Appendix K

Model Course Mapping in Middle and High School for the Next Generation Science Standards

Reaching the Potential:

Mapping out Model Courses for the Next Generation Science Standards

A Framework for K-12 Science Education casts a bold vision for science education, and the resulting Next Generation Science Standards (NGSS) have taken a huge leap toward putting this vision into practice, but there is still work to be done as states contemplate adoption and move toward implementation. This appendix focuses on one aspect of this work – organizing the grade banded performance expectations into courses.

The 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. This arrangement is due to the fact that standards at these levels are handled very differently in different states and because there is not conclusive research that identifies the ideal sequence for student learning.

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. Decisions about this organization are handled differently in different states. Sometimes a decision is prescribed by the state education agency, sometimes by a regional office or a local school district, and other times it falls to the lone grade 6–12 science teacher – who may not only move between two buildings and teach seven different preparations each day, but is also active in school sponsored extracurricular activities – to determine what science gets taught at what level.

Recognizing the many ways that decisions about what to teach when are made, this appendix is provided as a tool for guiding this decision-making process. To realize the vision of the *Framework* and NGSS, courses need to be thoughtfully scaffolded at levels of complexity that are developmentally appropriate for students to build knowledge both within courses and over the sequence of courses. *It is also important to note that these are merely the first of several models that will be developed.* There are also plans in the works to develop accelerated models to propel students toward Advanced Placement courses earlier in their high school careers as well as models that integrate the NGSS and career technical education pathways such as engineering and medicine.

Foundational Understandings for NGSS Model Course Maps:

To use these model course maps effectively, it is absolutely essential to understand the thought processes that were involved in building them. This section outlines the foundational decisions that were made in the development of all the model course maps, and it attempts to clarify the intent for use of the course maps. Each of these six foundational understandings will be more fully explained below; they serve as the basis for effective use of these model course maps.

1. Model Course Maps are starting points, not finished products.

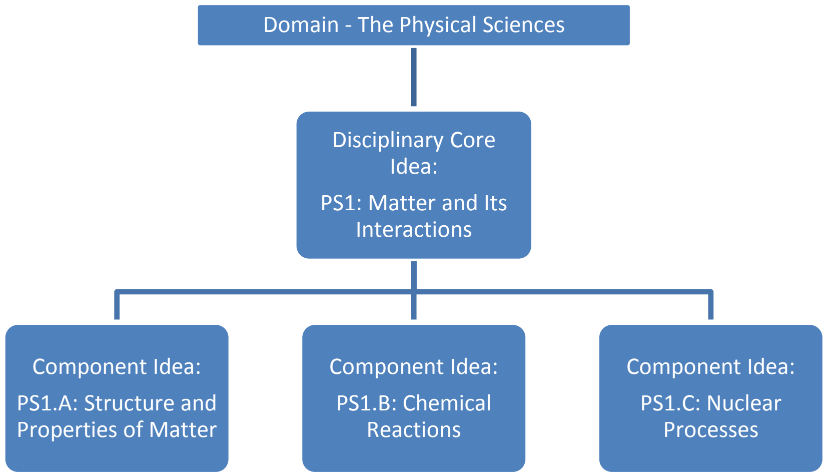
States and districts/local education agencies are not expected to adopt these models; rather, they are encouraged to use them as a starting point for developing their own course descriptions and sequences. The model course maps described here are both models of process for planning courses and sequences *and* models of potential 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. The word "model" is used here as it is in the *Framework* – as a tool for understanding, not necessarily as an ideal state.

2. Model course map organization is built on the structure of the *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. Within each domain, the *Framework* describes how a small set of **disciplinary core ideas** was developed using a set of specific criteria (NRC 2012, p. 31). Each core idea is broken into three or four **component ideas** which provide more organizational development of the core idea. **Figure 1: Physical Science Core Idea (PS1) and Component Ideas** below provides an example how one core idea, Matter and Its Interactions (PS1), includes three component ideas: PS1.A: Structure and Properties of Matter, PS1.B: Chemical Reactions, and PS1.C: Nuclear Processes.

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

This in an example from the *Framework* organization to demonstrate the relationship between "domains," "disciplinary core ideas," and "component ideas."



Though the disciplinary core ideas were used as a starting point for building these model course maps, it will be important for coordinated learning that the other dimensions of the *Framework* – Scientific and Engineering Practices and Crosscutting Concepts – be woven together in instruction (see #5 below). Curriculum designers should consult the *Framework* and the NGSS appendices for progressions of learning for Scientific and Engineering Practices and Crosscutting Concepts.

3. "All Standards, All Students."

All the standards are expected of all students. Though this is a foundational commitment of the *Framework* and is discussed at length in Appendix D of NGSS, it bears repeating here due to its implications for course design. This approach is much more than just a way to refute the common notion that learning physics is only for students in advanced math, or that taking Earth and Space Science is only for students who are not on the college track. All standards, all students.

For the 6–8 grade band, this clearly indicates that all of the grade banded standards should be addressed within the three-year span, and the flexibility of the high school science course sequence with required courses and elective courses provides a challenge to ensure that all students are prepared to demonstrate all of the performance expectations. The model course maps for the 9–12 grade band are all organized into three courses. This decision was made by balancing the "All Standards, All Students" vision with the reality of the finite amount of time in a school year. 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 that would enhance their preparation. It should be noted here, however, that an extensive review of the NGSS by college professors of first year science courses determined that the content in the NGSS would adequately prepare students to be college- and career-ready in science (see Appendix C).

Furthermore, it should also be noted that there is no set amount of time assigned to these courses. Although traditionally these would be considered year-long courses, there is nothing in these models that requires that a course fit into a set amount of time – they could be spread over a longer time than three years, extended to meet student needs, or accelerated. Some modes and settings of instruction-- such as proficiency or mastery-based learning, online learning, or alternative learning centers--may even find that structures other than courses are better fits for their situation. Even in these situations, the model course maps and the processes used in their development can help guide curriculum development.

4. Model Course Maps are NOT curriculum.

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

5. All Scientific and Engineering Practices and all Crosscutting Concepts in all courses.

It is the expectation of all the model course maps that *all* Scientific 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 the ones that are outlined in the performance expectations. The goal is not to teach the PEs, but rather to prepare students to be able to perform them by the end of the grade band course sequence. The PEs are written as grade band endpoints. Even though a particular performance expectation is placed "in a course," it may not be possible to address the depth of the expectation in its entirety within that course. It may, for example, take repeated exposure to a particular SEP over several courses before a student can achieve the proficiency expected in a given performance expectation, but by the end of the grade band, the student should be prepared to demonstrate each performance expectation as written.

6. Engineering for all.

As is more carefully detailed in Appendix I, NGSS represent a commitment to integrate engineering design into the structure of science education by raising engineering design to the same level as scientific inquiry when teaching science disciplines at all levels, from kindergarten to grade 12. Engineering standards have been integrated throughout the science domains of physical science, life science, and earth and space science. NGSS also includes PEs that focus explicitly on engineering design without a science domain context. Within the range affected by these model course maps, there are four engineering design PEs in the 6–8 grade band and four in the 9–12 grade band. All of the model course maps place the stand-alone engineering PEs with all courses as they help to organize and drive the instruction of the integrated engineering PEs within each course.

Model Course Maps:

Three model course maps are included as concrete examples to begin conversations about realizing the vision of the *Framework* and NGSS. If you skipped to this section without reading the section titled Foundational Understandings for NGSS Model Course Maps, please go back and read that section as it informs everything that follows.

Including the three options presented in this section *does not preclude other organizational sequences*. As states, districts, and teachers engage in conversations about the strengths and weaknesses of the model course maps that are presented here, it is expected that a wider variety of course maps will be collaboratively developed and shared. For example, a curricular and instructional program could be built around the National Academy of Engineering's 21st Century Grand Engineering Challenges; around a community-based theme that runs through all the courses and connects the performance expectations to science, engineering and technology used in everyday life; or around a focus on the *Framework*'s Crosscutting Concepts or Scientific and Engineering Practices instead of the Disciplinary Core Ideas. Furthermore, as was mentioned above, even the term "courses" may be an unnecessarily limiting definition that privileges a time-based system. Some teachers, schools, districts and states are moving toward a proficiency-based system, but even in such a situation these model course maps can help guide conversations about the connections between performance expectations and how to begin moving from standards to instruction focused on NGSS student performance/outcomes.

After the following list, details about each model course map, how it was developed, and ideas for next steps will be shared.

1. **Conceptual Progressions Model** (grades 6–8 and 9–12) – The grade banded 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** (grades 6–8 and 9–12) – The grade banded PEs are organized into content-specific courses that match the three science domains of the *Framework*: Physical Science, Life Science, and Earth and Space Science. Since the Engineering domain is mostly integrated into the other three disciplines in the NGSS, it was integrated in these course models rather than presented as a separate course in this sequence. (The four stand-alone engineering PEs in each of the grade bands are connected to all three courses at both levels.)
3. **Modified Science Domains Model** (grades 9–12) – The 9–12 grade band performance expectations are organized into content-specific courses that match a common high school course sequence of biology, chemistry, and physics. To ensure all students have access to all standards, the PEs connected to the Earth and Space Science domain of the *Framework* are divided among these courses. It was included as a model for comparison because it is currently a common sequence in high schools across the United States.

