Is it a Scientific Explanation?

A group of students were talking about Scientific Explanations. They each had a different idea about the definition of a Scientific Explanation. Which student do you most agree with?

Katie: I think a scientific explanation is a summary that uses evidence from text.

Angel: I think a scientific explanation is a story about what you observed or did in an experiment.

Blake: I think a scientific explanation is a presentation, like a science fair project.

Jada: I think a scientific explanation is an answer to a question that has a claim, evidence, and reasoning.

Cori: I think a scientific explanation is when you write a procedure for how to conduct an investigation.

I agree with ______________________________________. Explain why you picked this idea and why you did not pick the others.

__________________________________________________________________________________________________

__________________________________________________________________________________________________

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__________________________________________________________________________________________________
Is it a Claim?

Facilitation Notes

Purpose
The purpose of this assessment probe is to elicit learners’ ideas about what constitutes a CLAIM in a scientific explanation. If these ideas are not uncovered they could prevent a learner from fully understanding the CER framework.

Explanation
Students may have some confusion about how a scientific explanation differs from an everyday explanation.

The best answer is JADA’s- that a scientific explanation answers a question with a claim, evidence, and reasoning.

The other students’ ideas represent possible misconceptions that students may have about scientific explanations.

Facilitation Considerations
This probe is a Formative Assessment Classroom Technique (FACT) called a Friendly Talk Probe. It begins with a scenario about a concept. Examples that fit (or possibly do not fit) the scenario are then listed via Student Talk. Learners pick the student idea that best matches their own and provide justification explaining their rule or reasons for their selection. This assessment probe can also be used to provide an opportunity for learners to engage in the ideas and modify their thinking based on new evidence or research.

Misconceptions
Learners may have a variety of misconceptions regarding what constitutes a scientific explanation. The examples in the probe represent a range of common ideas students may express when considering a scientific explanation.

Administering the Probe
This probe is best used at the beginning of instruction on a CER framework OR just after some initial instruction. Learners should be encouraged to share their choices and thinking with a partner. The teacher should circulate around the room to observe the responses, and the conversation occurring between partners. Use this information to inform your ongoing instruction on the CER framework.

It is recommended to immediately use this probe to debrief as a whole class. Are they noticing how a scientific explanation is different than other explanations? Do students have a broad or specific definition of a scientific explanation? How could you use this information to influence your upcoming instruction on how to write a scientific explanation?

References
Supporting Grade 5-8 Students in Constructing Explanations in Science, McNeill & Krajcik (2011)
http://books.google.com/books/about/Supporting_Grade_5_8_Students_in_Constructing_Explanations_in_Science.html?id=._PzwAACAAJ

Created by Kirk Robbins
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Based on the Formative Assessment Probe framework developed by Page Keeley in her Uncovering Student Ideas in Science series
Write a Scientific Explanation

- Examine the data table below.
- Write a scientific explanation stating whether fat and soap are the same substance or different substances.

<table>
<thead>
<tr>
<th></th>
<th>Color</th>
<th>Hardness</th>
<th>Solubility</th>
<th>Melting Point</th>
<th>Density</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fat</strong></td>
<td>Off-white or slightly yellow</td>
<td>Soft, squishy</td>
<td>Water- no Oil- yes</td>
<td>37 degrees C</td>
<td>0.92 g/cm³</td>
</tr>
<tr>
<td><strong>Soap</strong></td>
<td>Milky white</td>
<td>Hard</td>
<td>Water-yes Oil-no</td>
<td>Hotter than 100 degrees C</td>
<td>0.84 g/cm³</td>
</tr>
</tbody>
</table>

**Scientific Explanation**

- Fat is off-white or slightly yellow, soft, and squishy. It is soluble in water and not in oil, with a melting point of 37 degrees C and a density of 0.92 g/cm³.
- Soap is milky white, hard, and soluble in water but not in oil. It has a melting point hotter than 100 degrees C and a density of 0.84 g/cm³.

From the data, we can see that fat and soap have different physical properties, such as color, hardness, solubility, and melting point. Therefore, they are different substances.
Write a Scientific Explanation

Examine the following student explanation.

