

## **Appendix J – Model Course Mapping in Middle and High School for the Next Generation Science Standards**

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## Reaching the Potential:

### Mapping out Model Courses for the Next Generation Science Standards

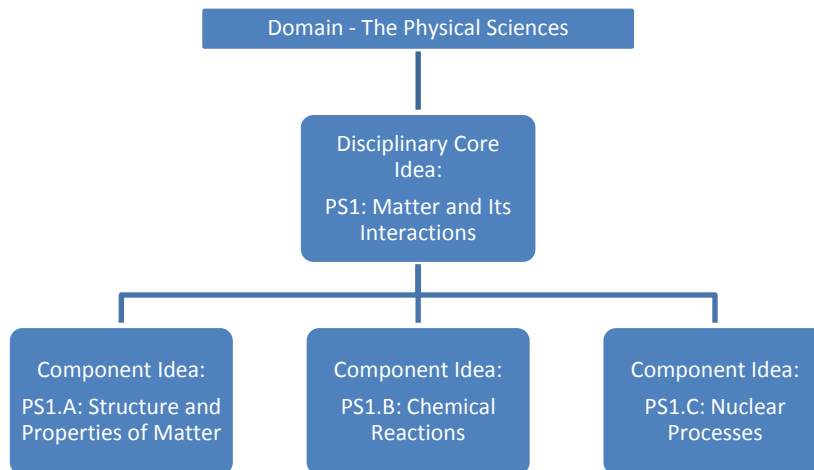
The Next Generation Science Standards (NGSS) are organized by grade level for kindergarten through grade five, but as grade banded expectations at the middle school (6-8) and high school (9-12) levels. As states and districts consider implementation of NGSS, it will be important to thoughtfully consider how to organize these grade-banded standards into courses that best prepare students for post-secondary success in college and career. To help facilitate a decision-making process at the state or district level, several potential directions for this process are outlined in this section.

Courses need to be thoughtfully scaffolded within the curriculum at levels of complexity that are developmentally appropriate for students to build knowledge both within courses and over the sequence of courses. In fact, the engineering of an effective learning program is a complex and challenging task that depends on instructor knowledge of the content and pedagogy, materials that support good instruction, determination and implementation of learning progressions, assessments for formative and summative purposes, even school climate; issues much beyond the goals of this document.

In considering these model course maps, please keep the following in mind:

- 1. The model course maps described here are as much models of process for planning courses and sequences as they are models of end products.** Every attempt has been made to describe the intent and assumptions underlying each model and the process of model development so that states and districts can utilize similar processes to organize the standards in a useful way. These models illustrate *possible* approaches to organizing the content of the NGSS into coherent and rigorous courses that lead to college and career readiness. States and local education agencies (LEAs) are not expected to adopt these models; rather, they are encouraged to use them as a starting point for developing their own course descriptions and sequences.
- 2. The models utilize the foundational ideas and organization of *A Framework for K-12 Science Education (Framework)*.** The *Framework* is organized into four major domains: the physical sciences, the life sciences, the earth and space sciences, and engineering, technology and applications of science. (In NGSS, the fourth domain is integrated into the other three. This was a deliberate decision made to incorporate these disciplines rather than teach them separately.) Within each domain the *Framework* describes how a small set of core ideas, were developed using a set of specific criteria (NRC 2011, p. 31). Each core idea is broken into three or four component ideas which provide more organizational development of the core idea. Figure 1 below provides an example how one core idea, Matter and Its Interactions, is made up of three component ideas:

**Figure 1: Physical Science Core Idea (PS1) and Component Ideas**



**3. All students are expected to accomplish all of the performance expectations (PEs) of the NGSS.** It is a foundational commitment of the *Framework* that the science outlined in the three dimensions is for all students. This commitment was also a guiding principle in the development of the NGSS; consequently, all the course map models described here maintain this commitment—all PEs for all students.

The 9-12 grade band course maps are all organized into three courses. Keeping in mind the vision of the *Framework* that includes the expectation of preparing all students to demonstrate proficiency on the full spectrum of performance expectations and balancing that with the reality of the finite amount of time in a school year, at least three courses in science are necessary. It would certainly be recommended that students, especially those considering careers in a STEM-related field, would go beyond these courses to take science, technology, engineering, and mathematics courses to enhance their preparation.

**4. The Next Generation Science Standards are student outcomes and are explicitly NOT curriculum.** Even though within each performance expectation Science and Engineering Practices (SEP) are partnered with a particular Disciplinary Core Idea (DCI) and Crosscutting Concept (CC) in the NGSS, these intersections do not predetermine how the three are linked in the curriculum, units, or lessons; they simply clarify the expectations of what students will know and be able to do by the end of the grade or grade band. Additional work will be needed to create coherent instructional programs that help students achieve these standards.

**5. The performance expectations are grade band endpoints.** Even though a particular performance expectation is placed in a course, it may not be entirely possible to address all of the depth of that expectation within that course. It may, for example, take repeated exposure to a particular SEP over several grades or courses before a student can achieve proficiency in the SEP aspect of the performance

expectation. It is the expectation of all the model course maps that all science and engineering practices and crosscutting concepts will be blended into instruction with aspects of the disciplinary core ideas in *every* course in the sequence and not just limited to the ones that are outlined in the performance expectations.

## Model Course Maps

Three model course maps are included for consideration:

1. **Conceptual Progressions Model** (6-8 and 9-12) — the 6-8 and 9-12 grade band PEs are organized so that student understanding of concepts is built progressively throughout the course sequence. This model maps PEs into courses based on what concepts are needed for support without focusing on keeping disciplines separate.
2. **Science Domains Model** (6-8 and 9-12) — the 6-8 and 9-12 grade band PEs are organized into content-specific courses that match the three science domains of the *Framework*: Physical Science, Life Science, and Earth Science. Since the Engineering domain is integrated into the other three in the NGSS, it was not separated out.
3. **Modified Science Domains Model** (9-12) — the 9-12 grade band performance expectations are organized into content-specific courses that do not match the domains of the *Framework*, but rather match a common high school course sequence of biology, chemistry, and physics.

Including these three alternatives does not preclude other organizational sequences or foci. For example, a curricular and instructional program could be built around the National Academy of Engineering's 21<sup>st</sup> Century Grand Engineering Challenges, science, engineering and technology used in everyday life, or even using the Framework's crosscutting concept as the bases around which PEs are distributed and curriculums are built.

## Course Map 1—Conceptual Understanding Model (6-8 and 9-12)

Process and Assumptions: Where did this course map come from?