Course Map 1 – Conceptual Understanding Model (grades 6–8 and 9–12)

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

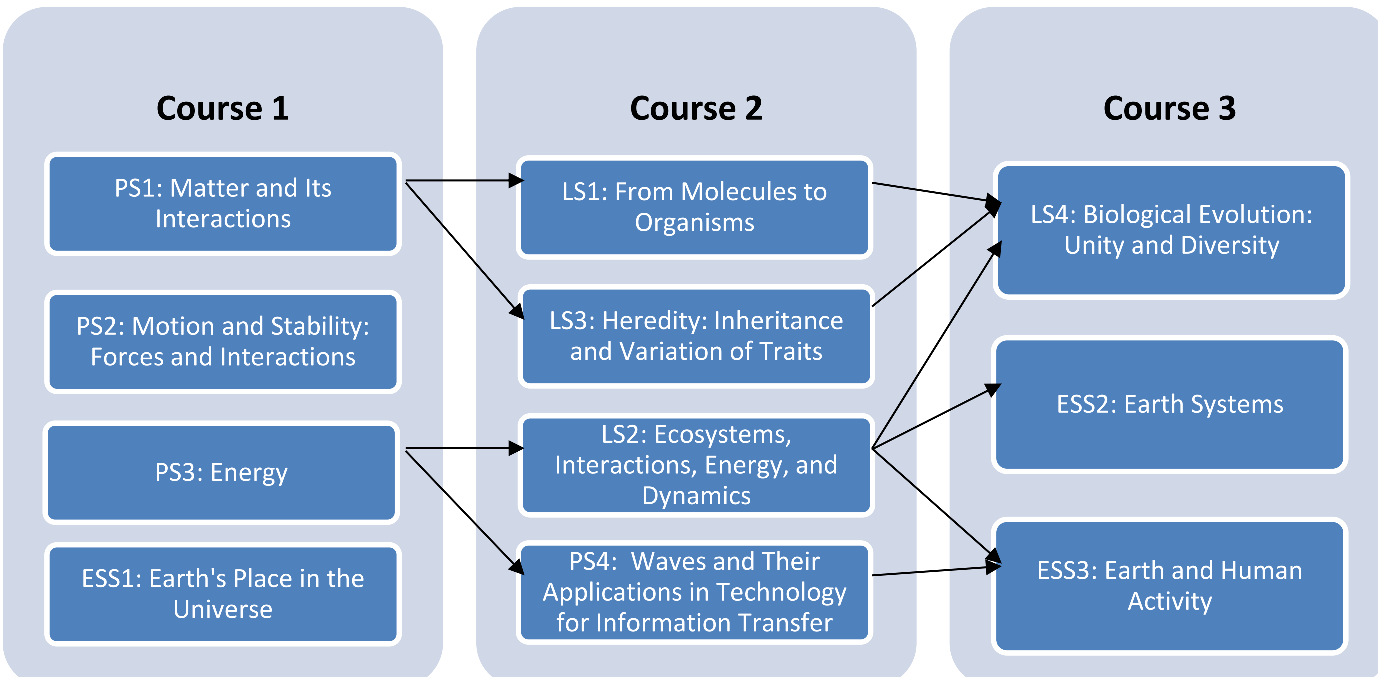
This model course map arranges PEs so that the component ideas of the Disciplinary Core Ideas (DCIs) progressively build with each course upon the skills and knowledge described in preceding courses. The fifth of the six Fundamental Understandings for Using Model Course Maps (pg 2) includes the idea that although all three dimensions described in the *Framework* are specifically integrated within the grade band endpoints, curriculum and instruction will provide students with opportunities to learn the components of the dimensions in a variety of ways to prepare them to perform these endpoints. Students should have multiple opportunities to engage all of the Scientific and Engineering Practices and Crosscutting Concepts in each course. The premise of this Model Course Map 1, however, is that the DCIs *do* contain content that can be logically sequenced. Creating a logical sequence for the DCI portion of the performance expectations for this model course map was a multi-stage effort that relied heavily on the *Framework*.

> *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. This sense of development has been conceptualized in the idea of learning progressions. 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 2012, p. 26).*

The first step in this process was separating the core ideas based on their reliance on other core ideas. For example, it is clear just from the titles of the core ideas that to learn about *LS1: From Molecules To Organisms: Structures And Processes*, a student would benefit from an understanding of core idea *PS1: Matter and its Interactions*. Knowing about atoms, molecules, and how they interact should enhance the student's understanding of how molecules operate in living organisms. This would put core idea PS1 in a course before core idea LS1. Just looking at the titles of the core ideas, however, is not enough to understand the full scope of what content is included in a core idea. Ordering core ideas for this model course map was done by thoroughly comparing the descriptions for each core idea in the *Framework*. Any core ideas that did not have significant reliance upon the content in other core ideas were placed in the first course. Core ideas that required 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. The resulting skeletal sequence based on disciplinary core ideas is shown in **Figure 2**. As was discussed in the sixth foundational understanding for all model course maps, there are four PEs in each grade band that focus exclusively on engineering design. Though these PEs are not represented in the chart below, the stand-alone engineering PEs are included in all three courses, as they should help organize and drive the instruction of the integrated engineering PEs in all three courses and they will appear in subsequent tables.

Figure 2: Organization of Disciplinary Core Ideas for Course Map 1

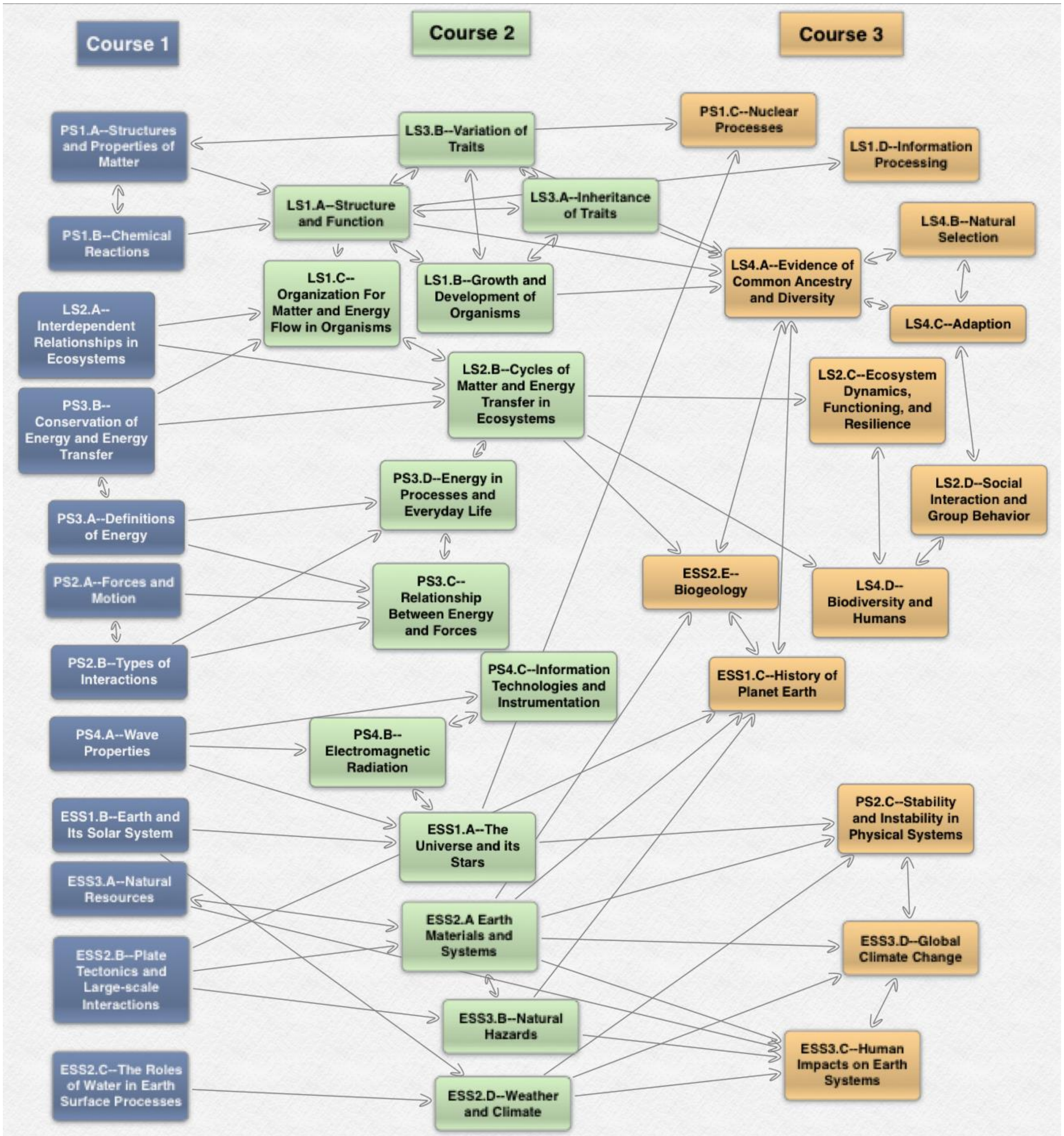
The figure below outlines the first step of organizing the NGSS into courses based on a conceptual progression of the science content outlined in the Disciplinary Core Ideas of the *Framework*.



Sorting core ideas is a step in the direction of course mapping, but it is at far too big of a grain size to be useful for curriculum development. To get closer to a usable grain size, the core ideas were reanalyzed by splitting each one into its component ideas (identified in the *Framework*) and again sorting them into courses to refine their positioning. Essentially, the process used for sorting the DCIs was repeated, but the component ideas disconnected from the core idea and, when appropriate, moved to a different course in the map based on the grade band endpoint descriptions in the *Framework*. For example, although *PS1: Matter and Its Interactions* was originally placed in the first course, its component idea *PS1.C: Nuclear Processes* requires content in both courses one and two, so it was shifted to course three. *PS1.A: Structures and Properties of Matter* and *PS1.B: Chemical Reactions* remained in course one because they do not require content from other component ideas. **Figure 3** shows the end result of reassigning component ideas to courses. Since this organization is based on the *Framework*, it works for both the 6–8 and 9–12 grade bands.

Figure 3: Component idea organization for Model Course Map 1

The diagram below outlines the second step of mapping the NGSS into courses – refining the arrangement seen in Figure 2 by evaluating the Disciplinary Core Ideas at the finer grain size of the component ideas that they are made of. The arrows illustrate the connections that were used to sort the component ideas into courses, not to determine an order for curriculum.



The final step in the process of building Model Course Map 1 was to reevaluate the organization at the level of the performance expectations themselves. The tables below outline the first step in this process – connecting the component ideas with their PEs. These tables were built using the information in the NGSS foundation boxes which documents the connections between the PEs and each component idea. Due to the overlapping nature of the content in the component ideas, some PEs are linked to more than one component idea. In these cases, PEs are only listed once in the top section of the table. PE repeats – PEs that are connected to more than one component idea within a course, or between courses – and secondary connections are identified in the bottom section of each table.

Table 1: Conceptual Progressions Model Course Map – Middle School

The table below connects the middle school NGSS performance expectations to the component ideas from the *Framework*. These connections are based on the information in the NGSS foundation boxes. In this table, the component ideas are arranged into courses based on the organization shown in Figure 3.

COURSE 1

PS1.A	MS-PS1-1 .
	MS-PS1-2 .
	MS-PS1-3 .
	MS-PS1-4
PS1.B	MS-PS1-5.
	MS-PS1-6.
PS2.A	MS-PS2-1.
	MS-PS2-2.
PS2.B	MS-PS2-3.
	MS-PS2-4.
	MS-PS2-5.
PS3.A	MS-PS3-1.
	MS-PS3-2.
	MS-PS3-3.
	MS-PS3-4.
PS3.B	MS-PS3-5.
PS4.A	MS-PS4-1.
	MS-PS4-2.
LS2.A	MS-LS2-1.
	MS-LS2-2.
ESS1.B	MS-ESS1-1.
	MS-ESS1-2.
	MS-ESS1-3.
ESS2.B	MS-ESS2-3.
ESS2.C	MS-ESS2-2.
	MS-ESS2-4.
	MS-ESS2-5.
	MS-ESS2-6.
ESS3.A	MS-ESS3-1.
ETS1.A	MS-ETS1-1.
ETS1.B	MS-ETS1-2.
	MS-ETS1-3.
	MS-ETS1-4.
ETS1.C	MS-ETS1-3.
	MS-ETS1-4.

