The Importance of Pre-Service Training for the Success of the NGSS

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Abstract

Pre-service teacher training is critical to the success of the Next Generation Science Standards (NGSS). The NGSS arguably represent the largest shift in U.S. K-12 science education of the past century, and will require a wholly new approach toward teacher training before the full impact of the NGSS can be realized. In-service training for current teachers is also important, but given the realities of limited funds and resources for teacher PD, a fully effective transition to NGSS-aligned teaching is not realistically possible with the existing teacher work force. There are several reasons for this: (1) NGSS-aligned teaching involves an entirely different approach to teaching, moving away from the "sage on the stage" toward student-centered active learning and problem-based learning methods that have been identified by recent advances in pedagogy and child psychology; (2) NGSS-aligned teaching integrates STEM concepts of the engineering design process and computational methods that have not been part of past traditional science curricula; (3) NGSS-aligned teaching involves a shift away from a dominant focus on the content of science, fostered by the growth of dependencies upon multiple-choice-answered assessments, toward the practices of science, to be assessed through higher levels of Bloom's taxonomy of student cognition, and (4) NGSS-aligned curricula dispense with a view of science as a structure of classifications and categorizations in favor of systems-based learning, epitomized by the Earth Systems Science approach. However, new teachers, trained in the concepts of the NGSS, will face great challenges as they enter the work force. They need to be prepared for an educational system that is weighed down by extreme inertia and be willing to push for educational reforms. New K-5 teachers will need to expand the mean daily science allotment beyond the 20-25 minutes/day that currently exists and is not likely to change, even with the replacement of NCLB by ESSA. And new science teachers will need to be prepared for push-back from parents, administrators, and politicians who still equate science literacy with encyclopedic memory recall. Great patience is needed for the success of the NGSS reforms, and a key part of this is quality pre-service training for future science teachers.

The 5 NGSS Innovations

- Innovation 1: Making Sense of Phenomena & Designing Solutions to Problems
- Innovation 2: Three-Dimensional Learning
- Innovation 3: Building K-12 Progressions
- Innovation 4: Alignment with English Language Arts and Mathematics
- Innovation 5: All Standards, All Students

Training should emphasize the 5 innovations that are unique to the NGSS and make it a powerful means of building student understanding

Innovation #1: Making Sense of Phenomena and Designing Solutions to Problems

NGSS Middle School "Phenomenon" Model

Grade 6	Grade 7	Grade 8
1) How important are our natural resources?	1) Why do people live and farm on volcanoes?	1) How have Earth processes changed populations of organisms?
2) How does a change in thermal energy affect matter?	2) What causes climates to be so different across the Earth?	2) How can people influence other organisms?
3) What are chemical reactions?	3) Why can we predict solar eclipses?	3) How can people influence Earth?
4) What happens when objects collide?	4) Why are bones so hard?	
5) How can objects interact at a distance?	5) Why do some parents and offspring look different?	

The Disciplinary Core Ideas (DCIs), Science and Engineering Practices (SEPs), and Crosscutting Concepts (CCCs) should be learned in the context of constructing an explanation to an overarching scientific Essential Question and/or designing a solution to a problem or challenge.

NGSS Bundling Examples: Phenomenon-Based Learning

Example Bundles:
Read First: Introduction and Guide

Kindergarten
Thematic Model
Topics Model
1st Grade
Thematic Model
Topics Model
2nd Grade
Thematic Model
Topics Model
3rd Grade
Thematic Model
Topics Model
4th Grade
Thematic Model
Topics Model
5th Grade
Thematic Model
Topics Model

Middle School
Course 1: Phenomenon Model
Course 2: Phenomenon Model
Course 3: Phenomenon Model
(Course Map #1)

Course 1: Topics Model
Course 2: Topics Model
Course 3: Topics Model
(California Integrated Middle School Program)