This model course map focuses on arranging PEs so that the component ideas of the Disciplinary Core Idea (DCIs) build in a progressive manner with each PE building upon the skills and knowledge described in PEs which precedes it. One of the guiding assumptions of all the model course maps is that, although all three dimensions described in the *Framework* are specifically integrated within the grade band endpoints, the curriculum and instruction will provide students with opportunities to learn the components of the dimensions in a variety of ways to reach these endpoints. In other words, multiple practices and crosscutting concepts may be integrated with a particular disciplinary core idea in instruction to reach a common grade band endpoint. Students should have multiple opportunities to engage all of the practices and crosscutting concepts in their learning experiences. Courses need to be thoughtfully scaffolded within the curriculum at levels of complexity that are developmentally appropriate for students to build knowledge both within courses and over the sequence of courses. It should be noted that the DCIs, however, do contain content that can be logically sequenced:

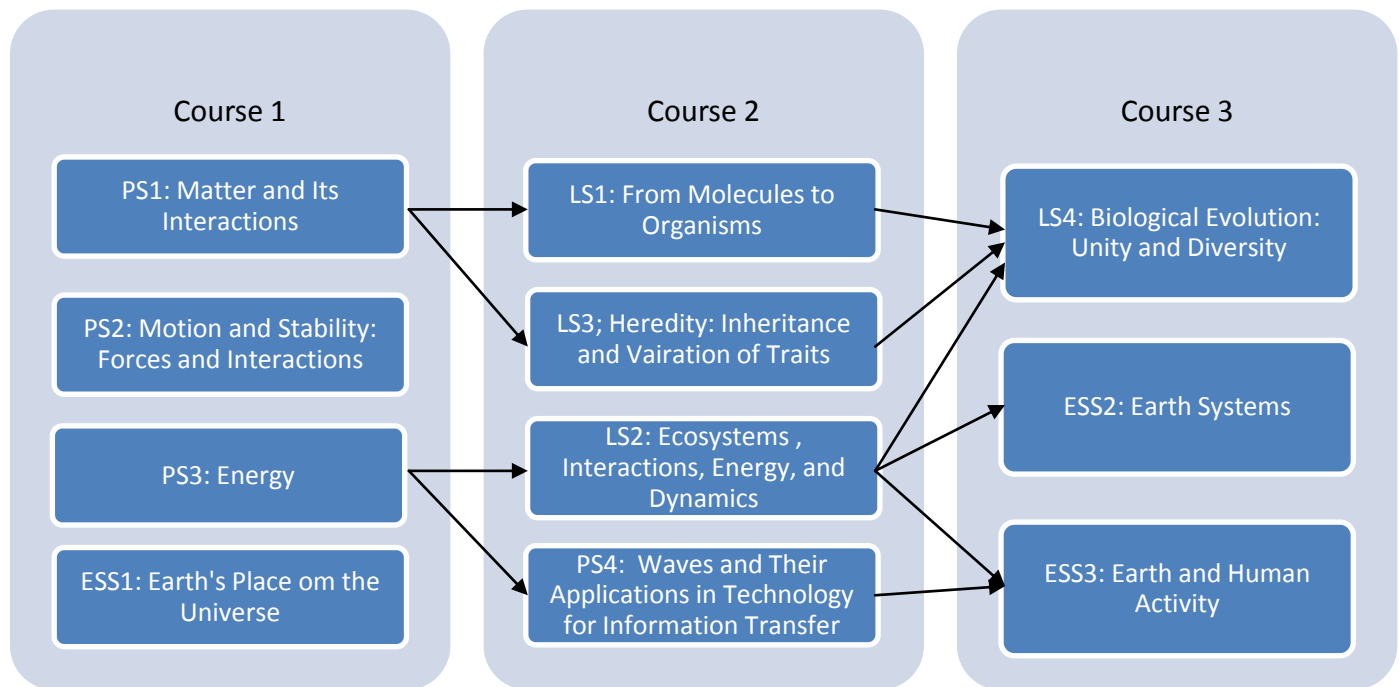
*To develop a thorough understanding of scientific explanations of the world, students need sustained opportunities to work with and develop the underlying ideas and to appreciate those ideas' interconnections over a period of years rather than weeks or months [1]. This sense of development has been conceptualized in the idea of learning progressions [1, 25, 26]. If mastery of a core idea in a science discipline is the ultimate educational destination, then well-designed learning progressions provide a map of the routes that can be taken to reach that destination.*

*Such progressions describe both how students' understanding of the idea matures over time and the instructional supports and experiences that are needed for them to make progress. Learning progressions may extend all the way from preschool to 12th grade and beyond—indeed, people can continue learning about scientific core ideas their entire lives. Because learning progressions extend over multiple years, they can prompt educators to consider how topics are presented at each grade level so that they build on prior understanding and can support increasingly sophisticated learning. Hence, core ideas and their related learning progressions are key organizing principles for the design of the framework (NRC 2011, p. 26).*

This model course map was created by the first separating the core ideas based on their reliance on other core ideas. Core ideas that did not have significant reliance upon other core ideas were placed in the first course. For example, it is clear just from the names of the core ideas that, to learn about *LS1: From Molecules To Organisms: Structures And Processes*, a student would have had to have built understanding from core idea *PS1: Matter and its interactions*. This would put core idea PS1 in a course before core idea LS1. However, just looking at the titles of the core ideas is not necessarily the best indicator of what is contained in the core idea, so deciding whether or not a core idea depended on other core ideas were made by referring to the descriptions of the grade band endpoints in *A Framework for K-*

*12 Education.* Core ideas that required only support from those in the first course were placed in the second course, and core ideas that required support from core ideas in the second course were placed in the third course; resulting in a skeletal sequence based on disciplinary core ideas (see Figure 2).

**Figure 2:** Organization of Disciplinary Core Ideas in Course Map 1



After sorting all of the core ideas into courses, the component ideas of the core ideas were then sorted to further refine their positioning. Essentially, the same process used for the DCIs was repeated, but now we “disconnected” the component ideas from the core idea and, when appropriate, moved them to a different course in the course map. For example, although *PS1: Matter and Its Interactions* was originally placed in the first course, the component idea *PS1.C: Nuclear Processes* requires content in both courses one and two, so it was shifted to course three while *PS1.A: Structures and Properties of Matter* and *PS1.B: Chemical Reactions*, which do not require content from other component ideas, remained in course one. Here is the organization after reassigning component ideas to courses. This organization works at both the 6-8 and 9-12 grade band levels.