COURSE 1 Repeats

PS1.B	MS-PS1-2.
	MS-PS1-3.
PS3.A	*MS-PS1-4.*
PS3.B	MS-PS3-3.
	MS-PS3-4.

COURSE 2

PS4.C	MS-PS4-3.
LS1.A	MS-LS1-1.
	MS-LS1-2.
	MS-LS1-3.
LS1.B	MS-LS1-4.
	MS-LS1-5.
LS1.C	MS-LS1-6.
	MS-LS1-7.
LS2.B	MS-LS2-3.
LS3.A	MS-LS3-1.
	MS-LS3-2.
ESS2.A	MS-ESS2-1.
ESS2.D	MS-ESS2-5.
	MS-ESS2-6.
ESS3.B	MS-ESS3-2.

COURSE 2 repeats

PS3.C	MS-PS3-2.
PS3.D	*MS-LS1-6.*
	MS-LS1-7.
PS4.B	MS-PS4-2.
LS1.B	*MS-LS3-2.*
LS3.B	MS-LS3-1.
	MS-LS3-2.
ESS1.A	MS-ESS1-1.
	MS-ESS1-2.
ESS2.A	MS-ESS2-2.
ETS1.A	MS-ETS1-1.
ETS1.B	MS-ETS1-2.
	MS-ETS1-3.
	MS-ETS1-4.
ETS1.C	MS-ETS1-3.
	MS-ETS1-4.

COURSE 3

LS1.D	MS-LS1-8.
LS2.C	MS-LS2-4.
	MS-LS2-5.
LS4.A	MS-LS4-1.
	MS-LS4-2.
	MS-LS4-3.
LS4.B	MS-LS4-4.
	MS-LS4-5.
LS4.C	MS-LS4-6.
ESS1.C	MS-ESS1-4.
ESS3.C	MS-ESS3-3.
	MS-ESS3-4.
ESS3.D	MS-ESS3-5.

COURSE 3 Repeats

LS4.D	*MS-LS2-5.*
ESS1.C	*MS-ESS2-3.*
ESS2.D	MS-ESS2-5.
	MS-ESS2-6.
ETS1.A	MS-ETS1-1.
ETS1.B	MS-ETS1-2.
	MS-ETS1-3.
	MS-ETS1-4.
ETS1.C	MS-ETS1-3.
	MS-ETS1-4.

Key to Highlighting
PE appears in two DCIs within the same course
PE is identified in NGSS as a secondary connection to this component idea
PE connected to two component ideas between two courses

Table 2: Conceptual Progression Model Course Map – High School

The table below connects the high school NGSS performance expectations to the component ideas from the *Framework* that they were based on. These connections are based on the information in the NGSS foundation boxes. In this table, the component ideas are arranged into courses based on the organization shown in Figure 3.

COURSE 1

PS1.A	HS-PS1-1.
	HS-PS1-2.
	HS-PS1-3.
	HS-PS1-4.
PS1.B	HS-PS1-5.
	HS-PS1-6.
	HS-PS1-7.
PS2.A	HS-PS2-1.
	HS-PS2-2.
	HS-PS2-3.
PS2.B	HS-PS2-4.
	HS-PS2-5.
	HS-PS2-6.
PS3.A	HS-PS3-2.
	HS-PS3-3.
PS3.B	HS-PS3-1.
	HS-PS3-4.
PS4.A	HS-PS4-1.
	HS-PS4-2.
	HS-PS4-3.
	HS-PS4-5.
LS2.A	HS-LS2-1.
	HS-LS2-2.
ESS1.B	HS-ESS1-4.
ESS2.B	HS-ESS2-1.
	HS-ESS2-3.
ESS2.C	HS-ESS2-5.
ESS3.A	HS-ESS3-2.
ETS1.A	HS-ETS1-1
ETS1.B	HS-ETS1-3
	HS-ETS1-4
ETS1.C	HS-ETS1-2

COURSE 1 Repeats

PS1.B	HS-PS1-2.
	HS-PS1-4.
PS2.B	*HS-PS1-1.*
	HS-PS1-3.
PS3.A	*HS-PS2-5.*
PS3.B	HS-PS3-1.
PS4.A	*HS-ESS2-3.*
ESS1.B	*HS-ESS2-4.*
ESS2.B	*HS-ESS1-5.*

COURSE 2

PS3.C	HS-PS3-5.
PS4.B	HS-PS4-4.
LS1.A	HS-LS1-1.
	HS-LS1-2.
	HS-LS1-3.
LS1.B	HS-LS1-4.
LS1.C	HS-LS1-5.
	HS-LS1-6.
	HS-LS1-7.
LS2.B	HS-LS2-3.
	HS-LS2-4.
	HS-LS2-5.
LS3.A	HS-LS3-1.
LS3.B	HS-LS3-2.
	HS-LS3-3.
ESS1.A	HS-ESS1-1.
	HS-ESS1-2.
	HS-ESS1-3.
ESS2.A	HS-ESS2-1.
	HS-ESS2-2.
	HS-ESS2-3.
	HS-ESS2-4.
ESS2.D	HS-ESS2-6.
ESS3.B	HS-ESS3-1.

COURSE 2 Repeats

PS3.D	HS-PS3-3.
	HS-PS3-4.
	HS-PS4-5.
	HS-LS2-5.
	HS-ESS1-1.
PS4.B	HS-PS4-3.
	HS-PS4-5.
	HS-ESS1-2.
PS4.C	HS-PS4-5.
ESS2.A	HS-ESS2-1.
	HS-ESS2-3.
ETS1.A	HS-ETS1-1
ETS1.B	HS-ETS1-3
	HS-ETS1-4
ETS1.C	HS-ETS1-2

COURSE 3

PS1.C	HS-PS1-8.
LS2.C	HS-LS2-6.
	HS-LS2-7.
LS2.D	HS-LS2-8.
LS4.A	HS-LS4-1.
LS4.B	HS-LS4-2.
	HS-LS4-3.
LS4.C	HS-LS4-4.
	HS-LS4-5.
LS4.D	HS-LS4-6.
ESS1.C	HS-ESS1-5.
	HS-ESS1-6.
ESS2.E	HS-ESS2-7.
ESS3.C	HS-ESS3-3.
	HS-ESS3-4.
ESS3.D	HS-ESS3-5.
	HS-ESS3-6.

COURSE 3 Repeats

PS1.C	*HS-ESS1-5.*
	HS-ESS1-6.
LS2.C	HS-LS2-2.
LS4.C	HS-LS4-2.
	HS-LS4-3.
	HS-LS4-6.
ESS2.D	HS-ESS2-4.
	HS-ESS2-7.
	HS-ESS3-6.
ESS3.A	HS-ESS3-1.
ETS1.A	HS-ETS1-1
ETS1.B	HS-ETS1-3
	HS-ETS1-4
ETS1.C	HS-ETS1-2

Key to Highlighting
PE appears in two DCIs within the same course
PE is identified in NGSS as a secondary connection to this component idea
PE connected to two component ideas between two courses

Next Steps for Course Map 1

It should be clear at this point that this course map will need revision as curricula are developed, but this arrangement should give a good starting point for conversations about what is taught when and why. To help guide these conversations, here are several recommendations and steps that states or districts should consider as they work from this starting point toward developing curricula and instructional unit plans:

1. Revisit the suggested arrangements 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 up with a different arrangement than what is presented here, but collaboratively engaging a broad group of teachers and administrators in this process results in courses that work for schools, teachers, and students and offers greater buy-in for implementation.

2. As performance expectations are bundled into curriculum units and lesson plans, it is important to balance this structured arrangement of PEs with creating courses and units that flow well and engage students in learning. Use the final PE arrangement that you develop (or the one provided by Model Course Map 1) as a *starting point* for building instructional units. As you bundle the student outcomes described in the performance expectations into meaningful units to build the flow within and between courses, PEs may well be pulled from different courses in the map to make this happen. The course map is there to make sure that when you move PEs from one course to another, you adjust instruction accordingly; it is not meant to be a prescriptive, static document. For example, you may decide to connect HS-ESS2-3 ("Develop a model based on evidence of Earth's interior to describe the cycling of matter by thermal convection.") and HS-PS3-2 ("Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as either motions of particles or energy stored in fields.") from Course 1 with HS-PS3-3 from Course 2 ("Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.[*]) in an instructional unit that has students engaging in argumentation about sources of energy (gas, electric, geothermal, solar, etc.) for heating and cooling homes as a part of Course 1.

3. As PEs are bundled into instructional units and these units are tied together into courses, units may need to be moved from one course to another to make sure that courses are balanced. This doesn't necessarily mean that the courses have the same number of PEs. Curriculum units with fewer PEs may take longer than those with more PEs depending on how those PEs are addressed in the lesson plans. It is recommended to pay particular attention to the repeat PEs listed in the tables in this process. PEs that are connected to more than one component idea may bundle better with PEs in just one course rather than being represented in two courses.

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* The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice or Disciplinary Core Idea.

4. While rearranging PEs and building instructional units, remember that the performance expectations are *grade banded* student outcomes and map out student course expectations appropriately. It may be that, though a PE is placed in a course, a student may not be ready to perform all aspects of that PE by the end of the course. For example, a PE may be placed in the first course because the DCI dimension is determined to be foundational to a PE in the second course, but the depth of the Scientific and Engineering Practice described in 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. In other words, though the expectation is that all Scientific and Engineering Practices will be in all courses, it would make sense for students in sixth grade to engage differently from those in eighth grade; one needs to deliberately build complexity of practices over the middle school sequence. Model Course Map 1 attempts to organize PEs in a way that scaffolds the content from course to course, but as these are rearranged for curriculum development, it may be that some core ideas in performance expectations may need scaffolding within a course to prepare students to learn the content.

5. The math and English Language Arts NGSS connections boxes and their supporting appendices (Math – Appendix L; ELA – Appendix M) should be consulted to make sure that courses are not expecting math or ELA content or practices before they are expected in the science sequence. At the high school level, the Common Core also has grade banded expectations, so this discussion will need to occur at the state, district, and building level to make sure that the course map for science does not demand math and ELA performances before they are expected in those curricula. At the middle school level, there are two performance expectations (MS-PS3-1 and MS-PS4-1) that are presented in the course map before they are expected in the Common Core. This issue is addressed at length in the Middle School Revision below.