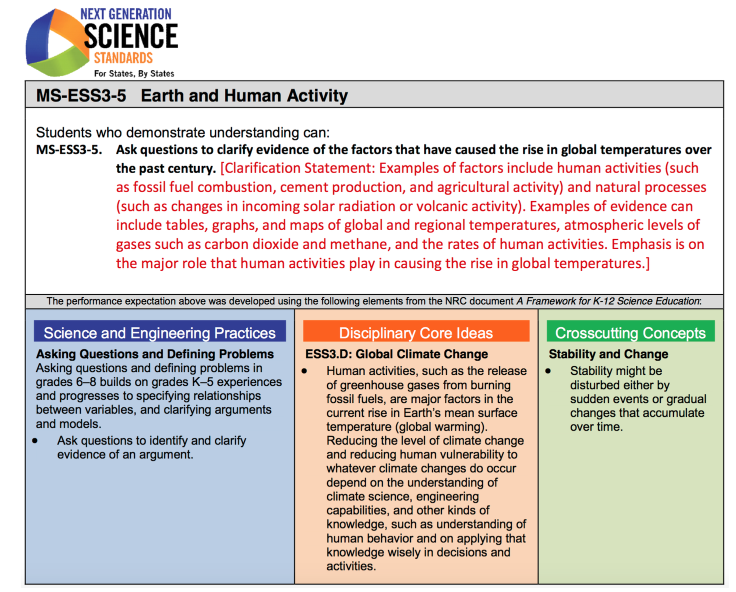
High School
Course 1: Conceptual Progressions Model
Course 2: Conceptual Progressions Model
Course 3: Conceptual Progressions Model
(Course Map #1)

Course 1: Modified Domains Model: Chemistry w/Earth and Space Science
Course 2: Modified Domains Model: Physics w/Earth and Space Science
Course 3: Modified Domains Model: Biology w/Earth and Space Science
(Course Map #3)

NGSS sample Bundlings show several ideas for bundling the performance expectations around big-picture phenomenon-based questions.

A (4th-grade, here) curricular example is the problem- based "Quests" that each runs all through a chapter, start to finish, of the "Elevate Science" K-8 textbook program (Padilla, Miller, and Wysession, 2017). All DCIs, SEPs, and CCCs are learned within the context of an chapter-wide Essential Question and the engineering-based Quest.

Innovation #2: Three-Dimensional Learning



All learning, instruction, and assessment occurs within the context of the integration of the three dimensions of the DCIs, SEPs, and CCCs. Not one is to be taught without the others.

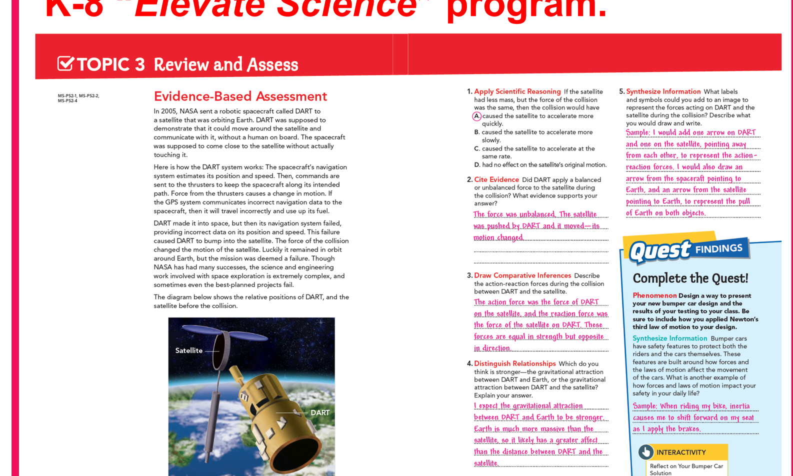
The Practices: Guiding Principles

1. Students in grades K-12 should engage in all eight practices over each grade band
2. Practices grow in complexity and sophistication across the grades
3. Performance expectations focus on some but not all of the ***elements*** associated with a practice (i.e., students need only focus on one aspect of a practice, not the full grade or grade-band description)
4. The practices are interconnected – they work together

Performance Expectations combine a single SEP with a single CCC to accompany a set of DCIs for assessment. However, instruction should be done combining additional SEPs and CCCs to build mastery.