**Brandon’s First Explanation about Soap and Fat**

Fat and soap are both stuff but they are different substances. Fat is used for cooking and soap is used for washing. They are both things we use everyday. The data table is my evidence that they are different substances. Stuff can be different.

What strengths do you see in this scientific explanation?

What feedback might you give to this student?

What are some key features/components of a quality scientific explanation?
Examine the following explanation.

**Brandon's Second Explanation about Soap and Fat**

Fat and soap are different substances.
Fat is of white and soap is milky white.
Fat is soft squishy and soap is hard.
Fat is soluble in oil, but soap is not soluble in oil.
Fat has a melting point of 37 degrees C and soap has a melting point above 100 degrees C. Fat has a density of 0.92 g/cm³ and soap has a...

What changes did Brandon make to his explanation?

In what ways did these changes make the explanation more clear?

If you were going to teach your students to write scientific explanations, how might you scaffold this for them?
<table>
<thead>
<tr>
<th>Your Thoughts</th>
<th>Another Person</th>
<th>Landmark Partner</th>
</tr>
</thead>
<tbody>
<tr>
<td>Which answers are you least sure of regarding the implementation of the NGSS?</td>
<td></td>
<td>Fremont Troll Partner:</td>
</tr>
<tr>
<td>What answers are you most confident of regarding the implementation of the NGSS?</td>
<td></td>
<td>Pike Place Pig Partner:</td>
</tr>
<tr>
<td>What aspects of the NGSS are you interested in learning more about?</td>
<td></td>
<td>Mt. Rainier Partner:</td>
</tr>
</tbody>
</table>
Walkabout Activity – From *The Adaptive School* by Bruce Wellman and Robert Garmston
Q: What is the relationship between the NGSS and *A Framework for K-12 Science Education*?
A: *A Framework for K-12 Science Education* is the parent document for the Next Generation Science Standards (NGSS). The Framework provides the foundational research, information, and narrative description of student learning from which the NGSS were distilled. The NGSS is difficult to understand and use for assessment or planning without the Framework.

Q: Are the NGSS adopted nationwide like the CCSS?
A: Twenty-six “lead states” donated resources and expertise to the development of the NGSS. Of those lead states, Washington was the 8th to adopt the NGSS (October 4, 2013).

Q: How do the NGSS relate to the CCSS?
A: Common Core State Standards cover Mathematics (-M) and English Language Arts (-ELA) only. While CCSS includes standards for literacy in science and technical subjects, they do not include science standards. The Next Generation Science Standards reference relevant CCSS-M and CCSS-ELA standards and practices. The Next Generation Science Standards were constructed with the CCSS in mind, but their inception and development have been guided by leaders in science education and the National Science Teachers Association (NSTA).

Q: What about assessment?
A: At the time of this writing, the federal No Child Left Behind law still requires students to be tested in science once each in elementary school, middle school, and high school. Science assessments will continue to be administered at grades 5, 8 and in high school. Students will take the Measurements of Student Progress (MSP) and Biology End-Of-Course exams based on the 2009 K-12 Science Learning Standards until an assessment for the NGSS is developed.

- Washington is participating in the State Collaborative on Assessment and Student Standards (SCASS) for Science supported by CCSSO to assist in developing evidence statements and tasks aligned to the NGSS. The SCASS will also work to identify priorities, timelines, and next steps in planning for NGSS assessments. At the time of this writing, WA expects the earliest that an assessments based on the NGSS could be available is the 2016-17 school year.
- Achieve Inc. is crafting sample tasks for each grade level that could be used formatively. These are not yet available to view.
- House Bill 1450 (see section 4(2)(a)) indicates the intent to transition to a comprehensive high school science assessment consistent with the way in which the state transitioned to an English language arts assessment and a comprehensive mathematics assessment.
Q: In the 2013-14 school year, what can Washington science educators do to prepare for the NGSS?

