Dr. Art's Overview Grade Span 6-8 CCC Recommendations

NOTE: Please read this Overview before reading recommendations for a specific 6-8 grade level.

Compared with K-5, the middle school grades have significantly more Performance Expectations (PE) in each year. Since each science discipline PE has a cited CCC, there are more CCC citations per year. The Table below shows there are 55 CCC citations across the 6-8 grade span. Each grade year is very likely to have a citation for six or all seven CCCs.

Overview of Middle School CCC Citations		
CCC	**Number of Citations**	**Batch Description**
Patterns	9	**Batch A**: 24 citations for Patterns + Cause/Effect The foundation for these are covered well in the prior K-5 grade span. Humans are hard-wired to notice patterns and to infer causal relationships based on perceived patterns.
Cause & Effect	15	
Scale, Proportion, & Quantity	7	**"Batch" B**: 7 citations. Introduced mostly in Grade 5. Unlike Batch A, understandings related to scale, proportion and quantity are generally not intuitive. NGSS treatment of Scale in 6-8 needs deepening.
Systems & System Models	6	**Batch C**: 24 citations for this "Systems thinking" batch. Mostly introduced in Grades 4 and 5. Similar to the Scale "Batch" B, understandings related to systems thinking are generally not intuitive. NGSS treatment of Systems in 6-8 needs deepening.
Energy & Matter (through systems)	8	
Structure/Function (of systems)	5	
Stability & Change (of systems)	5	

The best way to learn how to skillfully use a CCC is to use the same CCC multiple times within a year, and to do so in different contexts. While students may encounter all seven CCCs in a given middle school year, it is best to focus attention on fewer of the CCCs. As explained below, batching and strategic grade level allocations can enable both focused attention on specific CCCs within each year and still have deep coverage of all the CCCs over the grade span.

The Table divides the CCCs into three Batches. Dr. Art's recommendation is that each middle school year should have a focus within each of the three batches. School or district teams can ensure that all the CCCs are well covered in Grades 6 through 8 by strategically allocating the

CCC citations across the three middle school grades,. The next section of this document describes the rationale for the three Batches. That section is then followed by discussion and recommendations with respect to each of the CCCs in middle school.

Batching the CCCs

Batch A combines citations from **Patterns** and from **Cause and Effect.** Utilizing these two CCCs can build on their extensive coverage in the elementary grades. In addition, humans are naturally hard wired to notice patterns and to infer causal relationships to explain the perceived patterns. Further, there are many contexts in each 6-8 grade course (in both the California Integrated model and in the Discipline Specific model) that readily lend themselves to connecting both a cited Pattern CCC bullet and a cited Cause and Effect CCC bullet. Dr. Art's grade level documents provide descriptions and specific recommendations for utilizing **Patterns** and **Cause and Effect** in grade 6, grade 7, and grade 8.

Batch B focuses on the CCC of **Scale, Proportion, and Quantity**. This "batch" has only one CCC and just seven citations in middle school. A primary aim should be to experience how Scale can provide a very powerful lens for approaching, investigating, and ultimately explaining a phenomenon or problem. That lens involves moving beyond the limits and mental habits of our macroscopic level of reality.

Educators and students need to develop an appreciation that many key features of the universe exist across an unimaginable range of sizes. In particular, we have mindsets and expectations based on our perception of reality at our scales of time, mass, distance, and energy. These macroscopic mindsets and expectations are not appropriate when they are applied at very different scales of reality.

We have to significantly adjust our thinking when we try to understand scales of reality that differ from ours, especially at the atomic and cosmic levels. If we do not consciously develop and apply "scale CCC'ing," we make significant mistakes. We cannot understand observable phenomena if we think that the underlying molecular level and energy wave/field level operate in the same patterns or according to the same "rules" as pulleys and baseballs. Each middle school grade should include its own deep experience of "scale CCC'ing," and the three grades together need to provide a sufficient diversity of scale experiences.

Batch C is different from Batch B in that it combines four CCCs and it has many more bullet citations across the three grades. It is similar to Batch B in that it emphasizes a way of thinking that does not come as naturally to us as discerning patterns and making causality inferences. This way of thinking is often referred to as "systems thinking." The **Systems and System Models** CCC complements the Science and Engineering Practice of developing and using models and clearly relates to systems thinking. Perhaps less obviously, the three following CCCs also embody systems thinking. They can be easily rephrased as:

***Energy and Matter** into, within, and out of systems
* **Structure and Function** of systems
* **Stability and Change** of systems

The recommendation is that each of the three grades include a focus on Systems Thinking that includes **Systems and System Models** plus at least one of the other system CCCs. Here too the Dr. Art recommendations for each of the middle school grades provides examples that work well with the contexts at that specific grade level.