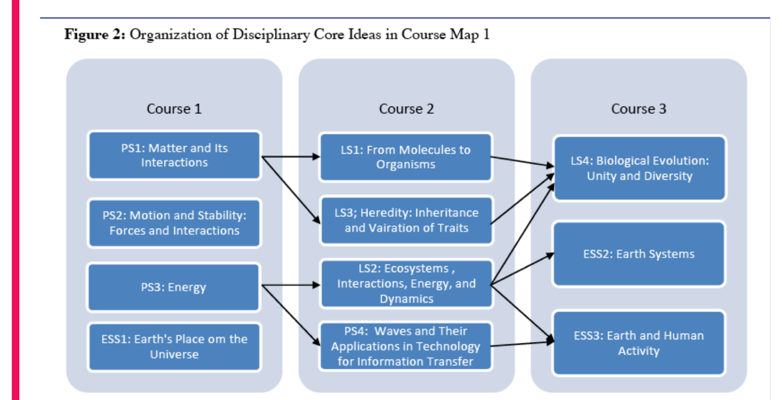
3-dimensional learning, emphasizing the practices, leads to a more open-ended, student-centric form of learning.

Assessments also need to weave together all 3 dimensions, as in this 8th-grade example of the end-of-chapter Evidence-Based Assessments from the K-8 *"Elevate Science"* program.

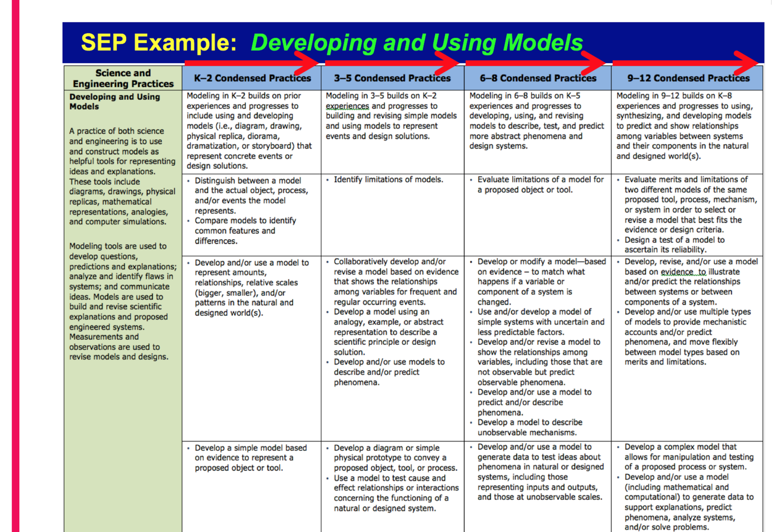


Innovation #3: Building K-12 Progressions

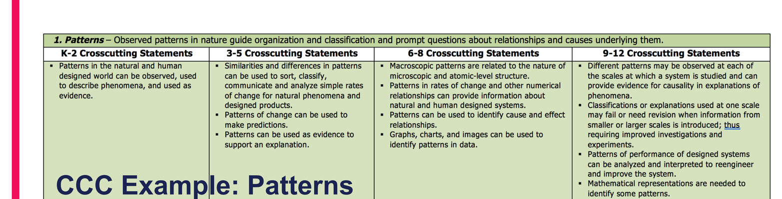
All aspects of the NGSS play out in a set of scaffolded learning sequences that progressively build across K-12. This holds for the DCIs (from the NRC *Framework*), SEPs, CCCs, and the Nature of Science and Engineering/ Science/ Technology concepts. This is informed by research on learning progressions.