- This school year is an opportunity for science educators become aware of the NGSS, to learn, digest, and try things out.
- Science educators should take part in professional learning opportunities that focus on *A Framework for K-12 Science Education* (the foundation document to the NGSS) in order to gain a deep understanding of the dimensions of the “Framework” (i.e., Science and Engineering Practices, Crosscutting Concepts, Disciplinary Core Ideas of science); and to understand how these dimensions are integrated into Performance Expectations.
- Teachers should pick 2-3 practices or cross-cutting concepts they would like to improve on in their classrooms and implement them intentionally and well.

Q: What resources are available for the NGSS?

- Attend professional development through your Educational Service District or LASER Alliance.
- Visit the Regional Science Coordinator website at *www.washingtonesds.org*.
- Visit the OSPI NGSS website at: *http://www.k12.wa.us/Science/NGSS.aspx*
- Visit the NGSS website at *www.nextgenscience.org*.
- Download the free NGSS app and CCSS app from Mastery Connects.
- Download or purchase, read, and study *A Framework for Science Education* available at: *http://www.nap.edu/catalog.php?record_id=13165*

Q: In the 2013-14 school year, what instructional practices should Washington science educators continue to use?

A: Washington science educators have been working hard at building students’ science content knowledge and practices. Science educators should continue:

- Using instructional materials that align to 2009 WA K-12 Science Learning Standards.
- Being intentional about WA Inquiry, Application, and Systems standards.
- Expecting their students to use claims, evidence, and reasoning in their discourse about science concepts.
- Using effective science instructional practices (i.e., help students surface prior knowledge, construct understanding, make sense of learning experiences, and promote a positive learning environment and appropriate scientific discourse.)

Q: How do existing K-12 science instructional materials align with the NGSS?

A: At this time, Washington Educators are encouraged to stick with their current instructional materials and district adoptions.

- Currently, there exist no materials known to be *truly* NGSS-aligned.
● In Winter of 2014 Achieve Inc. will release a tool called Educators Evaluating the Quality of Instructional Products (EQuIP) to help science educators identify high-quality materials that align to the NGSS. And in Spring of 2014, Achieve Inc. will release a Publisher’s Criteria tool to help publishers create science instructional materials that are aligned to NGSS.
● At the time of this writing, science educators and leaders across the state are collaborating to examine high-use K-5 instructional materials to provide advice for placement and/or modifications.
● Mostly, educators are encouraged to learn deeply about the science and engineering practices and the crosscutting concepts, and to use those to teach from their current instructional materials. That way, if future alignments shift where the content is located in a gradeband, we will have solid, exemplary instruction already in place everywhere.

Q: How will the move to NGSS affect secondary science courses?
● Appendix K of the NGSS outlines some course maps for secondary science courses.
● Additional course maps are scheduled to be released Winter, 2014.
● Summer of 2014 high school and post-high school alignment institutes will take place.
● National groups will also examine correlations between Advanced Placement science courses and the NGSS.
● Washington currently requires two years of science to graduate, Washington STEM, in addition to other state-level groups are advocating for a third year of science.

Q: How can Washington’s Regional Science Coordinators help you?
● Disseminate news and information about state-level decisions related to Washington’s transition to NGSS.
● Connect you to State and National NGSS resources.
● Provide professional learning to:
  o Understand A Framework for K-12 Science Education and the NGSS.
  o Implement effective instructional practices for the NGSS.
  o Make informed curricular decisions.

QUESTIONS? CONTACT US!

OSPI Science Teaching and Learning
Dr. Ellen Ebert, Science Director
### Washington’s Regional Science Coordinators

<table>
<thead>
<tr>
<th>NEWESD 101</th>
<th>Puget Sound ESD 121</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wendy Whitmer</td>
<td>Cheryl Lydon</td>
</tr>
<tr>
<td><a href="mailto:wwhitmer@esd101.net">wwhitmer@esd101.net</a></td>
<td>clydon@p sesd.org</td>
</tr>
<tr>
<td>Mike Brown</td>
<td>ESD 123</td>
</tr>
<tr>
<td><a href="mailto:mike.brown@esd105.org">mike.brown@esd105.org</a></td>
<td>Georgia Boatman</td>
</tr>
<tr>
<td>Ford Morishita</td>
<td>North Central ESD 171</td>
</tr>
<tr>
<td><a href="mailto:ford.morishita@esd112.org">ford.morishita@esd112.org</a></td>
<td>Mechelle LaLanne</td>
</tr>
<tr>
<td>Craig Gabler</td>
<td>Northwest ESD 189</td>
</tr>
<tr>
<td><a href="mailto:cgabler@esd113.org">cgabler@esd113.org</a></td>
<td>Brian MacNevin</td>
</tr>
<tr>
<td>Jeff Ryan</td>
<td><a href="mailto:bmacnevin@nwesd.org">bmacnevin@nwesd.org</a></td>
</tr>
<tr>
<td><a href="mailto:jryan@oesd.wednet.edu">jryan@oesd.wednet.edu</a></td>
<td>Olympic ESD 114</td>
</tr>
</tbody>
</table>