6. It also may be determined that getting all students prepared for all PEs requires more than three courses at the high school level. Organizing the standards into four science courses would simply mean repeating the 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 for all students. Alternatively, some education systems – especially those heading toward a proficiency-based system – could address some of the PEs in other course structures such as Career and Technical Education, agriculture education, elective science courses, integrated mathematics or STEM courses, alternative education or online modules.

Next Steps Example: Middle School Revision

With work left to do on these models, it might seem overwhelming and difficult to move forward, so this section provides an example of the types of decisions that might be made to move a revision forward. In this case, the focus is on revising the Conceptual Progressions Course Map described in **Table 1**. This revision pulls from several of the suggested next steps described above to provide an example of a result of this revision process.

> Unsure about whether or not the Conceptual Progressions Model Course Map would work in their middle school, John, Deb, and Carmen – the only 6th, 7th, and 8th grade science teachers for Randolph Middle School – decide to dig into the middle school course map and see how it looks after they do a bit of re-arranging. In a local option state that has recently adopted NGSS, the decision for what will happen with the grade-banded middle and high school standards ends up at the district level and John, Deb, and Carmen are the district's middle school teachers. They had been teaching middle school science courses that were discipline specific as John likes biology, Carmen likes physical science, and Deb has always enjoyed Earth and Space Science. But following a recent K–12 district science meeting in which they took a stab at sorting the disciplinary core ideas into courses, both the middle and high school teachers walked out seriously considering using Model Course Map 1. At their next in-service day, John, Deb, and Carmen were able to schedule a half-day to work on what their courses might look like next year.
>
> Not sure where to start, Deb suggests starting with the next steps section for Model Course Map 1 to see if any of the suggestions can get them started. After reading through the steps, the group decides that they still don't have a good sense of what this course map might look like in the classroom, so their starting point is to look for related component ideas that could be bundled together for coordinated instruction. Maybe by looking for related performance expectations and organizing them into units of instruction, they'll get a better sense of what it would mean to teach more interdisciplinary courses. In performing this analysis, they noticed that several component ideas only had a few PEs and they didn't seem to relate too closely to the other component ideas in that course. Whenever they found what they started calling "orphan PEs," the component idea and attached PEs were moved to a course that had related ideas, as long as this repositioning did not alter the concept flow. For example, John noticed that *LS2.B Cycles of Energy and Matter Transfer in Ecosystems* in Course 2 had only one PE directly linked to it (see Table 1). Though there were other life science PEs in Course 2, Carmen suggested that they move *LS2.B* and its orphan PE to Course 1 because it would bundle nicely with *LS2.A Interdependent Relationships in Ecosystems.* John was initially unsure about moving the component idea to another course since it also had some connection to component ideas in course two until Deb pointed out that LS2.A (and its two PEs) was the only life science PE in Course 1 and adding another life science PE not only found a home for the orphan PE, but also made course 1 more coherent. They quickly reviewed the math and ELA connections and didn't discover a reason not to move this component idea to Course 1 at the middle school level. A similar line of logic led the group to move *ESS2.D*

Weather and Climate from Course 2 to Course 1– there was only one PE connected to the component idea and a closer examination of the PEs revealed that it bundled well with *ESS1.A Universe and its Stars* and *ESS2.C The Roles of Water in Earth Surface Processes*.

As they were more closely examining the PEs (their previous work was with the *Framework)* they had some concerns that some PEs were not in the right course based on the cognitive complexity they demanded. Sometimes the aspect of the component idea emphasized in a PE at the middle school level seemed different than what they remembered from conversations with their high school colleagues at the K–12 district meeting. For example, at the middle school level, *ESS1.A Universe and its Stars* focuses on the motions of the solar system. Deb suggested that they move this component idea to Course 1 because it fits well with component idea *ESS1.B Earth and its Solar System*. (At the high school level, *ESS1.A* includes ideas about the Big Bang theory – a better fit with *PS4.B Electromagnetic Radiation* in Course 2). By comparing **Table 1** and **Table 2**, John picked up on another difference between middle school and high school – several component ideas do not have PEs at the middle school level, so they eliminated the following component ideas from their middle school course map: *PS1.C Nuclear Processes, LS2.D Social Interaction and Group Behavior, ESS2.E Biogeology,* and *PS2.C Stability and Instability in Physical Systems* – all of which were placed in Course 3 in the original component idea organization.

Having moved several component ideas from Course 2 to Course 1 and having just eliminated a number of component ideas from Course 3, the group had a growing concern about courses becoming unbalanced, so they changed their approach and each of them looked at their content area specialties for component ideas that might be a good fit to move. Deb nominated *PS3.B Conservation of Energy and Energy Transfer* as a good candidate to move from Course 1 to Course 2. She explained that there was only one PE unique to this component idea and it had good connections with other chemistry PEs in the second course--*PS3.B* was moved to the second course. John suggested moving *LS3.A Inheritance of Traits* and *LS3.B Variation of Traits* to Course 3 – both PEs tie in well with the LS4 component ideas that focus on natural selection and evolution – and Carmen proposed moving *ESS3.A Natural Resources* to Course 3 as well because it fits together well with the PEs from *ESS3.A Natural Hazards* and *ESS1.C History of Planet Earth*.

Feeling like they were getting close to something that might work, the group turned their thoughts to what they could make work in their building. They realized that, with the room arrangement at the school and the differences in schedule between 6th and 7th grade, it simply wouldn't work to have *PS1.B Chemical Reactions* at the 6th grade level. They just didn't have the chemistry lab space, safety equipment and supplies available to make it happen. They decided that advocating for any big changes in room arrangements or schedules wasn't where they wanted to spend their energy, and they moved *PS1.B* to Course 2. In looking closely at *PS1.B*, Carmen also noticed that there a couple PEs that were connected to both *PS1.A* (still in Course 1) and *PS1.B* (now in Course 2). Rather than having these PEs listed in both courses, the group decided that they would evaluate MS-PS1-2 and MS-PS1-3 to determine which course was better for them to bundle with other PEs. After comparing the PEs, they decided to list MS-PS1-2 with *PS1.B* in Course 2 and MS-PS1-3 with *PS1.A* in Course 1.

Feeling now like they had arranged the science in a conceptual progression that could work for their school, the group decided to do a double check to make sure that the model course map they had just developed wasn't requiring mathematics before students were expected to be prepared to learn them in their math courses. By examining the NGSS mathematics connections boxes and Appendix L: Connections to CCSS-Mathematics, it became apparent that a couple PEs needed to be reconsidered. MS-PS3-1 – *Construct and interpret graphical displays of data to describe the relationships of kinetic energy to the mass of an object and to the speed of an object* – was of concern because the concept of squares (as would be found in the graphical analysis of kinetic energy) and the graphical analysis of lines are not expected until the eighth grade in the Common Core State Standards. In their current arrangement (and the one listed above in **Table 1**), this PE (which is connected to component idea *PS3.A Definitions of Energy*) was placed in Course 1. Rather than moving this isolated PE to the third course, the group decided to move the entire component idea to course 3 (where it is in **Figure 4**), but they were a little concerned how it would fit in this course. They decided they wanted to talk with their math teachers about maybe developing a cross-disciplinary unit. If the math teachers were willing, they would leave the concept of kinetic energy in Course 1 where it bundles well with related PEs, but then collaboratively develop a unit for 8th grade where the math teachers would build on this conceptual foundation by using the science concept of kinetic energy as a context for teaching about squares and graphical analysis. Then when these students reached the 8th grade, the science teachers would loan some equipment (and a bit of science knowledge) to the math teachers so that they could actually collect data in their math class and use the analysis of this data to teach the mathematics components of the PE – preparing the students to be able to perform the PE by the end of the grade band. MS-PS4-1 – *Use mathematical representations to describe a simple model for waves that includes how the amplitude of a wave is related to the energy in a wave* – requires math that wouldn't be expected until the seventh grade and this PE was also housed in Course 1. In this case, it was decided to move the PE to the second course. There it bundles nicely with the component ideas *PS4.B Electromagnetic Radiation* and *PS4.C Information Technologies & Instrumentation*.

John, Deb, and Carmen's revisions described here are by no means exhaustive – more could be done along these same lines to truly adapt this model course map to local realities and the decisions that they have made may not fit another's reality – but continuing to engage in similar processes and collaborating on course map development within and between schools, districts, and states along with continued research on the relative effectiveness of the implementation of different course maps will better inform the next round of standards revision.

The revised middle school course map showing all of these changes can be found below in **Figure 4**, a component idea concept map, and also in **Table 3**.

Figure 4: REVISED Component idea organization for Model Course Map 1 – Middle School

The diagram below outlines the result of the refining the arrangement seen in Figure 3 using the process described in the Next Steps Example: Middle School Revision.