**Table 1:** Listing of all Component Ideas in Course Map 1

	Course 1: DCI component ideas	Course 2: DCI component ideas	Course 3: DCI component ideas
<b>Physical Science DCI</b>	PS1.A: Structure and Properties of Matter PS1.B: Chemical Reactions  PS2.A: Forces and Motion PS3.A: Definitions of Energy  PS3.B: Conservation of Energy and Energy Transfer PS3.C: Relationship Between Energy and Forces PS4.A: Wave Properties	PS2.B: Types of Interactions  PS3.D: Energy in Chemical Processes and Everyday Life  PS4.B: Electromagnetic PS4.C: Information Technologies and Instrumentation	PS1.C: Nuclear Processes  PS2.B: Types of Interactions
<b>Life Science DCI</b>	LS2.A: Interdependent Relationships in Ecosystems	LS1.A: Structure and Function  LS1.B: Growth and Development of Organisms LS1.C: Organization for Matter and Energy Flow in Organisms LS2.B: Cycles of Matter and Energy Transfer in Ecosystems LS3.A: Inheritance of Traits LS3.B: Variation of Traits	LS1.D: Information Processing  LS2.C: Ecosystems Dynamics, Functioning, and Resilience LS2.D: Social Interactions and Group Behavior LS4.A: Evidence of Common Ancestry and Diversity LS4.B: Natural Selection LS4.C: Adaptation LS4.D: Biodiversity and Humans
<b>Earth Science DCI</b>	ESS1.B: Earth and the Solar System ESS2.A: Earth Materials and Systems  ESS2.C: The Roles of Water in Earth's Surface Processes	ESS1.A: The Universe and Its Stars ESS2.B: Plate Tectonics and Large-Scale System Interactions	ESS1.C: The History of Planet Earth ESS2.C: The Roles of Water in Earth's Surface Processes ESS2.D: Weather and Climate  ESS3.A: Natural Resources ESS3.B: Natural Hazards ESS3.C: Human Impacts on Earth Systems ESS3.D: Global Climate Change

The final step in the process of building model course map 1 was to connect the PEs to each component idea. This was accomplished by analyzing the foundations boxes of the Next Generation Science Standards and recording all of the PEs connected to each DCI component idea. The result of this exercise produced the tables that map each of the performance expectations to a particular course in the sequence.



# Conceptual Understanding Model (6-8)

## Course 1

PS1.A	MS-PS1-a
	MS-PS1-b
	MS-PS1-c
PS1.B	MS-PS1-d
	MS-PS1-e
	MS-PS1-g
PS2.A	MS-PS2-a
	MS-PS2-b
PS3.A	MS-PS3-a
	MS-PS3-b
	MS-PS3-c
	MS-PS3-d
	MS-PS1-c
PS3.B	MS-PS3-c
	MS-PS3-d
PS3.C	MS-PS3-e
	MS-PS3-b
PS4.A	MS-PS4-a
	MS-PS4-c
	MS-PS4-b
LS2.A	MS-LS2-a
	MS-LS2-d
ESS1.B	MS-ESS1-a
	MS-ESS1-b
	MS-ESS1-d
ESS2.A	MS-ESS2-d
	MS-ESS3-f
	MS-ESS2-e
	MS-ESS2-f
	MS-ESS2-a
	MS-ESS2-b
ESS2.C	MS-ESS2-c
	MS-ESS2-h
	MS-ESS2-i
	MS-ESS2-j
	MS-ESS2-b
	MS-ESS2-k
	MS-ESS2-l
MS-ESS1-a	
MS-ESS1-b	

## Course 2

PS2.B	MS-PS2-c
	MS-PS2-d
	MS-PS2-e
PS3.D	MS-PS3-f
	MS-PS3-g
PS4.B	MS-PS4-a
	MS-PS4-c
	MS-PS4-b
PS4.C	MS-PS4-d
LS1.A	MS-LS1-a
	MS-LS1-b
	MS-LS1-c
	MS-LS1-d
LS1.B	MS-LS1-i
	MS-LS1-h
	MS-LS3-a
LS1.C	MS-LS1-g
	MS-LS1-j
	MS-LS2-e
	MS-LS2-f
LS2.B	MS-LS1-k
	MS-LS2-e
LS2.B	MS-LS2-f
	MS-LS1-k
LS3.A	MS-LS3-a
	MS-LS3-b
LS3.B	MS-LS3-a
	MS-LS3-b
ESS1.A	MS-ESS1-a
	MS-ESS1-b
	MS-ESS1-c
	MS-ESS1-e
ESS2.B	MS-ESS3-f

## Course 3

PS2.C	MS-PS2-f
LS1.D	MS-LS1-l
	MS-LS1-m,
LS2.C	MS-LS2-c
	MS-LS2-g
	MS-LS4-i
LS2.D	MS-LS2-i
	MS-LS2-h
LS4.A	MS-LS4-a
	MS-LS4-c
	MS-LS4-b
	MS-LS4-d
LS4.B	MS-LS4-e
	MS-LS4-f
LS4.C	MS-LS4-g
	MS-LS4-h
LS4.D	MS-LS4-i
	MS-LS4-j
ESS1.C	MS-ESS1-g
	MS-ESS1-f
	MS-ESS1-o
ESS2.D	MS-ESS2-e
	MS-ESS2-f
	MS-ESS2-m
	MS-ESS2-n
ESS2.E	MS-ESS2-h
	MS-ESS2-i
	MS-ESS2-j
ESS2.E	MS-ESS2-o
	MS-ESS2-p
ESS3.A	MS-ESS3-c
	MS-ESS3-d
ESS3.B	MS-ESS3-e
	MS-ESS2-g
	MS-ESS3-g
ESS3.C	MS-ESS3-h
	MS-ESS3-j
	MS-ESS3-i
	MS-ESS3-k
ESS3.D	MS-ESS3-e
	MS-ESS3-k
ESS3.D	MS-ESS3-k
	MS-ESS3-e

### KEY

PE appears in more than one DCI in the same course.

PE shared across more than one course because a component idea is divided between courses.

PE appears in more than one course and it is connected to more than one DCI component idea in the same course.