The rationale for Batch C is that educators and students need to develop new skills with respect to "systems thinking." A key feature of systems is that the whole system generally has features that are qualitatively different from those of the parts. These system features emerge from the interactions of the parts. Examples of system features include global temperature, liquidity of water, the carbon cycle, car fuel efficiency, a human being's personality, ecosystem services, and life itself. Knowing what these whole system properties are and how they arise can lead to a deep understanding of a phenomenon or problem.

More Detailed CCC Discussion and Recommendations

Patterns

This is probably the easiest of the seven CCCs to use. Humans are naturally hard wired to notice patterns. When we look at a sky that has interesting puffy clouds, we tend to see the changing shapes of faces, fanciful organisms or structures. When confronted with an optical illusion, our minds organize the lines, colors, and foreground/background to make a familiar pattern.

Patterning works. Quickly interpreting sense impressions in terms of a familiar pattern helped our ancestors obtain food, avoid predators, and successfully reproduce. Our genetic heritage and our culture predispose us to perceive these patterns. The main drawback is that sometimes our perceived patterns do not accurately represent reality. Acting as scientists and engineers, we need to cultivate a healthy skepticism about the patterns that we perceive. As we make predictions and conduct investigative tests based on our perceived patterns, we need to be prepared to use the obtained evidence to adjust our attitude, observations and conclusions about the pattern that we initially perceived.

Cause and Effect:

A very important **Cause and Effect** CCC bullet states that "Relationships can be classified as causal or correlational, and correlation does not necessarily imply causation." Just because two events appear to be linked in time and/or location does not necessarily mean that one of them causes the other. How can we decide if two events truly have a cause and effect relationship?

K-5 CCC bullets refer to **testing** as a way to determine cause and effect relationships. A 6-8 Cause/Effect CCC bullet states that "cause and effect relationships may be used to **predict** phenomena in natural or designed systems." Both testing and predicting can help distinguish between a true cause/effect relationship and one that is not. My favorite sports team might seem to win when I wear my special hat, but testing and predicting will reveal that wearing my special hat does not cause the team to win.

A connection of two events in time and/or place can simply be coincidence. It just happens a few times, but generally the events are not linked. A more subtle case of correlation occurs even if both events happen together very often, but they are both being caused by something else and are not causing each other. People who own very expensive homes often have expensive cars. The expensive homes and expensive cars do not cause each other. They are both caused by having very rich owners who like to buy expensive things.

Examples of coincidence and correlation can help students understand why the CCC emphasizes both testing and predicting to determine cause and effect relationships. Without repeated applications of the CCC, students might recite what they have been told about testing and predicting phenomena without really understanding the difference between correlation and causation, or how testing and predicting help distinguish between the two.

This Cause and Effect example serves to highlight an important consideration with respect to CCCs in middle school and high school. Students are now more capable of abstract reasoning with respect to their own thinking and practices. We want to help them question and reason about the CCCs and their preliminary conclusions, and thereby develop deeper understandings and more effective skills in effectively applying a CCC when encountering a new phenomenon.

The complete name for this CCC is actually listed as **Cause and Effect: Mechanism and Prediction**. Can the idea of "mechanism" help distinguish between causation and correlation? The large body of scientific knowledge includes many examples of how interaction X causes effect Y. The mechanism by which it happens could be the application of a force, the transfer of a kind of energy, or the rearranging of connections among atoms.

Now when we see effect Y, we know that there are mechanisms that can cause that effect. We can apply our knowledge and experience of scientific mechanisms and mathematical probabilities in judging the veracity of claims of causality. If I play roulette and lose lots of money, I know that the mathematical probabilities and the physics of rolling balls were the mechanisms that caused that loss. Somebody mighty claim that I lost the money because of my astrological birth sign and the current alignment of the planets. I reject that causal claim because I do not know of any scientific mechanism whereby the position of planets changes the results of a spinning roulette wheel.