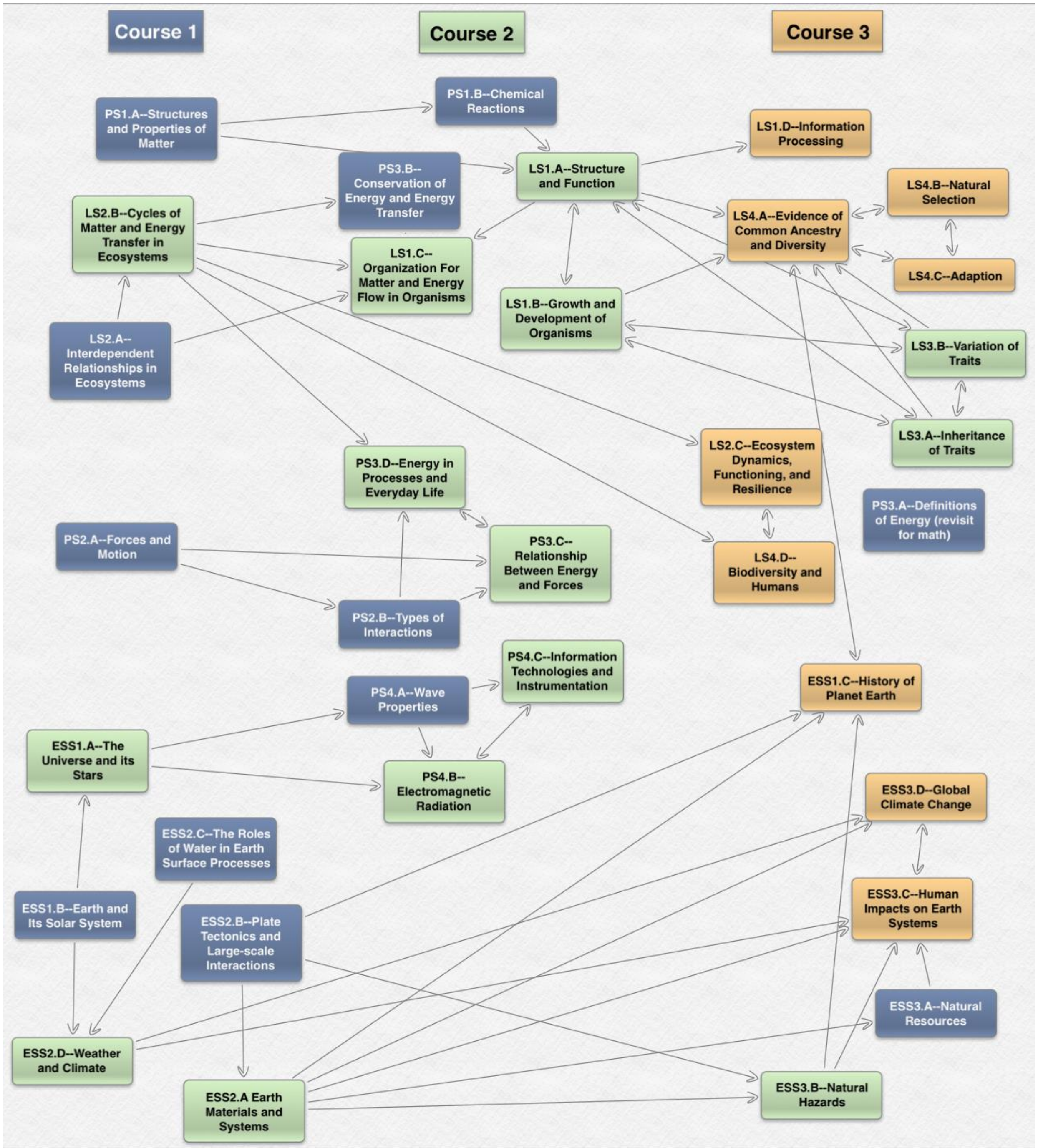

Table 3: REVISED Conceptual Progressions Model Course Map – Middle School

The table below connects the middle school NGSS performance expectations to the component ideas from the *Framework*. These connections are taken from the information in the NGSS foundation boxes. In this table, the component ideas are arranged into courses based on the revised organization described above and shown in Figure 4.

Course 1

PS1.A	MS-PS1-1.
	MS-PS1-3.
	MS-PS1-4.
PS2.A	MS-PS2-1.
	MS-PS2-2.
LS2.A	MS-LS2-1.
	MS-LS2-2.
LS2.B	MS-LS2-3.
ESS1.A	MS-ESS1-1.
	MS-ESS1-2.
ESS1.B	MS-ESS1-3.
ESS2.A	MS-ESS2-1.
	MS-ESS2-2.
ESS2.B	MS-ESS2-3.
ESS2.C	MS-ESS2-4.
ESS2.C	MS-ESS2-5.
	MS-ESS2-6.
ETS1.A	MS-ETS1-1.
ETS1.B	MS-ETS1-2.
	MS-ETS1-3.
	MS-ETS1-4.
ETS1.C	MS-ETS1-3.
	MS-ETS1-4.

COURSE 1 Repeats

ESS1.B	MS-ESS1-1.
	MS-ESS1-2.
ESS2.C	MS-ESS2-2.
ESS2.D	MS-ESS2-5.
	MS-ESS2-6.

Course 2

PS1.B	MS-PS1-2.
	MS-PS1-5.
	MS-PS1-6.
PS2.B	MS-PS2-3.
	MS-PS2-4.
	MS-PS2-5.
PS3.B	MS-PS3-3.
	MS-PS3-4.
	MS-PS3-5.
PS3.C	MS-PS3-2.
PS4.A	MS-PS4-1.
	MS-PS4-2.
PS4.C	MS-PS4-3.
LS1.A	MS-LS1-1.
	MS-LS1-2.
	MS-LS1-3.
LS1.B	MS-LS1-4.
	MS-LS1-5.
LS1.C	MS-LS1-6.
	MS-LS1-7.

COURSE 2 repeats

PS3.D	*MS-LS1-6.*
	MS-LS1-7.
PS4.B	MS-PS4-2.
LS1.B	*MS-LS3-2.*
ETS1.A	MS-ETS1-1.
ETS1.B	MS-ETS1-2.
	MS-ETS1-3.
	MS-ETS1-4.
ETS1.C	MS-ETS1-3.
	MS-ETS1-4.

Course 3

PS3.A	MS-PS3-1.
LS1.D	MS-LS1-8.
LS2.C	MS-LS2-4.
	MS-LS2-5.
LS3.A	MS-LS3-1.
	MS-LS3-2.
LS4.A	MS-LS4-1.
	MS-LS4-2.
	MS-LS4-3.
LS4.B	MS-LS4-4.
	MS-LS4-5.
LS4.C	MS-LS4-6.
ESS1.C	MS-ESS1-4.
ESS3.A	MS-ESS3-1.
ESS3.B	MS-ESS3-2.
ESS3.C	MS-ESS3-3.
	MS-ESS3-4.
ESS3.D	MS-ESS3-5.

COURSE 3 Repeats

PS3.A	MS-PS3-2.
	MS-PS3-3.
	MS-PS3-4.
	MS-PS1-4.
LS3.B	MS-LS3-1.
	MS-LS3-2.
LS4.D	*MS-LS2-5.*
ESS1.C	*MS-ESS2-3.*
ETS1.A	MS-ETS1-1.
ETS1.B	MS-ETS1-2.
	MS-ETS1-3.
	MS-ETS1-4.
ETS1.C	MS-ETS1-3.
	MS-ETS1-4.

Key to Highlighting
PE appears in two DCIs within the same course
PE is identified in NGSS as a secondary connection to this
PE connected to two component ideas between two courses

Next Steps Example: Middle School Revision 2, State Specific Model

As mentioned in the introductory section, the middle school and high school standards are grade banded due to the fact that standards at these levels are handled differently in different states. As states move forward toward adoption these models should be referenced for guidance on how to arrange the performance expectations. States are encouraged to edit the sample models and turn them into state specific models to reflect an organization that works best for the state. There are many unique factors that may influence a state's decision to arrange the performance expectations in a particular way.

The following is an example of a state revision where the focus is on revising the Conceptual Progressions Course Map described in **Table 1**. This revision was developed by California's Science Expert Panel (SEP), a group comprised of kindergarten through grade twelve teachers, scientists, educators, business industry representatives, and informal science educators.

The SEP used the following criteria to arrange the performance expectations for middle school grades six, seven, and eight:

1. Performance expectations (PEs) were placed at each grade level so that they support content articulation across grade levels (from fifth through eighth grade) and provide the opportunity for content integration within each grade level.
2. Performance expectations were aligned with the Common Core State Standards (CCSS) in English Language Arts (ELA) and Mathematics so that science learning would not be dependent upon math skills not yet acquired.
3. The final arrangement of performance expectations reflected a balance both in content complexity and number at each grade level with human impact and engineering performance expectations appropriately integrated.

In addition to these criteria, the SEP worked to ensure that the performance expectations could be bundled together in various ways to facilitate curriculum development.

Table 3A: California Integrated Learning Progressions Model – Middle School

The table below connects the middle school NGSS performance expectations to the component ideas from the *Framework*. These connections are taken from the information in the NGSS foundation boxes. In this table, the component ideas are arranged into courses based on California's revised organization.

Course 1

PS3.A	MS-PS3-3.
	MS-PS3-4.
PS3.B	MS-PS3-5.
LS1.A	MS-LS1-1.
	MS-LS1-2.
	MS-LS1-3.
LS1.B	MS-LS1-4.
	MS-LS1-5.
LS1.D	MS-LS1-8.
LS3.A	MS-LS3-2.
ESS2.C	MS-ESS2-4.
	MS-ESS2-5.
	MS-ESS2-6.
ESS3.C	MS-ESS3-3.
ESS3.D	MS-ESS3-5.
ETS1.A	MS-ETS1-1.
ETS1.B	MS-ETS1-2.
	MS-ETS1-3.
	MS-ETS1-4.
ETS1.C	MS-ETS1-3.
	MS-ETS1-4.

COURSE 1 Repeats

PS3.B	MS-PS3-3
	MS-PS3-4
LS1.B	*MS-LS3-2*
LS3.B	MS-LS3-2
ESS2.D	MS-ESS2-5.
	MS-ESS2-6.

Course 2

PS1.A	MS-PS1-1.
	MS-PS1-2.
	MS-PS1-3.
	MS-PS1-4.
PS1.B	MS-PS1-5.
	MS-PS1-6.
LS1.C	MS-LS1-6.
	MS-LS1-7.
LS2.A	MS-LS2-1.
	MS-LS2-2.
LS2.B	MS-LS2-3.
LS2.C	MS-LS2-4.
	MS-LS2-5.
ESS2.A	MS-ESS2-1.
	MS-ESS2-2.
ESS2.B	MS-ESS2-3.
ESS3.A	MS-ESS3-1.
ESS3.B	MS-ESS3-2

COURSE 2 repeats

PS1.B	MS-PS1-2.
	MS-PS1-3.
PS3.A	*MS-PS1-4.*
PS3.D	*MS-LS1-6.*
	MS-LS1-7.
LS4.D	*MS-LS2-5.*
ESS2.C	MS-ESS2-2.
ETS1.A	MS-ETS1-1.
ETS1.B	MS-ETS1-2.
	MS-ETS1-3.
	MS-ETS1-4.
ETS1.C	MS-ETS1-3.
	MS-ETS1-4.

Course 3

PS2.A	MS-PS2-1.
	MS-PS2-2.
PS2.B	MS-PS2-3.
	MS-PS2-4.
	MS-PS2-5.
PS3.A	MS-PS3-1.
	MS-PS3-2.
PS4.A	MS-PS4-1.
	MS-PS4-2.
PS4.C	MS-PS4-3.
LS3.A	MS-LS3-1.
LS4.A	MS-LS4-1.
	MS-LS4-2.
	MS-LS4-3.
LS4.B	MS-LS4-4.
	MS-LS4-5.
LS4.C	MS-LS4-6.
ESS1.A	MS-ESS1-1.
	MS-ESS1-2.
ESS1.B	MS-ESS1-3.
ESS1.C	MS-ESS1-4.
ESS3.C	MS-ESS3-4.

COURSE 3 Repeats

PS3.C	MS-PS3-2.
PS4.B	MS-PS4-2.
LS3.B	MS-LS3-1.
ESS1.B	MS-ESS1-1.
	MS-ESS1-2.
ETS1.A	MS-ETS1-1.
ETS1.B	MS-ETS1-2.
	MS-ETS1-3.
	MS-ETS1-4.
ETS1.C	MS-ETS1-3.
	MS-ETS1-4.