# Conceptual Understanding Model (9-12)

## COURSE 1

PS1.A	HS-PS1-a
	HS-PS1-b
	HS-PS1-c
	HS-PS2-f
PS1.B	HS-PS1-e
	HS-PS1-f
	HS-PS1-g
	HS-PS1-h
PS2.A	HS-PS2-a
	HS-PS2-b
	HS-PS2-c
PS3.A	HS-PS3-a
	HS-PS3-b
	HS-PS3-c
PS3.B	HS-PS3-a
	HS-PS3-b
PS4.A	HS-PS4-a
	HS-PS4-b
	HS-PS4-c
	HS-PS4-d
LS2.A	HS-LS2-a
	HS-LS2-b
ESS1.B	HS-ESS1-e
	HS-ESS1-f
ESS2.A	HS-ESS2-c
	HS-ESS2-d
	HS-ESS2-a
	HS-ESS2-b
	HS-ESS2-e
	HS-ESS2-f
	HS-ESS2-g
	HS-ESS2-h

## COURSE 2

PS2.B	HS-PS2-d
	HS-PS2-e
PS3.D	HS-PS3-b
	HS-PS3-d
	HS-PS3-f
	HS-PS3-g
PS4.B	HS-PS4-a
	HS-PS4-e
	HS-PS4-f
	HS-PS4-g
	HS-PS4-h
PS4.C	HS-ESS1-b
	HS-PS4-f
LS1.A	HS-LS1-a
	HS-LS1-b
	HS-LS1-c
	HS-LS1-d
LS1.B	HS-LS1-e
	HS-LS1-f
	HS-LS1-g
	HS-LS3-c
LS1.C	HS-LS1-h
	HS-LS1-i
	HS-LS1-j
	HS-LS2-d
	HS-LS2-e
	HS-LS2-c
LS2.B	HS-LS1-i
	HS-LS1-j
	HS-LS2-d
	HS-LS2-g
	HS-LS2-e
	HS-LS2-f
LS3.A	HS-LS3-a
	HS-LS1-f
	HS-LS3-d
LS3.B	HS-LS3-a
	HS-LS3-b
ESS1.A	HS-LS3-d
	HS-ESS1-b
	HS-ESS1-c
	HS-ESS1-a
ESS2.D	HS-ESS1-d
	HS-ESS2-d
	HS-ESS2-a
ESS2.D	HS-ESS2-a
	HS-ESS1-h

## COURSE 3

PS1.C	HS-PS1-j
	HS-PS1-g
PS2.C	HS-PS2-b
	HS-PS2-c
	HS-PS2-b
LS1.D	HS-LS1-k
	HS-LS1-l
LS2.C	HS-LS2-h
	HS-LS2-i
	HS-LS2-j
LS2.D	HS-LS2-k
	HS-LS2-b
LS4.A	HS-LS4-f
	HS-LS4-b
	HS-LS4-d
	HS-LS4-e
LS4.B	HS-LS4-b
	HS-LS4-d
	HS-LS4-e
LS4.C	HS-LS4-b
	HS-LS4-d
	HS-LS4-c
	HS-LS4-e
LS4.D	HS-LS4-a
	HS-LS2-l
ESS1.C	HS-ESS1-g
	HS-ESS1-i
	HS-ESS1-j
	HS-ESS1-h
ESS2.C	HS-ESS1-l
	HS-ESS2-j
	HS-ESS2-k
	HS-ESS2-e
	HS-ESS2-f
ESS2.D	HS-ESS3-g
	HS-ESS3-h
	HS-ESS3-a
	HS-ESS3-b
ESS3.A	HS-ESS3-c
	HS-ESS3-d
ESS3.B	HS-ESS3-e
	HS-ESS3-f
ESS3.C	HS-ESS3-i
	HS-ESS3-g
	HS-ESS3-h
ESS3.D	HS-ESS3-g
	HS-ESS3-h

### KEY

	PE appears in more than one DCI in the same course
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	PE shared across more than one course because a component idea is divided between courses.
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	PE appears in more than one course and it is connected to more than one DCI in the same course.
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## Refining Course Map 1

There are several recommended next steps that states or LEAs should consider in order to develop curriculum based on this course map. As was mentioned in the introduction, these maps are not intended to be finished products, but rather as beginning points for conversations that will hopefully lead to a successful implementation process. As LEAs begin the work of using the NGSS, there will be need to develop curricula and instructional unit plans to guide students to the expected grade-band outcomes of the NGSS. The following points suggest initial next steps to facilitate the development process:

1. Revisit the suggested arrangement of DCIs and DCI component ideas to ensure that they progress from course to course in a logical fashion. In this process, make sure to read the descriptions of the core ideas and the component ideas in the *Framework*, rather than only relying on past experiences with those concepts or topics. This may mean that you end with a different arrangement than we did, but constructively engaging a broad group of teachers and administrators in this process results in greater buy-in for implementation.
2. Evaluate the next level of specificity within each of the component ideas to determine if any of the PEs need to be shifted to another course. Our process stopped at sorting the component ideas, so basically repeat the same process for the PEs that was done with the DCIs and DCI component ideas. To facilitate this process, we have grouped the text from the performance expectations together with the relevant text from the *Framework* component ideas. The Course Map Storylines are included at the end of this section.
3. As curriculum units and lesson plans are designed, maintain that the performance expectations are grade-banded student outcomes and map out student course expectations appropriately. For example, it could be that the content of a PE needs to be introduced in the first course, but the depth of the science and engineering practice required by the PE may not be reached until the third year. The curriculum will need to be designed in a way that accounts for this reality.
4. It may be determined that getting all students prepared for all PEs requires more than three courses. To accomplish this would simply require repeating this same process as described above, but sorting into four courses instead of three. In order for this to still align with the vision of the framework of all of the PEs being for all students, all four courses would need to be required in this case.
5. It is, of course, important to balance this structured arrangement of PEs with creating courses and units that flow well and engage students in learning.

## Course Map 2— Science Domains Model (6-8 and 9-12)

Process and Assumptions: Where did this model come from?

This model was built as an example of the way NGSS Performance Expectations could be placed into a structure that reflects the organization of *A Framework for K-12 Science Education*. One course is assigned to each of the Disciplinary Core Idea domains—Life Science, Physical Science, and Earth and Space Science. A fourth course for the Engineering domain is not included as the decision was made to incorporate NGSS Engineering performance expectations into the other domains. This model does not assume a particular order for these three courses.

Developing this course map was much less laborious than the first model that was proposed as the organization was already pre-determined by the *Framework*—the domains from the *Framework* defined the parameters of each course. All component ideas from a given domain and all of the performance expectations connected to each of those component ideas (as noted in the NGSS foundation boxes) were compiled to define each course.

