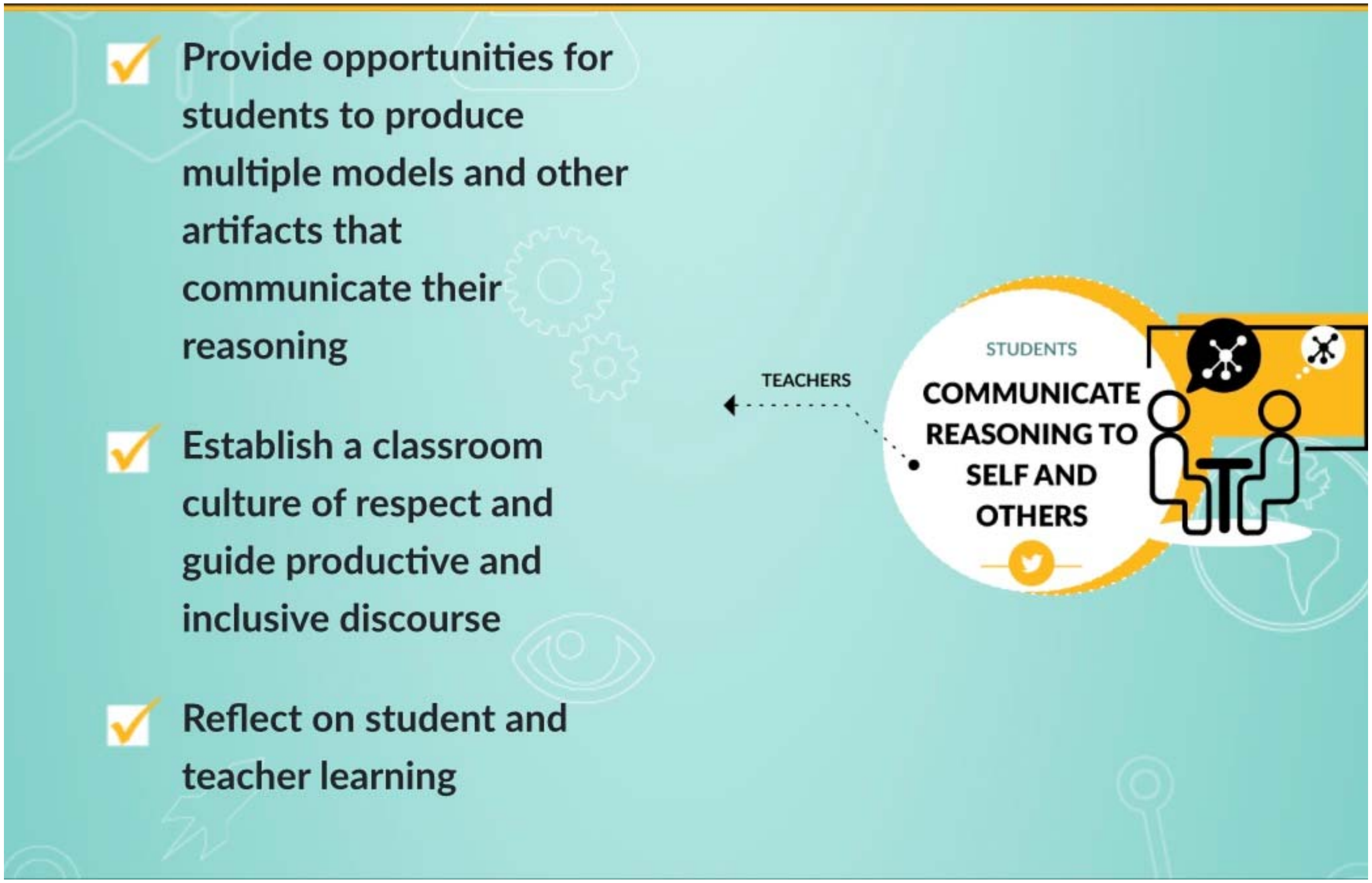
Opportunities for teachers to observe student learning and embed assessment into the flow of learning experiences allows students as well as teachers to reflect on learning.

What did the investigation revealed about how bacteria survive and reproduce?

What does this data tell us about how bacteria can change over time?