Amber Farthing, Science Specialist
amber.farthing@k12.wa.us
The NGSS has been Adopted... now what?

Place an X next to the descriptions that you think are correct.

___ Districts should begin aligning their curriculum to the NGSS

___ Eight states have adopted the NGSS as their state standards

___ Performance Expectations should be written on the board as Learning Targets

___ Performance Expectations are just examples of how students might demonstrate understanding of the standards.

___ Teachers should use “all and any of the practices” that build toward the Performance Expectation. In other words we don’t need to limit ourselves to practice in the PE.

___ There is little difference between adoption and implementation

___ Students need to know how and why they know science content

___ Washington State currently plans to develop its own state assessment of NGSS

___ Several national projects are working on supporting implementation of the NGSS.

___ Publishers have already developed instructional materials that are well aligned to NGSS

___ There is instruction that needs to happen before students are able to demonstrate the PEs.

___ There are great differences between our current Washington State Standards and the NGSS.

___ There are state groups working to support districts and teachers in building understanding and beginning to implement the NGSS.

Explain your thinking. Which of the answers above are you the least sure about regarding the implementation of the NGSS?
Opportunities and Challenges in Next Generation Standards

E. K. Stage, H. Asturias, T. Cheuk, P. A. Daro, S. B. Hampton

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Writing standards and with the science practices, e.g., “(5) validating the conclusions by comparing them with the situation, and then either improving the model or, if it is acceptable, (6) reporting on the conclusions and the reasoning behind them. Choices, assumptions, and approximations are present throughout this cycle” (4).

Literacy and math standards include practices that are challenging to teach in science without support from teachers of other subjects. Standards for Speaking and Listening include, “Evaluate a speaker’s point of view, reasoning, and use of evidence and rhetoric” (3). Standards for Mathematical Practice include, “Construct viable arguments and critique the reasoning of others” (4).

Operationizing Inquiry
In this promising context, science standards have been drafted, working from the NRC framework, that operationalyzed “inquiry” with eight practices of science and engineering: (i) asking questions and defining problems; (ii) developing and using models; (iii) planning and carrying out investigations; (iv) analyzing and interpreting data; (v) using mathematics and computational thinking; (vi) constructing explanations and designing solutions; (vii) engaging in argument from evidence; and (viii) obtaining, evaluating, and communicating information (2).

The framework attempted to narrow the number of core disciplinary ideas, although reviewers of draft science standards have said that the volume of content undermines the sense making required by the practices (11). The framework retained the idea of crosscutting concepts (e.g., structure and function, stability and change of systems), and argued that practices, core disciplinary ideas, and crosscutting concepts should not be taught or assessed separately from each other. Each draft science performance expectation incorporates one or more disciplinary idea, practice, and/or crosscutting concept. These performance expectations also cross-reference the literacy and math standards; the convergence is shown in the chart (12).

Science educators have decried the common practice of reading textbooks instead of doing investigations; the former is still alive and well (13). Literacy educators are concerned about increased emphasis on informational text in the CCSS (14). It is time to embrace the coherence and learning that can be achieved by making meaningful connections between and among direct experience with science and engineering practices and reading, writing, speaking, and listening (15).

What’s Next?
Forty-five states have adopted the CCSS. If a substantial number of states adopt the NGSS, it increases the likelihood that developers and publishers of instructional and assessment materials will focus on creating a common set of tools, at least at elementary and middle grades. If colleges and universities accept high school courses that are based on the standards and the College Board continues to revise the Advanced Placement syllabi, high schools are more likely to follow them.