# Science Domains Model (6-8)

## Physical Science

PS1.A	MS-PS1-a
	MS-PS1-b
	MS-PS1-c
PS1.B	MS-PS1-d
	MS-PS1-e
	MS-PS1-g
PS2.A	MS-PS2-a
	MS-PS2-b
PS2.B	MS-PS2-c
	MS-PS2-d
	MS-PS2-e
PS2.C	MS-PS2-f
PS3.A	MS-PS3-a
	MS-PS3-b
	MS-PS3-c
	MS-PS3-d
PS3.B	MS-PS3-c
	MS-PS3-d
	MS-PS3-e
PS3.C	MS-PS3-b
PS3.D	MS-PS3-f
	MS-PS3-g
PS4.A	MS-PS4-a
	MS-PS4-c
	MS-PS4-b
PS4.B	MS-PS4-a
	MS-PS4-c
	MS-PS4-b
PS4.C	MS-PS4-c

## Life Science

LS1.A	MS-LS1-a
	MS-LS1-b
	MS-LS1-c
	MS-LS1-d
LS1.B	MS-LS1-i
	MS-LS1-h
	MS-LS3-a
	MS-LS1-g
LS1.C	MS-LS1-j
	MS-LS2-e
	MS-LS2-f
	MS-LS1-k
LS1.D	MS-LS1-l
	MS-LS1-m
LS2.A	MS-LS2-a
	MS-LS2-d
LS2.B	MS-LS2-e
	MS-LS2-f
	MS-LS1-k
LS2.C	MS-LS2-c
	MS-LS2-g
	MS-LS4-i
LS2.D	MS-LS2-i
	MS-LS2-h
LS3.A	MS-LS3-a
	MS-LS3-b
LS3.B	MS-LS3-a
	MS-LS3-b
LS4.A	MS-LS4-a
	MS-LS4-c
	MS-LS4-b
	MS-LS4-d
LS4.B	MS-LS4-e
	MS-LS4-f
	MS-LS4-g
LS4.C	MS-LS4-f
	MS-LS4-h
LS4.D	MS-LS4-i
	MS-LS4-j

## Earth and Space Science

ESS1.A	MS-ESS1-a
	MS-ESS1-b
	MS-ESS1-c
	MS-ESS1-e
ESS1.B	MS-ESS1-a
	MS-ESS1-b
	MS-ESS1-d
ESS1.C	MS-ESS1-g
	MS-ESS1-f
	MS-ESS2-o
	MS-ESS2-e
ESS2.A	MS-ESS2-f
	MS-ESS2-d
	MS-ESS3-f
	MS-ESS2-e
	MS-ESS2-f
ESS2.B	MS-ESS2-a
	MS-ESS2-b
	MS-ESS2-c
	MS-ESS3-f
	MS-ESS2-h
	MS-ESS2-i
ESS2.C	MS-ESS2-j
	MS-ESS2-b
	MS-ESS2-k
	MS-ESS2-l
	MS-ESS1-a
	MS-ESS1-b
ESS2.D	MS-ESS2-m
	MS-ESS2-n
	MS-ESS2-h
	MS-ESS2-h
	MS-ESS2-i
ESS2.E	MS-ESS2-j
	MS-ESS2-o
ESS3.A	MS-ESS2-p
	MS-ESS3-c
	MS-ESS3-d
ESS3.B	MS-ESS3-e
	MS-ESS2-g
	MS-ESS3-g
ESS3.C	MS-ESS3-h
	MS-ESS3-j
	MS-ESS3-i
	MS-ESS3-k
ESS3.D	MS-ESS3-e
	MS-ESS3-k

### KEY

	PE appears in more than one DCI in the same course.
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# Science Domains Model (9-12)

## Physical Science

PS1.A	HS-PS1-a
	HS-PS1-b
	HS-PS1-c
	HS-PS2-f
PS1.B	HS-PS1-e
	HS-PS1-f
	HS-PS1-g
	HS-PS1-h
PS1.C	HS-PS1-i
	HS-PS1-j
PS2.A	HS-PS2-a
	HS-PS2-b
	HS-PS2-c
PS2.B	HS-PS2-d
	HS-PS2-e
PS2.C	HS-PS1-g
	HS-PS2-b
	HS-PS2-c
PS3.A	HS-PS3-a
	HS-PS3-b
	HS-PS3-c
PS3.B	HS-PS3-a
	HS-PS3-b
	HS-PS3-d
PS3.D	HS-PS3-b
	HS-PS3-d
	HS-PS3-f
	HS-PS3-g
PS4.A	HS-PS4-h
	HS-ESS1-a
	HS-PS4-a
	HS-PS4-b
	HS-PS4-c
PS4.B	HS-PS4-d
	HS-PS4-a
	HS-PS4-e
	HS-PS4-f
	HS-PS4-g
PS4-C	HS-PS4-h
	HS-ESS1-a
	HS-PS4-f

## Life Science

LS1.A	HS-LS1-a
	HS-LS1-b
	HS-LS1-c
	HS-LS1-d
LS1.B	HS-LS1-e
	HS-LS1-f
	HS-LS1-g
	HS-LS1-c
LS1.C	HS-LS1-h
	HS-LS1-i
	HS-LS1-j
	HS-LS2-d
	HS-LS2-g
	HS-LS2-e
LS1.D	HS-LS2-f
	HS-LS1-k
LS2.A	HS-LS1-l
	HS-LS2-a
LS2.B	HS-LS2-b
	HS-LS1-i
	HS-LS1-j
LS2.C	HS-LS2-d
	HS-LS2-e
	HS-LS2-c
LS2.D	HS-LS2-h
	HS-LS2-i
LS3.A	HS-LS2-j
	HS-LS2-b
	HS-LS2-k
LS3.B	HS-LS3-a
	HS-LS3-f
LS4.A	HS-LS3-d
	HS-LS3-a
	HS-LS3-b
	HS-LS4-f
LS4.B	HS-LS4-b
	HS-LS4-d
	HS-LS4-c
	HS-LS4-e
	HS-LS4-b
LS4.C	HS-LS4-d
	HS-LS4-c
	HS-LS4-e
LS4.D	HS-LS4-a
	HS-LS2-l
LS4.D	HS-LS2-l
	HS-LS2-j

## Earth and Space Science

ESS1.A	HS-ESS1-b
	HS-ESS1-c
	HS-ESS1-a
	HS-ESS1-d
ESS1.B	HS-ESS1-e
	HS-ESS1-f
ESS1.C	HS-ESS1-g
	HS-ESS1-i
	HS-ESS1-j
ESS2.A	HS-ESS1-h
	HS-ESS2-c
	HS-ESS2-d
	HS-ESS2-a
	HS-ESS2-b
	HS-ESS2-e
	HS-ESS2-f
	HS-ESS2-g
HS-ESS2-h	
ESS2.B	HS-ESS2-d
	HS-ESS2-a
	HS-ESS1-h
ESS2.C	HS-ESS2-i
	HS-ESS2-j
	HS-ESS2-k
ESS2.D	HS-ESS2-e
	HS-ESS2-f
	HS-ESS3-g
	HS-ESS3-h
ESS2.E	HS-ESS1-l
ESS3.A	HS-ESS3-a
	HS-ESS3-b
ESS3.B	HS-ESS3-c
	HS-ESS3-d
ESS3.C	HS-ESS3-e
	HS-ESS3-f
ESS3.D	HS-ESS3-i
	HS-ESS3-g
	HS-ESS3-h

### KEY

	PE appears in more than one DCI in the same course.
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	PE shared across more than one course because a component idea is divided between courses.
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	PE appears in more than one course and it is connected to more than one DCI component idea in the same course.
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## Refining Course Map 2