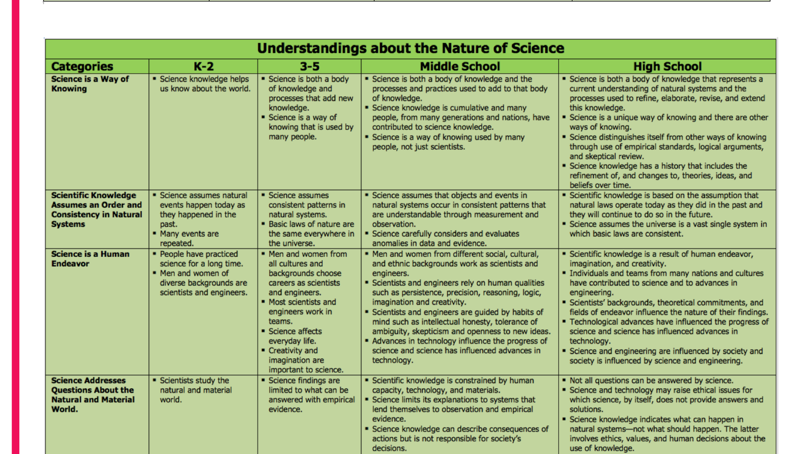


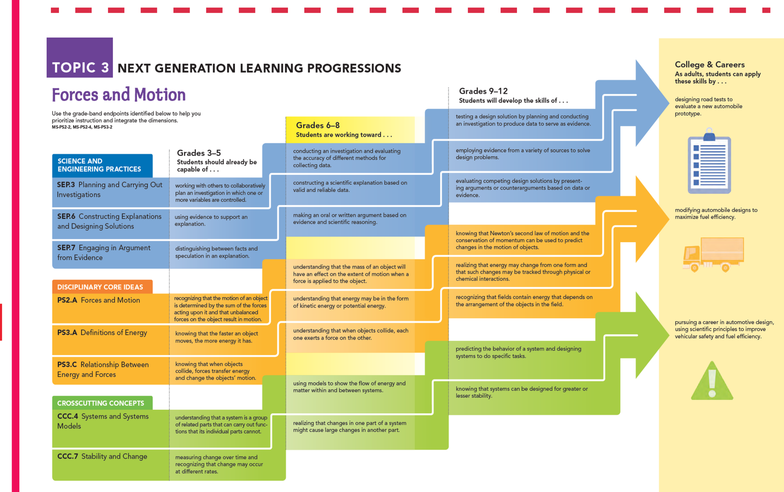
SEP Example: *Developing and Using Models*



CCC Example: Patterns

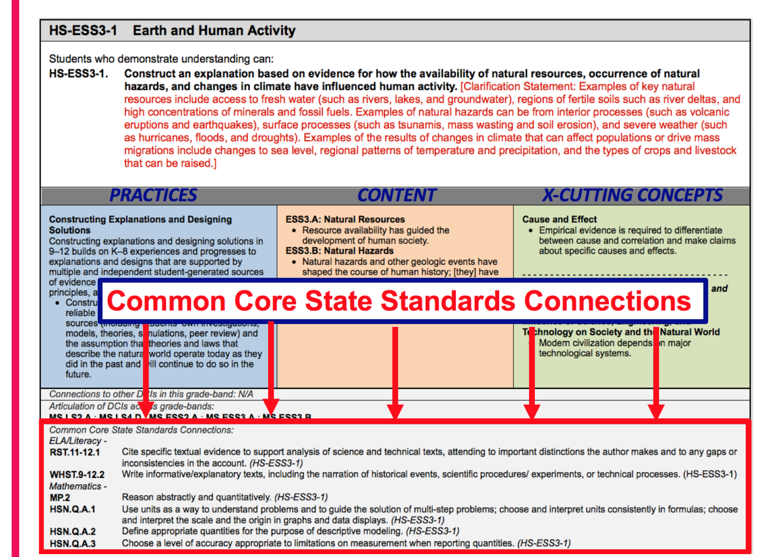






Instructional materials also need to have a clear plan for how the DCIs, SEPs, and CCCs will progress across grade bands, as in this 8th-grade example from *"Elevate Science."*

Innovation #4: Alignment with English Language Arts and Mathematics



In most cases, schools will be implementing the Common Core for Math and English, so the NGSS PEs are carefully aligned with CCSS math and English standards at all grade levels. Instruction needs to be coordinated horizontally and vertically with math and ELA instructors.