In addition to sufficient time and resources for educators and parents to learn how to support these more ambitious expectations, there are several challenges that scientists, educators, and policy-makers should consider. Advocates for high-quality science education for all students need to participate in conversations at the local and state level where educational policy is enacted. Scientists from higher education, research organizations, and corporations influence science education and can align their contributions with educational goals in the standards.

Historically, the United States has provided limited opportunity to learn science to most of its students and advanced training to a privileged few, focusing on the pipeline for future scientists and innovators without concomitant attention to a science literacy for citizenship. The system needs to be transformed to affirm high standards of accomplishment for all students and to provide resources for all students to reach them (8).

Although the literacy and math standards were widely adopted, and 26 states have served as partners in developing NGSS, momentum may be slowing; some states may reject the NGSS because of the inclusion of evolution and climate change (16). The National Center for Science Education, a defender of teaching evolution for more than three decades, broadened its mission to include the defense of teaching climate science.

Science education benefits from the learning sciences; scientists interested in the most effective teaching of science need to learn from education research. Formal schooling has been criticized as ineffective at motivating and inspiring students (17) and inadequate at recognizing the relation between interest and accomplishment (18). The NGSS can provide a platform for formal education to become more motivating. Many people are inspired by science in informal settings; parallel attention to the NGSS can contribute to “a wide-ranging and thriving ecosystem of opportunities that respond to the needs of children as well as communities” (19). Education and public outreach activities associated with research grants, whether in or out of school, should provide both preparation and inspiration. Local school districts, after-school providers, and informal science institutions need to create a coherent strategy for the regional science learning ecosystem.

This new round of standards development is an opportunity to improve science education that comes around once for each generation. We need to inform ourselves, figure out whether and how we want to get involved, and be intentional about our participation.

References
19. President’s Council of Advisors on Science and Technology, Prepare and Inspire: K-12 Education in Science, Technology, Engineering, and Math (STEM) for America’s Future (Office of the President, Washington, DC, 2010).
Sequence for Teaching & Practicing Scientific Explanations

1. Make the framework explicit.
3. Provide a rationale for creating explanations.
4. Connect to everyday explanations.
5. Assess and provide feedback to students.

Framework for the CI-Ev-R Scientific Explanation

Claim

1. Relevant → The claim directly & clearly responds to the question.
2. Stands-Alone → The claim statement is complete (stands alone).

Evidence

3. Appropriate → Is this the right type of evidence for this claim?
   (Discuss this in the “Reasoning” section.)
   a. Validity: Measurements & observations are relevant.
   b. Validity: Controlled variables focus attention on key factors.
4. Sufficient → Is there enough evidence?
   a. Reliability: Repeated trials will increase confidence.
   b. Full Range: Enough different conditions/values of variables?
   c. Full Range: The explanation cites enough examples to represent the whole data set without being tedious.

Reasoning

5. Stands-Out → Is the reasoning obvious, or hard-to-spot?
   a. DO NOT repeat the Claim or the Question.
   b. DO NOT repeat the Evidence.
6. Link → Why this data should count as evidence.
   a. Why it’s the right type of measurement/observation.
   b. How the controls help to validate the link.
7. “System Reason” → Use scientific principle or knowledge of the system:
   a. Why should this system behave this way, showing these results?
   b. What does this tell us about the system that we didn’t know before?

Note: A fuller scientific explanation will also contain a “Rebuttal,” which describes alternative Claims, plus the Evidence and/or Reasoning that refute the alternative Claim.
## Feedback Rubric for Scientific Explanations