How does the information help us to understand what is going on with Addie's case?

Communicate Reasoning to Self and Others

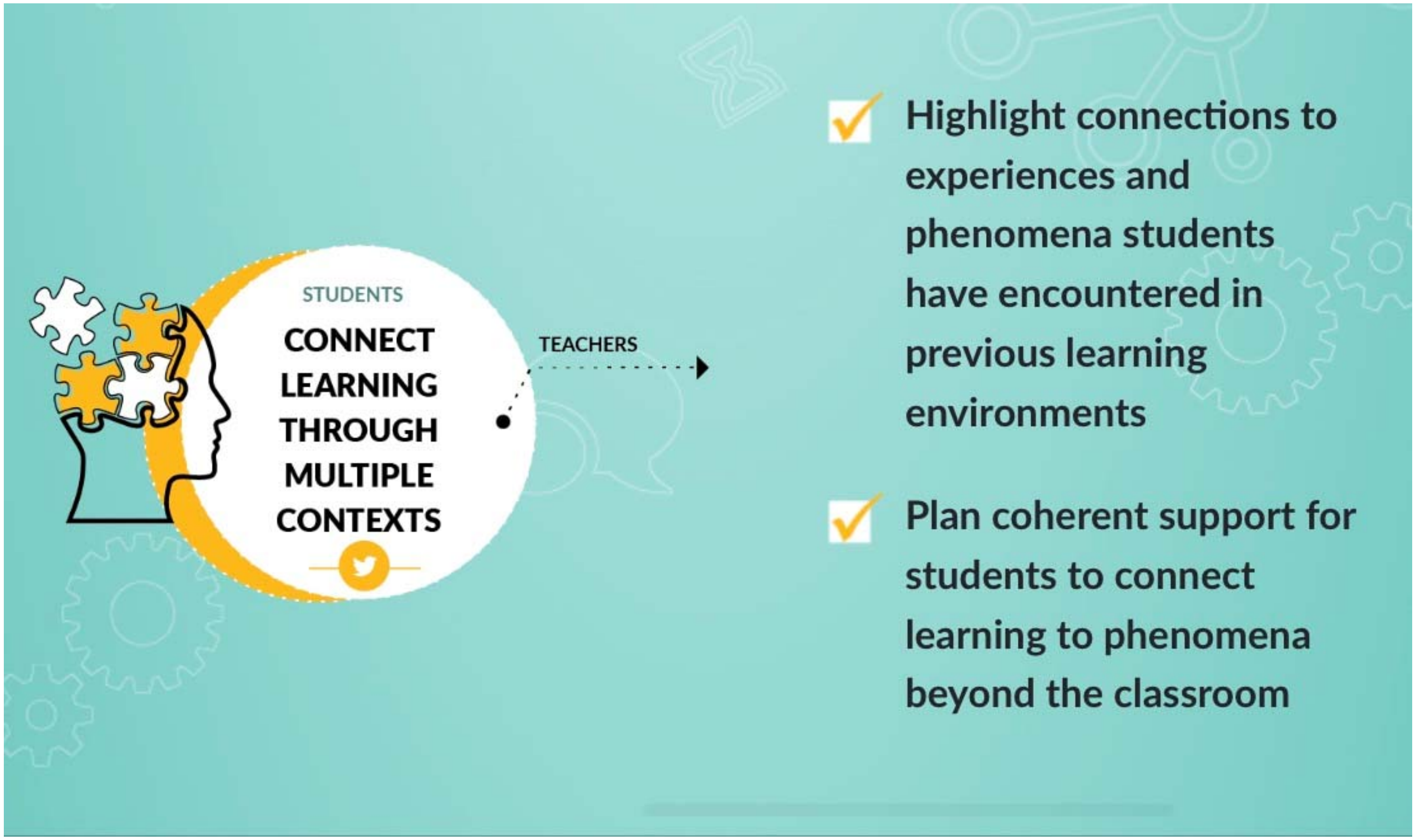


https://www.nap.edu/resource/25216/interactive/

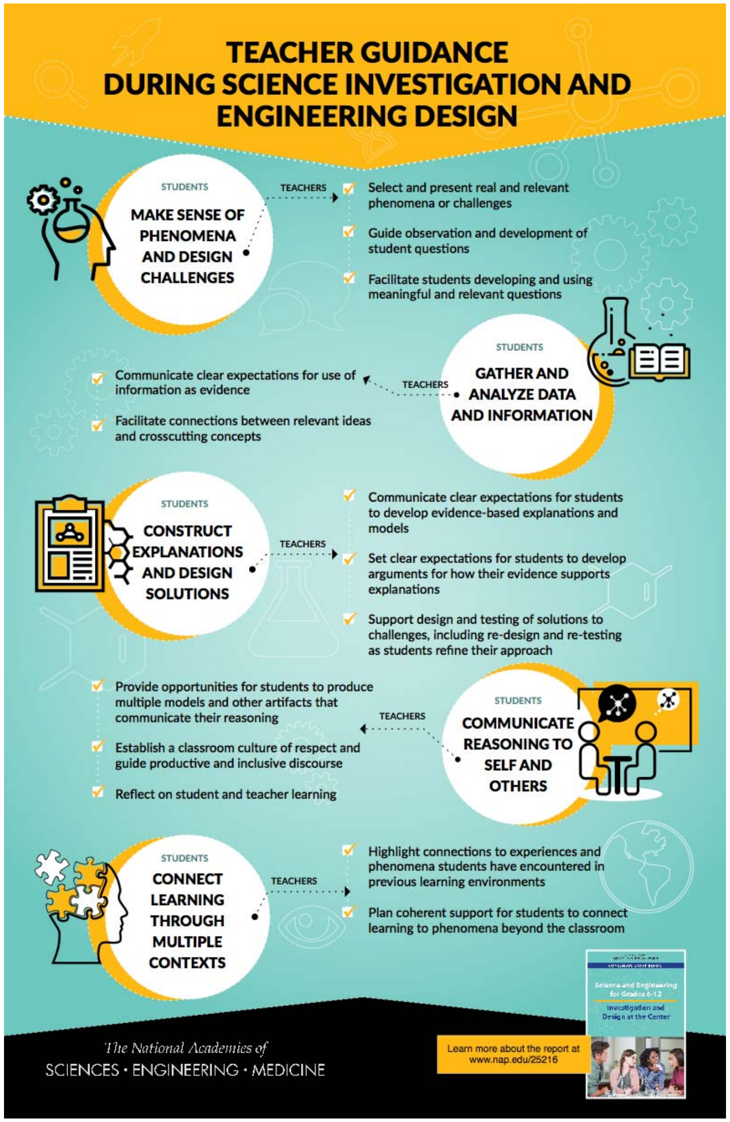
Communicate Reasoning to Self and Others

- Discourse
- Artifacts and representations
  - Writing, models, reports, videos, blogs, computer programs, presentations

Connect Learning Through Multiple Contexts



https://www.nap.edu/resource/25216/interactive/



QUESTIONS about Part I?

The full Interactive Infographic is available at
https://www.nap.edu/resource/25216/interactive/

Teacher Learning and Resources

- **Intentionally designed and sustained professional learning experiences that extend over months can help teachers prepare, implement, and refine approaches to investigation and design.**
- **Engaging students in investigation and design requires attention to facilities, budgets, human resources, technology, equipment, and supplies.**
- **Instructional resources are key to facilitating the careful sequencing of phenomena and design challenges across units and grade levels in order to increase coherence as students become increasingly sophisticated science and engineering learners.**

Professional Learning

- Teacher-learning experiences need to be close to the classroom. They must be relevant, recognizable, and realistic. Teachers should see, hear, and feel what this new vision of science looks like with students that compare to their own, over extended periods of time, in order to recognize the implications and adapt their practice.
- Teacher learning requires working with rich images of desired practice. These shifts in teaching and learning go beyond modifications of instruction. They call for an ability to engage students in building and refining scientific knowledge.

Box 7-1

The Surrounding System

Classroom-level change is impacted in various and sometimes conflicting ways by issues related to funding and resources, local community priorities, state standards, graduation requirements, college admission requirements, and local, state, and national assessments.

There are notable inequities within and among schools today in terms of access to educational experiences that engage students in science investigation and engineering design.