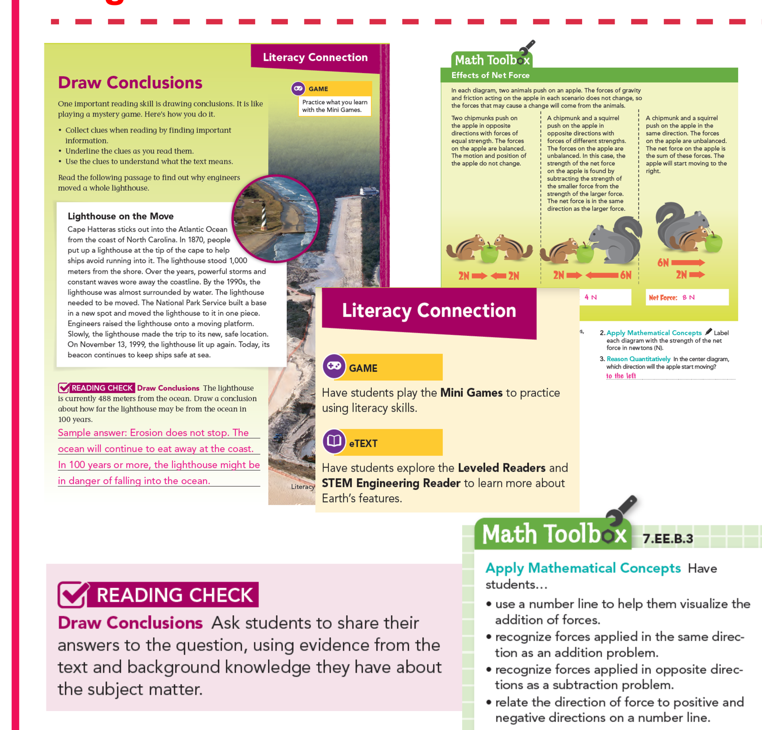
The Practices of Science and Engineering (SEPs)

1. Asking questions (*for science*) and defining problems (*for engineering*)
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations (*for science*) and designing solutions (*for engineering*)
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

Strong English Connections

Strong Math Connections

The SEPs all have a strong Common Core connection to either the Math or English CCSSs.