<table>
<thead>
<tr>
<th></th>
<th>4 - BEST</th>
<th>3 - GOOD</th>
<th>2</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Claim</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Relevant → The claim directly &amp; clearly responds to the question.</td>
<td>Claim directly &amp; clearly responds to the question.</td>
<td>Claim responds directly or clearly to the question.</td>
<td>Claim does not respond to the question.</td>
<td>No claim statement.</td>
</tr>
<tr>
<td>Stands-Alone → The claim statement is complete (stands alone).</td>
<td>Claim stands alone as a complete statement.</td>
<td>Minor missing piece to be a complete statement.</td>
<td>Vague or missing pieces.</td>
<td></td>
</tr>
<tr>
<td><strong>Evidence</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Appropriate → Is this the right type of evidence for this claim?</td>
<td>Data is relevant to the question. Controls focus on key variables.</td>
<td>Data is relevant, but there are not enough controlled variables.</td>
<td>Cites evidence that is not relevant to claim.</td>
<td>No evidence cited.</td>
</tr>
<tr>
<td>Sufficient → Is there enough evidence?</td>
<td>Full range of data is cited, and that data has several conditions and repeated trials.</td>
<td>Cites unbalanced parts of the data, or data that is not from repeated trials.</td>
<td>Cites a minimal amount of data.</td>
<td></td>
</tr>
<tr>
<td><strong>Reasoning</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stands-Out → Is the reasoning obvious, or hard-to-spot?</td>
<td>Reasoning statements stand out among other statements.</td>
<td>Reasoning is present, but is not obvious.</td>
<td>Repeats the Claim, Question, or Evidence.</td>
<td>No reasoning statements.</td>
</tr>
<tr>
<td>Link → Why this data should count as evidence.</td>
<td>Says how the data are the right data, and/or how the controls validate the data.</td>
<td>Minor piece is missing.</td>
<td>Attempts, but is unclear about how the data cited is relevant.</td>
<td></td>
</tr>
<tr>
<td>“System Reason” → Use scientific principle or knowledge of the system.</td>
<td>Describes how or why the system works in a way that is consistent with the evidence.</td>
<td>Describes how or why the system works, but weakly relates this to the evidence.</td>
<td>Lightly addresses the system, and fails to connect to claim or evidence.</td>
<td></td>
</tr>
</tbody>
</table>

**Notes:**
- Look at all parts to judge the strength and truth of the explanation. The truth of the claim should not be judged by itself.
- Look elsewhere to judge the accuracy of the data.
- Pieces of reasoning sometimes get embedded in the Claim statement.
  Separating reasoning from Claim and Evidence can make explanations clearer.

**Three Parts of Feedback:**
A. Specifically describe what was done well (see rubric).
B. Clarify the target: evidence-based explanation with CLAIM + EVIDENCE + REASONING.
C. Specifically describe what must be done next to improve the explanation (see rubric).
### Three Dimensions of the Next Generation Science Standards (NGSS)