Key to
PE appears in two DCIs within the same course
PE is identified in NGSS as a secondary connection to this
PE connected to two component ideas between two courses

Course Map 2 – Science Domains Model (grades 6–8 and 9–12)

Process and Assumptions: Where did this model come from?

This model course map was built by placing the NGSS performance expectations (PEs) into a course structure defined by the science domains outlined in the *Framework*: one course is assigned to each science domain of the *Framework* – Life Science, Physical Science, and Earth and Space Science. A fourth course is not included for the fourth domain of the *Framework*, Engineering, as most of the NGSS performance expectations connected to engineering are integrated into the science domains through the Scientific and Engineering Practices and Crosscutting Concepts. The NGSS does include four PEs in both the middle and high school grade bands that focus exclusively on core idea *ETS1: Engineering Design*. As noted in the sixth foundational understanding (pg 3), these stand-alone engineering PEs are included with all three courses as they help to organize and drive the instruction of the integrated engineering PEs.

This model does not assume a particular order for these three courses. There is not conclusive research at this point to recommend one sequence over another and there are a variety of factors that may affect the order determined for these courses if this model course map is selected as a starting point. Ideas for guiding this conversation are included in the next steps section following the presentation of the model.

This model course map is significantly less complicated in development relative to the Conceptual Progressions Model Course Map. The organization was essentially taken straight from the organization of the *Framework.* 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. **Tables 4 and 5** below display the resulting organization of courses based on the domains model.

Table 4: Science Domains Model – Middle School

The table below connects the middle school NGSS performance expectations to the component ideas from the *Framework* that they were based on. These connections are based on the information in the NGSS foundation boxes. In this table, the component ideas are arranged into courses based on the organization described as the Science Domains model-- one course is assigned to each science domain of the *Framework* – Life Science, Physical Science, and Earth and Space Science.

Physical Science

PS1.A	MS-PS1-1.
	MS-PS1-2.
	MS-PS1-3.
	MS-PS1-4.
PS1.B	MS-PS1-5.
	MS-PS1-6.
PS2.A	MS-PS2-1.
	MS-PS2-2.
PS2.B	MS-PS2-3.
	MS-PS2-4.
	MS-PS2-5.
PS3.A	MS-PS3-1.
	MS-PS3-2.
	MS-PS3-3.
	MS-PS3-4.
PS3.B	MS-PS3-5.
PS4.A	MS-PS4-1.
	MS-PS4-2.
PS4.C	MS-PS4-3.
ETS1.A	MS-ETS1-1.
ETS1.B	MS-ETS1-2.
	MS-ETS1-3.
	MS-ETS1-4.
ETS1.C	MS-ETS1-3.
	MS-ETS1-4.

Physical Science Repeats

PS1.B	MS-PS1-2.
	MS-PS1-3
PS3.A	*MS-PS1-4*
PS3.B	MS-PS3-3.
	MS-PS3-4.
PS3.C	MS-PS3-2.
PS3.D	*MS-LS1-6*.
	MS-LS1-7.
PS4.B	MS-PS4-2.

Life Science

LS1.A	MS-LS1-1.
	MS-LS1-2.
	MS-LS1-3.
LS1.B	MS-LS1-4.
	MS-LS1-5.
LS1.C	MS-LS1-6.
	MS-LS1-7.
LS1.D	MS-LS1-8.
LS2.A	MS-LS2-1.
	MS-LS2-2.
LS2.B	MS-LS2-3.
LS2.C	MS-LS2-4.
	MS-LS2-5.
LS3.A	MS-LS3-1.
	MS-LS3-2.
LS4.A	MS-LS4-1.
	MS-LS4-2.
	MS-LS4-3.
LS4.B	MS-LS4-4.
	MS-LS4-5.
LS4.C	MS-LS4-6.

Life Science Repeats

LS1.B	*MS-LS3-2.*
LS3.B	MS-LS3-1.
	MS-LS3-2.
LS4.D	*MS-LS2-5.*
ETS1.A	MS-ETS1-1.
ETS1.B	MS-ETS1-2.
	MS-ETS1-3.
	MS-ETS1-4.
ETS1.C	MS-ETS1-3.
	MS-ETS1-4.

Earth & Space Science

ESS1.A	MS-ESS1-1.
	MS-ESS1-2.
ESS1.B	MS-ESS1-3.
ESS1.C	MS-ESS1-4.
ESS2.A	MS-ESS2-1.
	MS-ESS2-2.
ESS2.B	MS-ESS2-3.
ESS2.C	MS-ESS2-4.
	MS-ESS2-5.
	MS-ESS2-6.
ESS3.A	MS-ESS3-1.
ESS3.B	MS-ESS3-2.
ESS3.C	MS-ESS3-3.
	MS-ESS3-4.
ESS3.D	MS-ESS3-5.

Earth & Space Science Repeats

ESS1.B	MS-ESS1-1.
	MS-ESS1-2.
ESS1.C	*MS-ESS2-3.*
ESS2.C	MS-ESS2-2.
ESS2.D	MS-ESS2-5.
	MS-ESS2-6.
ETS1.A	MS-ETS1-1.
ETS1.B	MS-ETS1-2.
	MS-ETS1-3.
	MS-ETS1-4.
ETS1.C	MS-ETS1-3.
	MS-ETS1-4.

Key to Highlighting
PE appears in two DCIs within the same course
PE is identified in NGSS as a secondary connection to this component idea
PE connected to two component ideas between two courses

Table 5: Science Domains Model – High School

The table below connects the high school NGSS performance expectations to the component ideas from the *Framework* that they were based on. These connections are based on the information in the NGSS foundation boxes. In this table, the component ideas are arranged into courses based on the organization described as the Science Domains model-- one course is assigned to each science domain of the *Framework* – Life Science, Physical Science, and Earth and Space Science.

Physical Science

PS1.A	HS-PS1-1.
	HS-PS1-2.
	HS-PS1-3.
	HS-PS1-4.
PS1.B	HS-PS1-5.
	HS-PS1-6.
	HS-PS1-7.
PS1.C	HS-PS1-8.
PS2.A	HS-PS2-1.
	HS-PS2-2.
	HS-PS2-3.
PS2.B	HS-PS2-4.
	HS-PS2-5.
	HS-PS2-6.
PS3.A	HS-PS3-1.
	HS-PS3-2.
	HS-PS3-3.
PS3.B	HS-PS3-4.
PS3.C	HS-PS3-5.
PS4.A	HS-PS4-1.
	HS-PS4-2.
	HS-PS4-3.
	HS-PS4-5.
PS4.B	HS-PS4-4.
ETS1.A	HS-ETS1-1.
ETS1.B	HS-ETS1-3.
	HS-ETS1-4.
ETS1.C	HS-ETS1-2.

Physical Science Repeats

PS1.B	HS-PS1-2.
	HS-PS1-4.
PS1.C	*HS-ESS1-5.*
	HS-ESS1-6.
PS2.B	*HS-PS1-1.*
	HS-PS1-3.
PS3.A	*HS-PS2-5.*
PS3.B	HS-PS3-1.
PS3.D	HS-PS3-3.
	HS-PS3-4.
	HS-PS4-5.
	HS-LS2-5.
	HS-ESS1-1.
PS4.A	*HS-ESS2-3.*
PS4.B	HS-PS4-3.
	HS-PS4-5.
	HS-ESS1-2.
PS4.C	HS-PS4-5.

Life Science

LS1.A	HS-LS1-1.
	HS-LS1-2.
	HS-LS1-3.
LS1.B	HS-LS1-4.
LS1.C	HS-LS1-5.
	HS-LS1-6.
	HS-LS1-7.
LS2.A	HS-LS2-1.
	HS-LS2-2.
LS2.B	HS-LS2-3.
	HS-LS2-4.
	HS-LS2-5.
LS2.C	HS-LS2-6.
	HS-LS2-7.
LS2.D	HS-LS2-8.
LS3.A	HS-LS3-1.
LS3.B	HS-LS3-2.
	HS-LS3-3.
LS4.A	HS-LS4-1.
LS4.B	HS-LS4-2.
	HS-LS4-3.
LS4.C	HS-LS4-4.
	HS-LS4-5.
	HS-LS4-6.

Life Science Repeats

LS2.C	HS-LS2-2.
LS4.C	HS-LS4-2.
	HS-LS4-3.
LS4.D	HS-LS4-6.
ETS1.A	HS-ETS1-1.
ETS1.B	HS-ETS1-3.
	HS-ETS1-4.
ETS1.C	HS-ETS1-2.

Earth & Space Science

ESS1.A	HS-ESS1-1.
	HS-ESS1-2.
	HS-ESS1-3.
ESS1.B	HS-ESS1-4.
ESS1.C	HS-ESS1-5.
	HS-ESS1-6.
ESS2.A	HS-ESS2-1.
	HS-ESS2-2.
	HS-ESS2-3.
	HS-ESS2-4.
ESS2.C	HS-ESS2-5.
ESS2.D	HS-ESS2-6.
	HS-ESS2-7.
ESS3.A	HS-ESS3-1.
	HS-ESS3-2.
ESS3.C	HS-ESS3-3.
	HS-ESS3-4.
ESS3.D	HS-ESS3-5.
	HS-ESS3-6.

Earth & Space Science Repeats

ESS1.B	*HS-ESS2-4.*
ESS2.B	*HS-ESS1-5.*
	HS-ESS2-1.
	HS-ESS2-3.
ESS2.D	HS-ESS2-4.
	HS-ESS3-6.
ESS2.E	HS-ESS2-7.
ESS3.B	HS-ESS3-1.
ETS1.A	HS-ETS1-1.
ETS1.B	HS-ETS1-3.
	HS-ETS1-4.
ETS1.C	HS-ETS1-2.

Key to Highlighting
PE appears in two DCIs within the same course
PE is identified in NGSS as a secondary connection to this
PE connected to two component ideas between two courses

Next Steps for Model Course Map 2

Since the courses were effectively designed based on the parameters of the domains of science defined in the *Framework*, any significant shuffling of PEs between courses would, in some sense, void the initial premise of this model, but getting to this point was mainly about taking a first step toward curriculum so there are several things to be considered in refining this model. As was mentioned in the next steps section for Model Course Map 1, it is important to balance this structured arrangement of PEs with creating courses and units that flow well and engage students in learning. This model course map is another potential *starting point* for building instructional units. When bundling together student outcomes into meaningful units to build the flow for courses, PEs may still be pulled from different courses in the map to make this work.