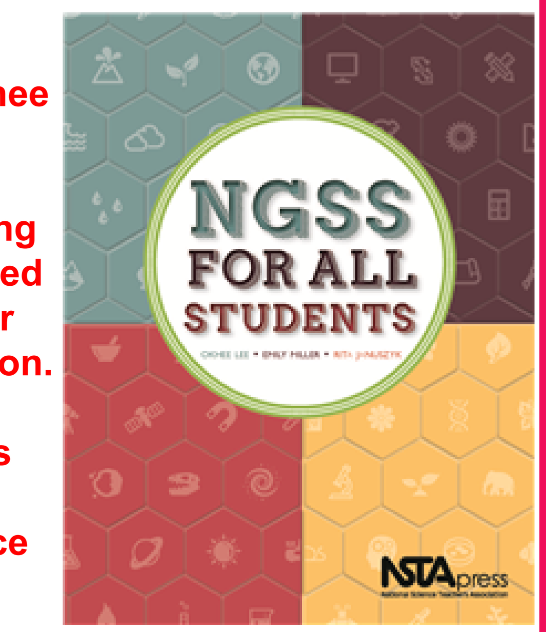


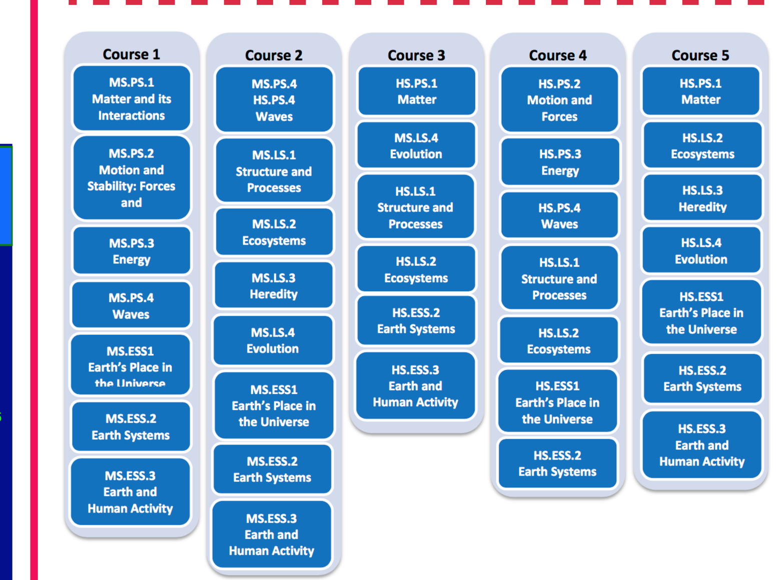
Scientific instruction must involve support at many levels for the simultaneous development of aligned Common Core math and ELA understandings, as do instructional materials (Examples are from *"Elevated Science"*).

Innovation #5: All Standards, All Students

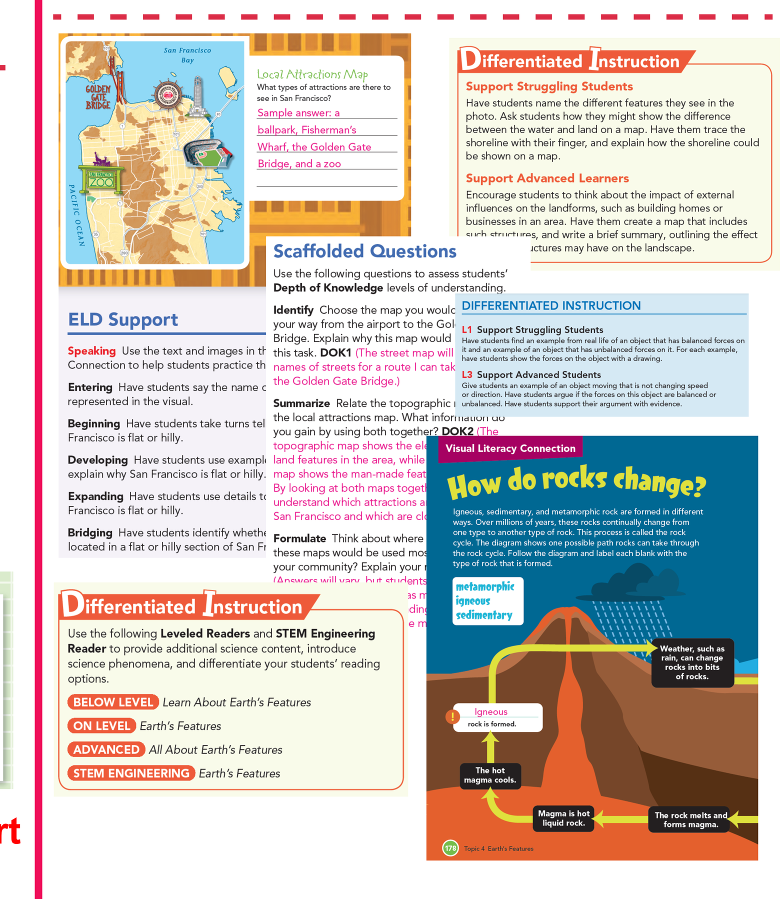
The NGSS are designed to be the minimum for all students. Instructional supports will therefore be needed for English language learners, language-deficient learners, disadvantaged students, etc., so that they all can share in the benefits of a science education.

This NSTA text, by Okhee Lee, is very helpful in implementing NGSS-aligned supports for differentiation. STEM education is an issue of social justice and equity.





At the same time, 5-year and 4-year accelerated course pathways for grades 6-12 exist for advanced/gifted students, to allow time for AP courses.