#### Scientific and Engineering Practices

<table>
<thead>
<tr>
<th>Asking Questions and Defining Problems</th>
<th>Developing and Using Models</th>
<th>Using Mathematics and Computational Thinking</th>
</tr>
</thead>
<tbody>
<tr>
<td>A practice of science is to ask and refine questions that lead to descriptions and explanations of how the natural and designed world works and which can be empirically tested. Engineering questions clarify problems to determine criteria—that is, which design best solves the problem within the designed world. Both scientists and engineers also ask questions to clarify the ideas of others.</td>
<td>A practice of both science and engineering is to use and construct models as helpful tools for representing ideas and explanations. These tools include diagrams, drawings, physical replicas, mathematical representations, analogies, and computer simulations. Modeling tools are used to develop questions, predictions and explanations; analyze and identify flaws in systems; and communicate ideas. Models are used to build and revise scientific explanations and proposed engineered systems. Measurements and observations are used to revise models and designs.</td>
<td>In both science and engineering, mathematics and computation are fundamental tools for representing physical variables and their relationships. They are used for a range of tasks such as constructing simulations; statistically analyzing data; and recognizing, expressing, and applying quantitative relationships. Mathematical and computational approaches enable scientists and engineers to predict the behavior of systems and test the validity of such predictions. Statistical methods are frequently used to identify significant patterns and establish correlational relationships.</td>
</tr>
<tr>
<td>Planning and Carrying Out Investigations</td>
<td>Constructing Explanations and Designing Solutions</td>
<td>Obtaining, Evaluating, and Communicating Information</td>
</tr>
<tr>
<td>Scientists and engineers plan and carry out investigations in the field or laboratory, working collaboratively as well as individually. Their investigations are systematic and require clarifying what counts as data and identifying variables or parameters. Engineering investigations identify the effectiveness, efficiency, and durability of designs under different conditions.</td>
<td>The products of science are explanations and the products of engineering are solutions. The goal of science is the construction of theories that provide explanatory accounts of the world. A theory becomes accepted when it has multiple lines of empirical evidence and greater explanatory power of phenomena than previous theories. The goal of engineering design is to find a systematic solution to problems that is based on scientific knowledge and models of the material world. Each proposed solution results from a process of balancing competing criteria of desired functions, technical feasibility, cost, safety, aesthetics, and compliance with legal requirements. The optimal choice depends on how well the proposed solutions meet criteria and constraints.</td>
<td>Scientists and engineers must be able to communicate clearly and persuasively the ideas and methods they generate. Critiquing and communicating ideas individually and in groups is a critical professional activity. Communicating information and ideas can be done in multiple ways: using tables, diagrams, graphs, models, and equations as well as orally, in writing, and through extended discussions. Scientists and engineers employ multiple sources to acquire information that is used to evaluate the merit and validity of claims, methods, and designs.</td>
</tr>
<tr>
<td>Analyzing and Interpreting Data</td>
<td>Engaging in Argument from Evidence</td>
<td></td>
</tr>
<tr>
<td>Scientific investigations produce data that must be analyzed in order to derive meaning. Because data patterns and trends are not always obvious, scientists use a range of tools—including tabulation, graphical interpretation, visualization, and statistical analysis—to identify the significant features and patterns in the data. Scientists identify sources of error in the investigations and calculate the degree of certainty in the results. Modern technology makes the collection of large data sets much easier, providing secondary sources for analysis. Engineering investigations include analysis of data collected in the tests of designs. This allows comparison of different solutions and determines how well each meets specific design criteria—that is, which design best solves the problem within given constraints. Like scientists, engineers require a range of tools to identify patterns within data and interpret the results. Advances in science make analysis of proposed solutions more efficient and effective.</td>
<td>Argumentation is the process by which explanations and solutions are reached. In science and engineering, reasoning and argument based on evidence are essential to identifying the best explanation for a natural phenomenon or the best solution to a design problem. Scientists and engineers use argumentation to listen to, compare, and evaluate competing ideas and methods based on merits. Scientists and engineers engage in argumentation when investigating a phenomenon, testing a design solution, resolving questions about measurements, building data models, and using evidence to identify strengths and weaknesses of claims.</td>
<td></td>
</tr>
<tr>
<td>Disciplinary Core Ideas in Physical Science</td>
<td>Disciplinary Core Ideas in Life Science</td>
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<td>LS3: Heredity: Inheritance and Variation of Traits</td>
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**Crosscutting Concepts**

**Patterns**

Observed patterns of forms and events guide organization and classification, and they prompt questions about relationships and the factors that influence them.

**Cause and Effect: Mechanism and Explanation**

Events have causes, sometimes simple, sometimes multifaceted. A major activity of science is investigating and explaining causal relationships and the mechanisms by which they are mediated. Such mechanisms can then be tested across given contexts and used to predict and explain events in new contexts.

**Scale, Proportion, and Quantity**

In considering phenomena, it is critical to recognize what is relevant at different measures of size, time, and energy and to recognize how changes in scale, proportion, or quantity affect a system’s structure or performance.

**Systems and System Models**

Defining the system under study—specifying its boundaries and making explicit a model of that system—provides tools for understanding and testing ideas that are applicable throughout science and engineering.

**Energy and Matter: Flows, Cycles, and Conservation**

Tracking fluxes of energy and matter into, out of, and within systems helps one understand the systems’ possibilities and limitations.

**Structure and Function**

The way in which an object or living thing is shaped and its substructure determine many of its properties and functions.

**Stability and Change**

For natural and built systems alike, conditions of stability and determinants of rates of change or evolution of a system are critical elements of study.

Developed by NSTA based on content from the Framework for K-12 Science Education and supporting documents for the May 2012 Public Draft of the NGSS