1. The order these courses would be offered was not predetermined by the course map, so sequencing the courses will be a decision that will need to be made before proceeding with curriculum development. It is important to not sequence courses based only on what your current courses are, but to look in detail at the performance expectations mapped to each course (including what is required for math and ELA to accomplish the performance expectations) and sequence courses to best benefit student learning. **Figure 3** and **Table 1** and **Table 2** from Model Course Map 1 provide insight about the interconnected nature of the component ideas and how they support each other in a progression of content. A close examination of these resources and the next steps suggested for the first model course map are very relevant to this decision-making process. Additionally, the math and English Language Arts connections boxes and their supporting appendices (math – Appendix L; ELA – Appendix M) should be consulted to make sure that courses are not expecting math or ELA content or practices before they are expected in the science sequence.

2. Regardless of the final sequence of courses, it is likely that some component ideas from other domains will need to be brought into each course. For example, if the life science course is taught before the physical science course, some content from the physical sciences will need to be included in the life course as prerequisite understandings for biological process. As performance expectations are bundled into curriculum units and lesson plans it is important to balance this structured arrangement of PEs with creating courses and units that flow well and engage students in learning. The model course map can be used as a *starting point* for building instructional units. When bundling together these student outcomes into meaningful units to build the flow for courses, PEs may be pulled from different courses in the map to make this work. The course map is not meant to be a prescriptive, static document, but is meant to provide structure for decision-making

3. While rearranging PEs and building instructional units, it's important to remember that the performance expectations are *grade banded* student outcomes and map out student course expectations appropriately. It may be, though a PE is placed in a course, that the student may not

be ready to perform all aspects of the PE by the end of the course. For example, it could be that a PE is placed in the first course because the DCI dimension is determined to be foundational to a PE in the second course, but the depth of the Scientific and Engineering Practice described in 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. In other words, though the expectation is that all Scientific and Engineering Practices will be in all courses, it would be make sense for students in sixth grade to engage in these differently than those in eighth grade – deliberately building complexity of practices over the middle school sequence is needed.

4. If, during the implementation process, restricting the 9–12 grade band to three courses does not meet local needs, a fourth course could be developed. If all four courses are required, a course map variation like this could still meet the vision of NGSS and 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 1 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 (grades 9–12)

Process and Assumptions: Where did this model come from?

The model course maps presented here attempt to organize the 9–12 grade band performance expectations based on the frequently taught courses of Biology, Chemistry and Physics. These courses represent a very common course distribution across many states – either through legislation, regulation, or tradition – so these examples are presented as tools for evaluating how this commonly used course sequence overlays with the expectations of the Next Generation Science Standards. The challenge of this model course map was to also address Earth and Space Science since it is a domain outlined in the *Framework*, but does not have a course of its own in this organization. A fundamental understanding of the NGSS and all of the Model Course Maps 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 Science PEs could be distributed between the three courses already described.

Most of the NGSS engineering performance expectations are integrated into the other domains; however, in the final draft of the NGSS there are four PEs in each grade band that focus exclusively on engineering design. These stand-alone engineering PEs are included in all three courses as they should help organize and drive the instruction of the integrated engineering PEs in all three courses.

The first step in mapping performance expectations to courses was to examine 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 more difficult step for the Physical Science component ideas as they had to be split between Chemistry and Physics courses.

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 all the performance expectations of the NGSS are 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 twelve 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.

As with Model Course Map 2, no course sequence has been assumed in this model.

Table 6: Modified Science Domains Model – High School

In this table, the component ideas are arranged into courses based on the organization described as the Modified Science Domains model – biology, chemistry, and physics. The table below uses the information in the NGSS foundation boxes to connect the high school NGSS performance expectations to the component ideas from the *Framework.*

Biology

LS1.A	HS-LS1-1.
	HS-LS1-2.
	HS-LS1-3.
LS1.B	HS-LS1-4.
LS1.C	HS-LS1-5.
	HS-LS1-6.
	HS-LS1-7.
LS2.A	HS-LS2-1.
	HS-LS2-2.
LS2.B	HS-LS2-3.
	HS-LS2-4.
	HS-LS2-5.
LS2.C	HS-LS2-6.
	HS-LS2-7.
LS2.D	HS-LS2-8.
LS3.A	HS-LS3-1.
LS3.B	HS-LS3-2.
	HS-LS3-3.
LS4.A	HS-LS4-1.
LS4.B	HS-LS4-2.
	HS-LS4-3.
LS4.C	HS-LS4-4.
	HS-LS4-5.
	HS-LS4-6.
ESS1.C	HS-ESS1-5.
	HS-ESS1-6.
ESS2.E	HS-ESS2-7.
ESS3.B	HS-ESS3-1.
ESS3.C	HS-ESS3-3.
	HS-ESS3-4.
ETS1.A	HS-ETS1-1.
ETS1.B	HS-ETS1-3.
	HS-ETS1-4.
ETS1.C	HS-ETS1-2.

Biology Repeats

LS2.C	HS-LS2-2.
LS4.C	HS-LS4-2.
	HS-LS4-3.
LS4.D	HS-LS4-6.

Chemistry

PS1.A	HS-PS1-1.
	HS-PS1-2.
	HS-PS1-3.
	HS-PS1-4.
PS1.B	HS-PS1-5.
	HS-PS1-6.
	HS-PS1-7.
PS1.C	HS-PS1-8.
PS3.B	HS-PS3-1.
	HS-PS3-4.
PS3.D	HS-PS3-3.
ESS2.C	HS-ESS2-5.
ESS2.D	HS-ESS2-4.
	HS-ESS2-6.
ESS3.A	HS-ESS3-2.
ESS3.D	HS-ESS3-5.
	HS-ESS3-6.

Chemistry Repeats

PS1.B	HS-PS1-2.
	HS-PS1-4.
PS1.C	*HS-ESS1-5.*
	HS-ESS1-6.
PS3.D	HS-PS3-4.
	HS-PS4-5.
	HS-LS2-5.
	HS-ESS1-1.
ESS2.D	HS-ESS2-7.
	HS-ESS3-6.
ESS3.A	HS-ESS3-1.
ETS1.A	HS-ETS1-1.
ETS1.B	HS-ETS1-3.
	HS-ETS1-4.
ETS1.C	HS-ETS1-2.

Physics

PS2.A	HS-PS2-1.
	HS-PS2-2.
	HS-PS2-3.
PS2.B	HS-PS2-4.
	HS-PS2-5.
	HS-PS2-6.
PS3.A	HS-PS3-2.
PS3.C	HS-PS3-5.
PS4.A	HS-PS4-1.
	HS-PS4-2.
	HS-PS4-3.
	HS-PS4-5.
PS4.B	HS-PS4-4.
ESS1.A	HS-ESS1-1.
	HS-ESS1-2.
	HS-ESS1-3.
ESS1.B	HS-ESS1-4.
ESS2.A	HS-ESS2-1.
	HS-ESS2-2.
	HS-ESS2-3.

Physics Repeats

PS2.B	*HS-PS1-1.*
	HS-PS1-3.
PS3.A	HS-PS3-1.
	HS-PS3-3.
	HS-PS2-5.
PS3.B	HS-PS3-1.
	HS-PS3-4.
PS4.A	*HS-ESS2-3.*
PS4.B	HS-PS4-3.
	HS-PS4-5.
	HS-ESS1-2.
ESS1.B	*HS-ESS2-4.*
ESS2.A	HS-ESS2-4.
ESS2.B	*HS-ESS1-5.*
	HS-ESS2-1.
	HS-ESS2-3.
ETS1.A	HS-ETS1-1.
ETS1.B	HS-ETS1-3.
	HS-ETS1-4.
ETS1.C	HS-ETS1-2.

Key to Highlighting
PE appears in two DCIs within the same course
PE is identified in NGSS as a secondary connection to this
PE connected to two component ideas between two courses

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 in Biology 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 earth-based and atmospheric 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*.

Next Steps for 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 they are designed within the constraint of having the courses Physics, Chemistry, and Biology, with the Earth and Space Science PEs split among courses. As was mentioned in the next steps sections for the previous two model course maps, it is important to balance this structured arrangement of PEs with creating courses and instructional units that flow well and engage students in learning. This PE arrangement can be used as a *starting point* for building instructional units. While bundling together student outcomes into meaningful units to build the flow for courses, PEs may be pulled from different courses in the map to make this work.

There are several other considerations when revising this model:

1. Much like Model Course Map 2, the sequence of courses is not predetermined, so deciding on an order would be one of the first decisions to make. It is important to not sequence courses based only on what your current courses are, but to look in detail at the performance expectations mapped to each course (including what is required for math and ELA to accomplish the performance expectations) and sequence courses to best benefit student learning. **Figure 3** and

Table 1 and **Table 2** from Model Course Map 1 provide insight about the interconnected nature of the component ideas and how they support each other in a progression of content. A close examination of these resources and the next steps suggested for the first model course map will support this decision-making process. Additionally, the math and English Language Arts connections boxes and their supporting appendices (math – Appendix L; ELA – Appendix M) should be consulted to make sure that courses are not expecting math or ELA content or practices before the grade level indicated in the Common Core.

2. The split of Earth and Space Science PEs also needs close examination to make sure that the PEs have been effectively arranged and that they fit the expectations of the state or local courses. The sequence of courses may have a significant impact on which Earth and Space Science PEs are placed in which course.

3. A quick glance at **Table 6**, which outlines how the performance expectations are organized in this model course map, makes it clear that this map has an imbalance of PEs in each course. This deserves examination as PEs are bundled into instructional units to determine if any PEs (or even entire component ideas) should shift courses. The Earth and Space Science PEs would be ready candidates for this move, but it might also be that a component idea, like *LS1.C Organization for Matter and Energy Flow in Organisms*, might be moved from Biology (which has the most PEs) to the Chemistry (which has the least). This move would also make sense because the content of *LS1.C* ties in nicely with some of the chemistry concepts. It should be noted here that simply counting the number of PEs in a course does not necessarily give a good sense of the time it will take to prepare students to be able to perform what is expected – this is better determined by the length of time needed for the instructional units that are developed.

4. While rearranging PEs and building instructional units remember that the performance expectations are *grade banded* student outcomes and map out student course expectations appropriately. It may be that, though a PE is placed in a course, the student may not be ready to perform all aspects of the PE by the end of the course. For example, it could be that a PE is placed in the first course because the DCI dimension is determined to be foundational to a PE in the second course, but the depth of the Scientific and Engineering Practices described in 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. In other words, though the expectation is that all Scientific and Engineering Practices will be in all courses, it would make sense for students in sixth grade to engage in these differently than those in eighth grade – deliberately building complexity of practices over the middle school sequence is needed.