Instruction should involve a variety of tools for support the differentiation of student learning styles and abilities. (Examples are from *"Elevated Science"*).

Inclusion of a Year of Earth and Space Science in both Middle and High School

The inclusion of a year of high school geoscience for all students is proving to be the largest curricular challenge for the 80% of national schools that are adopting or adapting the NGSS.

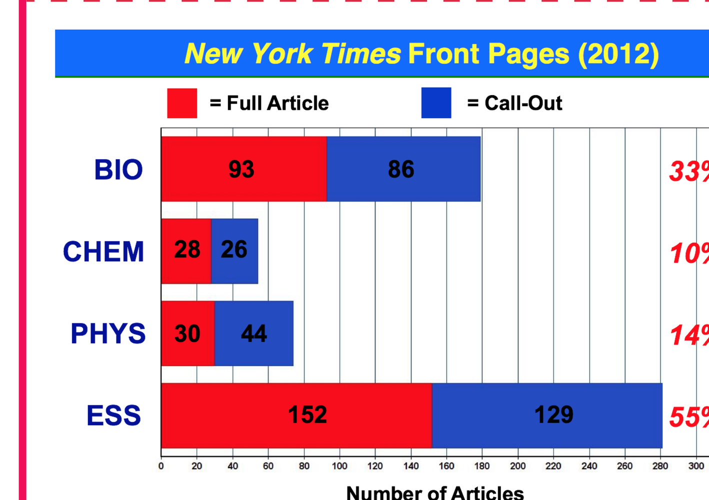
ESS3 Earth and Human Activity
- **ESS3A Natural Resources**
- **ESS3B Natural Hazards**
- **ESS3C Human Impacts on Earth Systems**
- **ESS3D Global Climate Change**

NGSS Performance Expectations called out for alignment with issues of *Science, Technology, and Society*

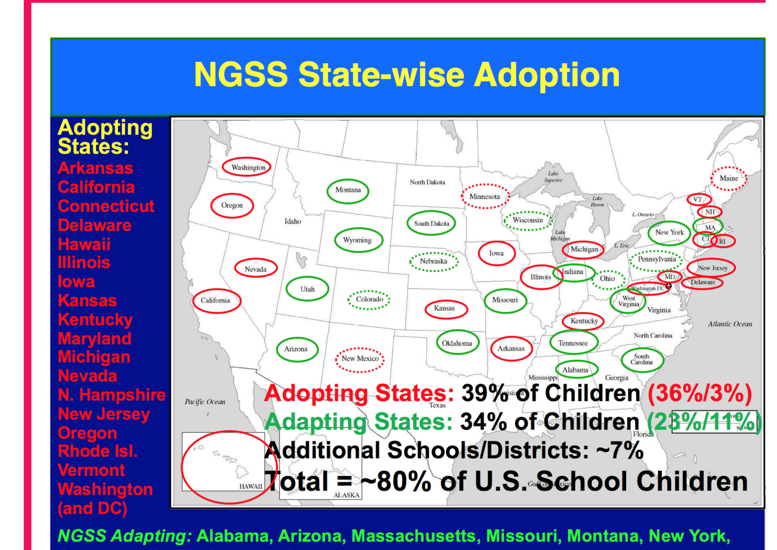
	Life	Phys	Earth & Space
Middle Sch	4	5	5
High Sch	2	5	8

The NGSS emphasizes relevancy to students' lives, and the importantance of ESS Big Idea 3 motivated the inclusion of a year of HS ESS.

This is supported by the large presence of STEM engineering in the NGSS, which is strongly aligned with issues of sustainability and designing solutions to minimize human impacts.



Analysis of media portrayal of science, such as this study of 2012 NYTimes front pages, shows that Geoscience topics (hazards, resources, human impacts, climate change) consistently appear more often than all other sciences (and most of the others relate to medicine).



The wide adopting/adapting of the NGSS across US states provides many new opportunties for grade 6-12 instruction of the Earth and Space Sciences.