There is less refining needed to Course Map 2 relative to course map one. Since the courses were effectively designed based on the parameters of the domains of science defined in the *Framework*, it wouldn't make sense to do any significant shuffling of PEs between courses, but there is at least one decision that needs to be made if this model is selected—the order courses would be offered. The Course Map Storylines which are included at the end of this section are a great resource for this process. It is important to not sequence courses based on what makes sense or based on what your current courses are, but to look in detail at the performance expectations mapped to each course and think about what makes the most sense for sequencing courses with these expectations. There is information in the sequencing of PEs for Course Map 1 that is relevant to this decision-making process. If, during the implementation process, restricting the 9-12 grade band to three courses does not prove to be preferable, a fourth course could be developed. If all four courses are required, a course map variation like this could still meet the vision of the *Framework*. Since the three domains fit fairly well into courses, there is not an obvious way to siphon PEs into a fourth course, but an examination of course map model one could provide direction to this process. Since the third course in that sequence contains PEs that are most dependent on content from other PEs, this would be a good starting point in determining which PEs should be considered for being a part of a fourth course.

### Course Map 3—Modified Science Domains Model (9-12)

Process and Assumptions: Where did this model come from?

This model was constructed by sorting DCI component idea of the grades 9-12 performance expectations (PEs) for life and physical science based on the frequently taught courses of Biology, Chemistry and Physics. These courses were chosen because they represent a very common course distribution across many states, either through legislation, regulation, or tradition. The challenge of this course map was to also address the Earth and Space Science PEs as the underlying assumption of all of the models, which is that all PEs are for all students. Since few states currently require four high school science courses, this model examined how the Earth and Space PEs could be effectively distributed between the three courses already described.

The first step in mapping performance expectations to courses was to look at the component idea level of the Disciplinary Core Ideas and decide with which course the component ideas best aligned, along with the associated performance expectations (as noted in the foundation boxes of the NGSS). These decisions were made through a careful reading for the text describing the grade band endpoints for each component idea in the *Framework*. This was easiest for the Life Science component ideas as they all ended up in Biology. It was a step more difficult for the Physical Science component ideas as they had to be split between Chemistry and Physics courses. In most cases all of the PEs for a single component idea remained together in the same course, but the topic of Energy is split across Chemistry and Physics, which is noted in the tables with an asterisk(\*).

The most challenging domain to organize into these three courses was Earth and Space Science as these performance expectations did not have a course of their own. Since a fundamental assumption of all of the model course maps is that the performance expectations of the NGSS are all for all students and many states do not require four courses of science, the decision was made to attempt to distribute the Earth and Space Science in a logical fashion across the Biology, Chemistry, and Physics Courses. This was done in a two step process: first the 12 Earth and Space Science DCI component ideas were assigned to a course based on their best conceptual fit, then the individual earth science PEs were sorted by their alignment to those component ideas. This was done using the alignment of PEs to component ideas in the DCI Foundation Boxes of the NGSS.

No course sequence has been assumed in this model.



# Modified Science Domains Model (9-12)

## Biology

LS1.A	HS-LS1-a
	HS-LS1-b
	HS-LS1-c
	HS-LS1-d
LS1.B	HS-LS1-e
	HS-LS1-f
	HS-LS1-g
LS1.C	HS-LS3-c
	HS-LS1-h
	HS-LS1-i
	HS-LS1-j
	HS-LS2-d
	HS-LS2-g
	HS-LS2-e
LS1.D	HS-LS2-c
	HS-LS1-k
LS2.A	HS-LS1-l
	HS-LS2-a
LS2.B	HS-LS2-b
	HS-LS1-i
	HS-LS1-j
	HS-LS2-d
	HS-LS2-g
	HS-LS2-e
	HS-LS2-f
LS2.C	HS-LS2-h
	HS-LS2-i
	HS-LS2-j
LS2.D	HS-LS2-b
	HS-LS2-k
LS3.A	HS-LS3-a
	HS-LS3-b
	HS-LS3-d
LS4.A	HS-LS4-f
LS4.B	HS-LS4-b
	HS-LS4-d
	HS-LS4-c
	HS-LS4-e
LS4.C	HS-LS4-b
	HS-LS4-d
	HS-LS4-c
	HS-LS4-e
LS4.D	HS-LS4-a
	HS-LS2-l
ESS1.C	HS-LS2-j
	HS-ESS1-g
	HS-ESS1-i
	HS-ESS1-j
ESS2.E	HS-ESS1-h
	HS-ESS1-l
ESS3.B	HS-ESS3-c
	HS-ESS3-d
ESS3.C	HS-ESS3-e
	HS-ESS3-f

## Chemistry

PS1.A	HS-PS1-a
	HS-PS1-b
	HS-PS1-c
	HS-PS2-f
	HS-PS1-d
	HS-PS1-j
PS1.B	HS-PS3-g
	HS-PS1-e
	HS-PS1-f
	HS-PS1-g
	HS-PS1-h
PS2.C	HS-PS1-i
	HS-PS1-g
PS3.B	HS-PS3-d
PS3.D	HS-PS3-d
ESS2.C	HS-ESS2-i
	HS-ESS2-j
	HS-ESS2-k
	HS-ESS2-e
	HS-ESS2-f
	HS-ESS3-g
ESS3.A	HS-ESS3-h
	HS-ESS3-a
	HS-ESS3-b
ESS3.D	HS-ESS3-i
	HS-ESS3-g
	HS-ESS3-h

## Physics

PS2.A	HS-PS2-a
	HS-PS2-b
	HS-PS2-c
PS2.B	HS-PS2-d
	HS-PS2-e
PS2.C	HS-PS1-g
	HS-PS2-b
PS3.A	HS-PS2-c
	HS-PS3-a
	HS-PS3-b
PS3.B	HS-PS3-c
	HS-PS3-a
	HS-PS3-b
	HS-PS3-d
PS3.C	HS-PS3-f
	HS-PS3-e
PS4.A	HS-PS4-a
	HS-PS4-b
	HS-PS4-c
	HS-PS4-d
PS4.B	HS-PS4-a
	HS-PS4-e
	HS-PS4-f
	HS-PS4-g
	HS-PS4-h
ESS1.A	HS-ESS1-b
	HS-ESS1-c
	HS-ESS1-a
ESS1.B	HS-ESS1-d
	HS-ESS1-e
ESS2.A	HS-ESS1-f
	HS-ESS2-c
	HS-ESS2-d
	HS-ESS2-a
	HS-ESS2-b
	HS-ESS2-e
HS-ESS2-f	
ESS2.B	HS-ESS2-g
	HS-ESS2-h
	HS-ESS2-d
	HS-ESS2-a
HS-ESS1-h	

### KEY

	PE appears in more than one DCI in the same course.
	PE shared across more than one course because a component idea is divided between courses.
	PE appears in more than one course and it is connected to more than one DCI component idea in the same course.