5. Another solution to mesh NGSS with an existing course sequence that includes physics, chemistry, and biology courses, would be to add a fourth course – Earth and Space Science – to the sequence. If all four courses are required, this variation would still meet the vision of the

Framework that all PEs are expected for all students. A reminder that these "courses" do not have a defined length of time – four courses does not necessarily mean four years.

Next Steps Example: Revising the Modified Science Domains Model--Four Courses

The following vignette describes an experience that a high school may have in deciding to use the Science Domains model, but with revisions to make it a four course model.

In this scenario, a school district decides that the Modified Science Domains model will be the easiest to implement because it aligns with the teacher licensure situation in the state/district and there is inflexibility in modifying qualified admissions criteria within the state university system. In this state, teacher licensure is restricted to particular content areas (there is no general science endorsement area) and it is particularly difficult to add areas of endorsement. The admissions criteria for state universities specifically require successful completion of a course called "Biology." The organization that regulates these admissions criteria has been historically resistant to make any changes to these criteria. The district is compelled by the vision of the Framework and NGSS and has decided to move forward quickly with implementation for the betterment of its students, but it sees these barriers as insurmountable in the short term and or beyond their control. The K-12 science team has decided that the Modified Science Domains model will be their starting point and that they will re-evaluate this decision in five years based on its effectiveness, any new research that evaluates the course maps at a larger scale, and any changes that are made to licensure and admissions criteria – which they perceive as barriers to using the other model course maps as starting points.

As the K-12 science team evaluates the Modified Science Domains Model they are unable to come to terms with how the Earth and Space Science PEs are divided between courses. Unable to propose a different arrangement that they find acceptable, they make a decision to pull out the Earth and Space Science component ideas into a separate fourth course. To make sure that this arrangement is robust, the K-12 science team assembles a strategic stakeholder team of local teachers, professors, science-related business and industry representatives, a local school board member who has an interest in science education, and the educator for the local science children's museum to organize the NGSS into four courses. They know that in order to still meet the vision of the NGSS of all standards for all students, they will have to change the graduation criteria for their high school, which currently only requires biology and two other science electives. There is a strong relationship between the K-12 science team and the local school board, and especially with the inclusion of a liaison to the board on their team, they are hopeful that this is possible – they at least perceive this to be within their realm of potential influence. This local control state has state graduation requirements, but local modifications are allowed if they exceed the state requirements.

Through discussions of this strategic stakeholder team, they decide to keep essentially the same content distribution of the Life Science and Physical Science PEs as they are in the Modified

Course Domains model, but pull the Earth and Space Science performance expectations into their own course. In addition to separating the PEs into four courses, their revised model course map also follows the example suggested in the third recommended next step (above) and moves LS1.C from Biology to Chemistry. The committee agrees that even though this is a Life Science component idea, the content has a fair amount of crossover with chemistry and this balances the courses a bit better.

After determining the arrangement of performance expectations for their course map (see Table 7,) the stakeholder group decides to outline a four-year tentative implementation plan to highlight all the necessary changes to curriculum, instruction, professional learning opportunities, and local graduation requirements. The K-12 science team, with the endorsement of the strategic stakeholder group, presents the course sequence and implementation plan to the local school board as a part of their request to increase the graduation requirements to include all four courses.

Table 7: REVISED Modified Science Domains Model – Four courses High School

In this table, the component ideas are arranged into courses based on the organization described as the Modified Science Domains model – biology, chemistry, and physics with a fourth course added for Earth and Space Science. The table below uses the information in the NGSS foundation boxes to connect the high school NGSS performance expectations to the component ideas from the *Framework.*

Biology

LS1.A	HS-LS1-1.
	HS-LS1-2.
	HS-LS1-3.
LS1.B	HS-LS1-4.
LS1.C*	HS-LS1-5.
	HS-LS1-6.
	HS-LS1-7.
LS2.A	HS-LS2-1.
	HS-LS2-2.
LS2.B	HS-LS2-3.
	HS-LS2-4.
	HS-LS2-5.
LS2.C	HS-LS2-6.
	HS-LS2-7.
LS2.D	HS-LS2-8.
LS3.A	HS-LS3-1.
LS3.B	HS-LS3-2.
	HS-LS3-3.
LS4.A	HS-LS4-1.
LS4.B	HS-LS4-2.
	HS-LS4-3.
LS4.C	HS-LS4-4.
	HS-LS4-5.
	HS-LS4-6.
ETS1.A	HS-ETS1-1.
ETS1.B	HS-ETS1-3.
	HS-ETS1-4.
ETS1.C	HS-ETS1-2.

Biology Repeats

LS2.C	HS-LS2-2.
LS4.C	HS-LS4-2.
	HS-LS4-3.
LS4.D	HS-LS4-6.

Chemistry

PS1.A	HS-PS1-1.
	HS-PS1-2.
	HS-PS1-3.
	HS-PS1-4.
PS1.B	HS-PS1-5.
	HS-PS1-6.
	HS-PS1-7.
PS3.B	HS-PS3-1.
	HS-PS3-4.
PS3.D	HS-PS3-3.

LS1.C moved from Biology	
LS1.C*	HS-LS1-5.
	HS-LS1-6.
	HS-LS1-7.

Chemistry Repeats

PS1.B	HS-PS1-2.
	HS-PS1-4.
PS3.D	*HS-PS4-5.*
	HS-LS2-5.
	HS-ESS1-1.
	HS-PS3-4.
ETS1.A	HS-ETS1-1.
ETS1.B	HS-ETS1-3.
	HS-ETS1-4.
ETS1.C	HS-ETS1-2.

Key to Highlighting

Key to Highlighting
PE appears in two DCIs within the same course
PE is identified in NGSS as a secondary connection to this
PE connected to two component ideas between two courses

Physics

PS2.A	HS-PS2-1.
	HS-PS2-2.
	HS-PS2-3.
PS2.B	HS-PS2-4.
	HS-PS2-5.
	HS-PS2-6.
PS1.C	HS-PS1-8.
PS3.A	HS-PS3-2.
PS3.C	HS-PS3-5.
PS4.A	HS-PS4-1.
	HS-PS4-2.
	HS-PS4-3.
	HS-PS4-5.
PS4.B	HS-PS4-4.

Physics Repeats

PS2.B	*HS-PS1-1.*
	HS-PS1-3.
PS3.A	HS-PS3-1.
	HS-PS3-3.
	HS-PS2-5.
PS3.B	HS-PS3-1.
	HS-PS3-4.
PS4.A	*HS-ESS2-3.*
PS4.B	HS-PS4-3.
	HS-PS4-5.
	HS-ESS1-2.
ETS1.A	HS-ETS1-1.
ETS1.B	HS-ETS1-3.
	HS-ETS1-4.
ETS1.C	HS-ETS1-2.

Earth & Space

ESS1.A	HS-ESS1-1.
	HS-ESS1-2.
	HS-ESS1-3.
ESS1.B	HS-ESS1-4.
ESS1.C	HS-ESS1-5.
	HS-ESS1-6.
ESS2.A	HS-ESS2-1.
	HS-ESS2-2.
	HS-ESS2-3.
	HS-ESS2-4.
ESS2.C	HS-ESS2-5.
ESS2.D	HS-ESS2-6.
	HS-ESS2-7.
ESS3.A	HS-ESS3-1.
	HS-ESS3-2.
ESS3.C	HS-ESS3-3.
	HS-ESS3-4.
ESS3.D	HS-ESS3-5.
	HS-ESS3-6.

Earth & Space Repeats

ESS1.B	*HS-ESS2-4*
ESS2.B	*HS-ESS1-5.*
	HS-ESS2-1.
	HS-ESS2-3.
ESS2.D	HS-ESS2-4.
	HS-ESS3-6.
ESS2.E	HS-ESS2-7.
ESS3.B	HS-ESS3-1.
ETS1.A	HS-ETS1-1.
ETS1.B	HS-ETS1-3.
	HS-ETS1-4.
ETS1.C	HS-ETS1-2.

Course Maps and Implementation

Choosing a Course Map

These course maps are not end products, rather they are models of processes 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, district, 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. 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 is already planning a re-design of teacher licensure, then selecting a model course map that doesn’t fit well with their existing teacher licensure system would not necessarily be a barrier to selecting that course map--it might even be a reason for selection because it aligns with the direction of the licensure re-design process. Likewise, what some may consider a “benefit,” others may see as a reason not to select a course map. Some may start with a particular course map because it contains courses that are very similar to what is currently offered, but others may see this as more of a drawback as it may result in teachers being less convinced they need to make and changes – making it difficult to ensure a complete and coherent implementation of the vision 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 Scientific 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, 2012). According to the *Framework*, “[b]y 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, 2012).

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 built directly from 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* (AAAS, 2001), 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. 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 (AAAS, 2001).

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 a more 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. "Credit" and "courses" do not describe what students know or are able to do; the system of PEs in the NGSS, all of which are for all students, detail what is to be achieved.

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

Any of the course map models (depending on the 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 used, 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?**

Existing resources, such as textbooks, workbooks, and even online resources, often sort information based on content in a way that is more similar to Course Maps 2 and 3. For state or districts that focus their curriculum on a particular textbook, this may affect the decision of how to map out courses, but for others that pull from a variety of resources and already use their textbook as a support for their curriculum rather than as the curriculum, this may be irrelevant. As new resources are written and existing resources are rewritten for the NGSS, they may be more frequently be designed with one course map or another in mind, but this too may be less of a concern due to the development of more flexible resources such as open education resources and editable digital textbook formats.

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 will be the one that everyone selects, but there may be good reasons for choosing a different model (including "none of the above"). In fact, engineering 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. Hopefully the factors described above will result in meaningful conversations in states and districts about their science education systems. Adopting the NGSS will require systemic changes to implement them with fidelity to the vision of the *Framework*. It is a great opportunity for deliberate decision-making about whether or not your system 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.

This situation of many states and districts utilizing the same standards, but with different course maps also has significant potential to inform our understanding of students learn science. As was mentioned in the introduction, the reason why we even have to juggle the idea of multiple course maps is that there is insufficient research to recommend a particular sequence. With fifty different sets of state standards, it has been difficult to determine if one sequence is more effective than another, but with many states considering adoption of these standards, there is fertile ground for historic research to move our understanding forward.

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, necessary professional learning opportunities will need to be accessed or developed to support implementation with fidelity. 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.

Recommendations for refining each course map is 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 PEs 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 – or it may mean starting from scratch.

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 complementary instruction across content areas. The connections boxes on the NGSS should also inform this conversation.

Works Cited

American Association for the Advancement of Science (AAAS). *Designs for Science Literacy.* New York: Oxford University Press, 2001.

National Research Council (NRC). *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*. Washington, DC: The National Academies Press, 2012.