RECOMMENDATION 1:
Investigation and Design is Central

- Teachers arrange their instruction around phenomena or design projects.

- Administrators support teachers by providing
  - Instructional resources
  - Sustained professional learning experiences
  - Opportunities for teachers to work collaboratively to design learning sequences that are interesting and relevant
  - Time to learn about inclusive pedagogies

RECOMMENDATION 2:
Three-dimensional science and engineering performances

- Teachers monitor learning via ongoing, embedded, and post-instruction assessment
- Teachers use formative assessment tasks and discourse strategies
- Students share, develop and revise their ideas
- Teachers use evidence from formative assessment to guide instructional choices

RECOMMENDATION 3: Instructional resources consistent with the *Framework* and knowledge about how students learn

- Teams of teachers and designers of instructional resources
  - Develop coherent sequences of lessons
  - Include information on strategies and options to increase relevance to students' backgrounds, cultures, and place

- Administrators provide access to
  - High-quality instructional resources
  - Space
  - Equipment
  - Supplies

RECOMMENDATION 4:
Sustained professional learning opportunities about evidence-based instructional practices

- Administrators identify and encourage participation in professional learning
- Professional development leaders provide teachers with the opportunity to learn in the manner in which they are expected to teach
- Professional development leaders prepare and empower teachers to make informed and professional decisions about adapting lessons to their students and the local environment
- Teachers receive feedback from peers and other experts.
- Administrators and education leaders provide opportunities for teachers to implement and reflect on new approaches

RECOMMENDATION 5: Prospective teachers experience *Framework*-aligned science investigation and engineering design as learners

- College and university faculty design and teach science classes that use evidence-based principles for learning
- Faculty design and teach *Framework*-aligned courses on pedagogy
- College and university administrators incentivize design of new *Framework*-aligned courses

RECOMMENDATION 6:
Address deep history of inequities

- Administrators ensure science investigation and engineering design approaches are used in all science courses for all students
- School and district staff systematically review policies and monitor and analyze
    - Differences in course offerings and content between schools
    - Patterns of enrollment
    - Differential student outcomes
- Administrators construct specific, concrete, and positive plans to address disparities
- State and national legislatures and departments of education provide additional resources to schools to broaden access

RECOMMENDATION 7:
Align components of the system

- State, regional, and district leaders
  - Commission and use valid and reliable summative assessment tools that mirror how teachers measure three-dimensional learning
  - Provide resources to support implementation across all grades and in all schools
  - Track and manage progress towards full implementation
  - Ensure that the staff in their own offices who oversee science instruction or science educators have a deep knowledge of *Framework*-aligned approaches to teaching and learning
  - Ensure that changes do not exacerbate existing inequities

RESEARCH AGENDA TOPICS

- The Classroom Experience
- Discourse
- Inclusive Pedagogies
- Technology
- Working with Data and Models
- Outcomes
- Professional Learning
- The Education System

RESEARCH AGENDA-EXAMPLE QUESTIONS

- How does the relevance, contextualization, and locality of a phenomenon or design challenge relate to what students learn as they engage in science investigations and engineering design?
- In what ways are particular technologies utilized by professional scientists, such as small- or large-scale visualizations or modeled data simulations, useful as a component of investigation and design?
- In what ways are students' experiences, lived histories, and other assets most meaningfully engaged in support of their participation of science investigation and engineering design? How can teachers honor and connect these experiences during science investigation and engineering design?
- How can teachers and administrators best learn to enact inclusive pedagogies in science investigation and engineering design? How does their effectiveness compare to other pedagogical interventions? How can these approaches be infused as an essential component in professional learning experiences?
- What practices and policies at the school, district, and/or state levels support or hinder widespread implementation of science investigations and engineering design projects for all students?

Upcoming Activities

Launch Event in Washington DC with Webcast
February 12 from 1:15-5pm EST
This is part of a STEM Education Day that will include a launch event and webcast about English Learners in STEM from 9am-noon that morning.

Webinar
Instruction for Investigation and Design
March 7 at 3pm EST

Webinar
Professional Learning for Investigation and Design
March 28 at 1pm EST

More Information and registration links for above events can be found at
nas.edu/Science-Investigation-and-Design