The assignment of the life science DCIs to Biology is self-evident based on conventional course descriptions, as is the assignment of the earth science DCI component idea *ESS2.E Biogeology*. The component idea of *ESS3.B Natural Hazards* is placed here because it offers an opportunity to examine the impact of earth systems on organisms. Conversely, *ESS3.C Human Impacts* is attached to Biology so students can examine the impact of the human organism on other organisms and earth systems. *ESS1.C History of the Earth* is included because of the interdependent nature of the co-evolution of the earth system and living organisms.

The DCI component idea *ESS3.A Natural Resources* is included in Chemistry because of the important role of many natural resources in chemical reactions that are crucial to modern human society. *ESS3.A Global Climate Change* is connected to Chemistry because many chemical processes drive systems that affect climate. Addressing *ESS2.D Weather and Climate* is then a logical progression once students better understand its driving mechanisms. *ESS2.C Water in Earth's Surface Processes* is included because many of the geological effects of water are a result of its molecular structure and chemical properties.

Forces, interactions, waves and electromagnetic radiation, and energy are historically all components of a Physics course. The DCI component ideas *ESS1.A The Universe and Stars*, and *ESS1.B The Earth and the Solar System* find their home in Physics because of the understanding of motion and forces needed to explain their interactions. Similarly, understanding energy flow and the interactions of forces helps explain the mechanisms described in *ESS2.A Earth Materials and Systems*,” and also in *ESS2.B Plate Tectonics*.

### Refining Course Map 3

Course Map 3 lies in between Course Maps 1 and 2 in terms of the needed refinement. The courses in this map were primarily driven by the domains of science defined in the *Framework*, but it is designed within the constraint of having the courses Physics, Chemistry, and Biology, the Earth and Space Science PEs split between courses. This split of Earth and Space Science PEs needs a close look during refinement to make sure that the PEs has been effectively arranged, that they fit the expectations of the state or local courses. A factor that might affect the decision for splitting up the Earth and Space Science PEs is determining the expected sequence for these courses as the course map doesn't assume the sequence of the courses. Another option would be to include the Earth and Space Science PEs as a separate course. If four courses are required, this variation would still meet the vision of the *Framework* that all PEs are expected for all students. The Course Map Storylines for Course Map 3 provide an excellent resource for both dividing the Earth and Space Science PEs and for thinking deliberately about course sequence. By using this resource it becomes more possible to focus a decision of course sequence on the performance expectations themselves and not just past experience. There is also information in the sequencing of courses for Course Map 1 that is relevant to this decision-making process.

## Steps toward Implementation

### Choosing a Course Map: Factors for Consideration

These course maps are not intended to be end products, rather models of process for mapping performance expectations onto courses and starting points for continued work. They are by no means the only arrangements possible, but are intended to be concrete examples to start conversations about the direction of science education at the building, LEA, and state level. This section highlights some of the factors to consider in making a decision to use one, more than one (at different grade bands), or none of the model course maps presented.

Any course map will have benefits and challenges linked to the underlying assumptions and processes that were involved in making them and to the local situation where they are to be implemented. Of course, “benefits” and “challenges” depend on one’s perspective. For example, something identified as a “challenge” may actually be a primary reason for selecting a model—if the challenge is one that is determined to be in the students’ best interest. For example, if a state education agency already plans a re-design of teacher licensure is needed, then a task that many would consider a challenge may actually be considered a benefit. Likewise, what some may consider a “benefit,” others may see as a reason not to select a course map. Some may consider it a benefit that a particular course map contains courses that are very similar to what is being used currently, but others may see this as more of a challenge as it may be more difficult to ensure a complete and coherent implementation of the *Framework*. The realities and needs in states and LEAs are quite different; therefore, outlined below are factors to consider in deciding how to map the grade-banded performance expectations onto courses for the NGSS.

### Factors for Consideration

#### **1. Are the performance expectations organized in a way to maximize student learning?**

Course Map 1, *Conceptual Understanding*, was the only model that was consciously designed with this in mind. DCI component ideas and their related Performance Expectations are deliberately sequenced to allow students to build their knowledge in a logical progression. This model supports students’ engagement in science and engineering practices and applies crosscutting concepts to deepen students’ understanding of physical science, life science and earth and space science core ideas over multiple years of school (p.8, NRC, 2011). By the end of the 12th grade, students should have gained sufficient knowledge of the practices, crosscutting concepts and core ideas of science and engineering to engage in public discussions on science-related issues, to be critical consumers of scientific information related to their everyday lives, and to continue to learn about science throughout their lives (p.9, NRC, 2011).

This does not mean that, through effective curriculum planning and lesson plan development, the other models course maps couldn’t be developed in a way that would also maximize student learning, but their infrastructure was not designed with this as a focus. With an organizational structure that focuses on the domains of the *Framework* (Course Map 2), or traditional scientific divisions (Course Map 3) it will take

a concerted effort to ensure that there are opportunities to build conceptual knowledge over time, especially for concepts that are cross-disciplinary.

## **2. Are the performance expectations organized in a way that increases efficiency in instruction?**

Among the many recommendations for improving the coherence and effectiveness of the K-12 curriculum, *Designs for Science Literacy*, is a cross-disciplinary organization that eliminates the unnecessary repetition of topics—the same ideas in the same contexts, often with the same activities and the same questions (2001, AAAS). A common student complaint is that the same topics are presented in successive grades, often in the same way. Similarly, a common teacher complaint is that the students did not receive instruction in important topics in prior grades and so these topics now have to be taught in the present grade thus perpetuating an instructional gap for the following grades (2001, AAAS).

In Course Map 1, the thoughtful sequence of DCI component ideas and PEs limits unnecessary repetition while still providing students prerequisite knowledge necessary for success in subsequent science courses. Course Maps 2 and 3 were not designed with this in mind and though the order that courses are sequenced within either model could alleviate some of this, there are performance expectations within every course that expect students to know concepts that are being addressed in other courses. If this is addressed thoughtfully in curriculum design, it could provide opportunity for cross-disciplinary connections, but in terms of instruction efficiency, it does mean that there will be times that teachers will have to allot class time to bring students up to speed on background concepts necessary to get to the concepts intended to be addressed in any given course.

## **3. Are the performance expectations organized in a way that represents the interconnectedness of science?**

The organization of scientific research has become more complex and has evolved from The Committee of Ten's constructs of 1893 which organized K-12 science education around astronomy, meteorology, botany, zoology, physiology, anatomy, hygiene, chemistry and physics. The cross-disciplinary organization of Course Map 1 makes natural connections across the science domains of the *Framework* more evident to teachers and students and provides for more a flexible, coherent and realistic pathway to developing deep understandings of science. Course Maps 2 and 3 were not designed with this in mind, though careful curriculum and lesson plan development could create these connections.