Scale, Proportion, and Quantity:

The description of Batch B explains my recommendation for emphasizing Scale as its own Batch. One of the NGSS Scale bullet statement supports that rationale by stating the generalization that, "Phenomena that can be observed at one scale may not be observable at another scale." Consider the macroscopic scale and the atomic scale. A common misconception about atoms and molecules is that they have properties that correspond to what we observe at our level of reality. In that reasonable but inaccurate view, a rock is hard because it is composed of hard molecules. Butter is soft and slippery because its molecules are flexible and slippery.

Contrary to that conception, atoms and molecules do not have the macroscopic properties of being hard, soft, solid, or liquid. Instead atoms and molecules jiggle, move, attract and repel each other because of their electromagnetic properties and the amount of energy in the system. At the macroscopic scale, we experience the **result** of all those atomic level motions, attractions and repulsions. We do not directly experience the atomic level motions, attractions and repulsions. I recommend adding a more specific Cause/Effect bullet stating : "Motions, attractions, and repulsions at the atomic/molecular level of reality result in phenomena and properties of matter that we perceive at our macroscopic level of reality."

Systems and System Models

The description of Batch C explains an essence of systems thinking and the rationale for integrating system models with relevant features of systems such as the flows of energy and matter, the structure/function relationships of systems, and the stability and change of systems.

Systems generally have **properties** that are qualitatively very different than those of their parts. Hydrogen and oxygen are both gases at ambient temperatures and pressures. Hydrogen is explosive. Oxygen is necessary for fires. Combine these two gases to form a new system of two hydrogen atoms combined with one oxygen atom, and the result is a liquid that puts out fires. Water has the whole system properties of being a liquid at ambient temperatures and pressures, of extinguishing fires, and of expanding when it freezes.

Combine wheels, tires, a battery, engine, axles, spark plugs, a gas tank and other parts in correct ways and you have created the system of a car. The function of a car is one of its whole system properties, namely the ability to transport people, animals and inanimate cargo. The car also has other whole system properties such as fuel efficiency and safety ratings.

Whole system properties **emerge** from the connections and interactions among the system's parts. Because whole system properties can differ so much from the parts, they can be quite surprising. Whole system properties are also called emergent properties.

The system related bullets do not sufficiently convey the reality or explanatory power of emergent whole system properties. It is helpful that some upper elementary and middle school CCC bullets do refer to the *function* of a system. However function is just one example of a whole system property. A general emphasis on whole system properties can aid more effective implementation of the systems thinking CCCs.

Energy and Matter: Flows, Cycles and Conservation

Observing, experimenting, modeling and reasoning about the flows and cycles of energy and matter can help reveal the workings of many phenomena.

Structure and Function

This CCC is particularly appropriate with respect to phenomena and problems that involve design. Considerations of structure and function are prominent in engineering design. Physical science in particular informs the structures and connections that are made. Medical devices combine elements of engineering, physical science, and life science.

Life science also features a very different design process through the process of natural selection. Organisms have structures that exquisitely perform functions. These systems have been selected by evolution because they helped and continue to help organisms successfully survive and reproduce. Humans have added features of “artificial selection” in selectively propagating organisms that better serve our purposes. With modern technologies, life science structures and functions may create new realms of beings.

In general, Earth’s systems have neither been naturally nor artificially designed. Structure and function is generally not a particularly appropriate CCC for Earth & Space Science.

Stability and Change

Scientists often focus on why and how a system is changing. If a system is very stable, they investigate why and how it is not changing. Dynamic equilibrium is a fairly common and particularly interesting situation where a system has features that are changing yet the system as a whole is stable. The system tends to remain in equilibrium. One of the middle school **Stability and Change** CCC bullets states, “Systems in dynamic equilibrium are stable due to a balance of feedback mechanisms.”

Concluding Advice

The CCCs and their bullet statements aim to provide important functions with respect to investigating and reasoning about phenomena. CCCs can function as powerful tools to guide investigations, analyses, and understanding. However, the number of CCCs and their bullet sentences do pose a danger of becoming names and factual statements that teachers and students repeat in communicating about the CCCs rather than actually using the CCCs as tools.

One potentially useful way to guide the use of CCCs as tools is to frequently ask oneself and others why we should care about using/citing a particular CCC or its bullet statement. Why do I care about how the energy is flowing or why did I choose a particular CCC in investigating a new phenomenon? If we can convincingly explain how the CCC helped, then we are probably using it effectively, and not just naming it and/or talking superficially about the CCC. In that favorable environment, the CCCs serve as tools that integrate well with the Science and Engineering Practices and the Disciplinary Core Ideas.