## **4. How does the course map align with current state guidelines/legislation/policies for course titles, course sequences, teacher licensure, credits for graduation, and college admissions expectations?**

States vary in terms of how these policies are created and the processes that are involved in changing them, but these are all important factors for consideration in selecting or developing a course map. For example, some states only require two science credits for graduation, but the NGSS performance

expectations are written for all students and none of the model course maps include fewer than three courses.

### **5. What are the implications for teaching positions?**

Any of the course map models (depending on the current realities of current teacher preparation and licensure policies, current course offerings, graduation requirements, course sequences, etc. and any changes that are proposed) may have a significant impact on the number of teachers prepared to teach courses. This could also be affected by the proposed sequencing of courses in Course Maps 2 and 3. For example, switching from a biology-chemistry-physics sequence in a state where biology is the only “required” science in a sequence of three required for graduation to using Course Map 2 and sequencing courses physical science-life science-earth science will put different demands on the system to provide teachers qualified to teach the courses. This would also potentially impact teacher certification/licensure policies, teacher preparation, and professional learning opportunities.

### **6. How do these course maps affect the focus of pre-service teacher preparation and professional learning opportunities?**

Transitioning from current state science standards to the NGSS provide significant opportunities to support advancing science instruction regardless of the course map that is utilized. Teachers of science will need intensive, ongoing and job-embedded professional development in order for their students to meet the challenges of the performance expectations defined in the NGSS. Teachers will need to wrestle with questions such as:

- What do we want students to learn?
- How will we know what students are learning?
- How will we respond when they do not learn?

The cross-disciplinary approach of Course Map 1 is somewhat different than common current practice in teacher preparation and professional development. Pre-service teachers are less likely to have experienced an explicitly cross-disciplinary course in their own courses, which will mean that those responsible for preparing them to be teachers will have to explicitly incorporate this into teaching and learning experiences. Many teachers already in the field are very passionate about the particular domain that they are teaching. They may have accumulated a significant amount of knowledge of practices and core ideas within a content area and may have less experience outside of their preferred domain. If Course Map 1 is selected, professional learning opportunities will need to be carefully crafted to value this expertise and support teachers in making this transition.

Course Map 2 does not require a specific focus for teacher preparation or professional learning other than those that are called for in transitioning to the NGSS.

Course Map 3 would also require a specific focus in teacher preparation and professional learning opportunities. The incorporation of the Earth and Space Science performance expectations across the biology, chemistry, and physics courses may not align with current practice. Teacher preparation and professional learning opportunities will need to be explicitly designed to support teachers in this transition.

### **7. Does the course map affect any plans for communicating about science education with stakeholders?**

In adopting the NGSS (an assumed step if now choosing a course map of these standards), communication with key stakeholders—students, parents, teachers, administrators, school boards, business and industry, etc.—will be important to support effective implementation. The course map model that is used may require additional specific communication with messaging targeted for stakeholder groups, in particular if the course map is requiring significant system changes.

### **8. How is the course map selected impacted by resource availability?**

There are currently no resources explicitly written for the NGSS, but there will likely be an avalanche of resources that are (or claim to be) in the next few years. As resources are rewritten for the NGSS, they may more frequently be designed with one course map or another in mind, but this may be less of a concern due to more flexible resources such as open education resources and editable digital textbook formats. Current existing resources, such as textbooks, often sort information based on content in a way that is more similar to Course Maps 2 and 3. This may be viewed as an advantage in that there are textbooks that exist that are similar, but it may also be viewed as a disadvantage in that it may discourage teachers from transitioning to the NGSS.

Additional resources include publications such as the Framework for K-12 Science Education and materials posted on the NGSS website.

## Conclusions

It may seem a forgone conclusion that the course map specifically designed to coherently build student conceptual understanding over time, maximize efficient use of class time, and prepare students for the cross-disciplinary reality of science research, but there may be good reasons for choosing a different model (including “none of the above”). Hopefully the factors described above will result in meaningful conversations in states about their science education systems. Adopting the NGSS will require changes in the system in order to implement them in a way that realizes the vision of the *Framework* for our students. It is a great opportunity for deliberate decision-making about the system design and whether or not it is designed in a way that gives students the best opportunities possible to realize this vision. Deciding on a course map is just one of the decisions that is important in this process, but requires careful consideration because of the potential impacts across the system.

## Developing a New Course Map



It might be that none of the course maps presented here meets the needs of your state or LEA. If this is the case, it would definitely make sense to design a course map model of your own rather than simply refining what has been provided. The multi-dimensionality of the NGSS would certainly allow for a course map based on something other than just DCIs—either by one of the other dimensions, or a combination of the three. These and other reasons for developing alternative course map models are certainly valid, but hopefully there is enough in the descriptions above to make this process a bit smoother. Examining the underlying assumptions of these course maps, reviewing the processes that were used to create the course maps provided, and weighing all this with the factors for consideration just described provides a framework to jumpstart the development of new course maps that meet the needs of the students in your local education agency or state.

### Refining a Course Map

Selecting one of the provided course maps does not mean the work is done, but it is the first step in a journey. The course map will need further refinement to meet local needs and then the real work begins to develop curricula and lessons based on the course map. Additionally, as with all scientific endeavors, you will want to plan out how you will determine if your efforts are successful. What types of data will you use to determine whether or not the arrangement “worked?” What processes will be put in place to refine your course map to increase its effectiveness? Even once these questions have been answered, as curriculum units and lesson plans are designed and refined in the classroom, it is likely that further refinement of the course map will be necessary.

Guidance for refining each course map can be found at the end of each of the model descriptions above, but more significant revisions may be in order if the underlying assumptions described in the introduction are not acceptable. For example, if your state requires four courses in science and there is not any intention to change this, then a three course sequence for high school may not be what you need. This may mean that you refine the models as presented—perhaps simply re-sorting PE in Course Map Model 1 into four courses; or using Course Map Model 3 with a separate Earth and Space Science course rather than splitting the Earth and Space Science PEs across biology, chemistry, and physics.

Additional work will also need to be done locally to consider the mathematics that is expected by the performance expectations in both grade bands. As local mathematics courses may differ, especially at the high school level, it will be important to have cross-disciplinary conversations to make sure that students are receiving complimentary instruction across content areas. To facilitate this process, we have included a chart of the performance expectations that explicitly reference mathematics, but the conversations will need to happen at the state and local level to ensure coordination. The connections boxes on the NGSS should also inform this conversation.