

Dیشهesh Josey

Crosscutting Concepts in the Sciences EDSC 8450 – Sec 002

Claudia Hagan, Ph.D.

Georgia State University Department of Middle & Secondary Education

Final – Proposing a Year-Long Learning Sequence for CCCs

May 04, 2026

I teach a career-focused Career, Technical, and Agricultural Education (CTAE) program that serves sixth-grade, seventh-grade, and eighth-grade students as part of a three-year specialty pathway aligned with the Georgia Department of Education curriculum for Transportation, Distribution, and Logistics. This pathway includes Fundamentals of Aerospace, Flight Operations I, Flight Operations II, and Unmanned Aerial Vehicles, allowing students to build knowledge and skills progressively over multiple years. Across grades 6–8, students investigate rockets, aircraft, and flight systems as part of a multi-year pathway designed to build but conceptual understanding and technical skills. This progression prepares students for future careers in aviation, aerospace, and related engineering fields.

These systems are highly visible and motivating, yet they involve complex interactions among forces, structures, energy, and design constraints that can be difficult for middle school students to explain. Teaching within this multi-year CTAE pathway has helped me understand how Crosscutting Concepts (CCCs) function as essential thinking tools that support student sense-making rather than labels added after instruction. When CCCs are used intentionally across grade levels and revisited across a school year, students are provided with a shared language for explaining patterns, mechanisms, systems and change.

The purpose of this paper is to propose and justify a deliberate year-long learning sequence for CCCs that supports students' sense-making, drawing on classroom evidence, research-based guidance on learning progression, and reflections collected earlier in the course. I reflect on how Structure and Function serve as an anchor CCC early in the pathway and how other CCCs are revisited and deepened over time, culminating in Scale, Proportion, and Quantity as a capstone that supports more advanced engineering design thinking in eighth grade. Across the year, this sequencing reflects how students move from noticing what

they can observe to explaining how and why systems work with each CCC building on the last rather than standing alone.

In a sixth-grade aerospace and aviation science course, the order in which Crosscutting Concepts (CCCs) are introduced matters because students are building understanding of complex systems that are both highly visible and deeply abstract. Rockets and aircraft serve as powerful anchor phenomena, but without a deliberate sequence, students can become overwhelmed by equations or isolated facts before they develop a conceptual framework to make sense of what they observe. For this reason, I propose beginning with Patterns, followed by Structure and Function, Cause and Effect, Systems and System Models, Energy and Matter, Stability and Change, and finally Scale, Proportion, and Quantity.

The course begins with Patterns because this CCC allows students to engage immediately with observable similarities and differences without requiring formal explanations. When students examine different aircraft, such as cargo planes, passenger planes, helicopters, and unmanned aerial vehicles, they quickly notice patterns in shape, size, wingspan, and function. Beginning with Patterns establishes that noticing and describing are valid scientific moves and prepares students to look more closely at design in later stages of the course.

At this early sequence stage, students describe what they notice using everyday language, with support from gallery walks, image sorting activities, and simple sentence starters for example “I notice...” or “A pattern I see is...”. Beginning with Patterns establishes that noticing and describing regularities are valid scientific practices and provides students with accessible ways to participate in sense-making. This early emphasis on observation prepares students to transition into deeper analysis of design and system behavior as they engage with subsequent Crosscutting Concepts (Andersen, 2013). This progression

aligns with research on learning progression and sense-making across CCCs (Nordine & Lee, 2021).

Structure and Function follows Patterns and serves as the anchor Crosscutting Concept for the course because once students identify patterns, they are ready to ask why those patterns exist. Aerospace systems are engineered systems, making Structure and Function a natural fit for sense-making. As students build model rockets, they use a graphic organizer to identify individual structures, including fins, nose cones, engines, and body tubes. Students then explain how each structure supports lift, stability, and upward motion. This approach allows students to move beyond observing what happens to explaining why it happens by explicitly linking design features to performance outcomes (NGSS Lead States, 2013).

Instructional scaffolds are critical during this transition from observation to explanation. As Nordine and Lee explain, Crosscutting Concepts function as shared language for sense-making, so word banks that shift students from everyday terms like “parts” to Structure and Function language, along with sentence frames and partner discussions, support students in explaining relationships rather than simply naming components (2021). This mirrors the instructional strategies modeled in Andersen’s structure and function resources, which emphasize guiding students to explain how and why specific structural features enable function rather than naming features in isolation (Andersen, 2022a). These same principles are reinforced in Andersen’s accompanying instructional materials (Andersen, 2022b).

Students then transfer this reasoning to commercial aircraft, explaining how wings, flaps, and engines support lift, control, and propulsion, demonstrating progression from component identification to system-level explanation. Real-world connections further strengthen Structure and Function reasoning. Real-world applications further strengthen this

reasoning, such as when students analyze NASA’s Artemis II mission to examine how capsule shape, heat shields, and rocket stages serve specific functions related to launch, protection, and safe return. Across the course, repeated reinforcement of Structure and Function anchors student thinking and supports deeper understanding as systems increase in complexity over time (Nordine & Lee, 2021).

After students understand how structures are designed for functions, Cause and Effect is introduced to help them explain what happens when conditions change within a system. At this point in the sequence and learning progression, students are ready to move beyond identifying components and begin analyzing the processes and mechanisms that produce observable outcomes. Students investigate how altering a structure, mass, or environmental conditions affects system performance, for instance how changes in fin size or placement impact rocket stability or how added mass influences aircraft takeoff. Instruction focused on Cause and Effect shifts student thinking from noticing patterns to interrogating why those patterns occur and what mechanisms are responsible.

Classroom evidence shows that without explicit support, students often base their explanations on what is first observed or what feels familiar, which can lead to incorrect conclusions. This becomes clear during investigations including building a simple barometer, where students initially assume the straw moves because something inside the jar changes, rather than recognizing that the movement is caused by changes in outside air pressure acting on the system. Explicit Cause and Effect instruction helps students identify the actual mechanism at work rather than attributing outcomes to coincidence or the most recent event they notice (Nordine & Lee, 2021).

Instructional supports such as claim–evidence–reasoning (CER) structures, T-charts, and guided team discussions are essential at this stage because they slow down student

thinking and require evidence-based justification. Multimedia resources created by Paul Andersen through Bozeman Science reinforce that for one event to cause another, there must be a clear interaction or mechanism linking them, not just correlation (Andersen, 2013). This emphasis on mechanism aligns with guidance from the National Science Teaching Association (NSTA, 2013).

With cause-and-effect relationships established, students are ready to engage with Systems and System Models, which shifts their focus from individual components to understanding how multiple parts interact within a defined system. Systems and System Models build directly on Cause and Effect by helping students see how several cause-and-effect relationships operate together rather than in isolation. Students define system boundaries, identify components, and trace inputs and outputs using simplified diagrams of aircraft systems. For example, students create system models that show how pilots' inputs, engines, control surfaces, fuel, and external forces interact to influence aircraft behavior.

This modeling process makes system interactions visible and supports deeper sense-making beyond isolated cause-and-effect statements (Nordine & Lee, 2021). As students work with system diagrams, they are required to coordinate multiple relationships at the same time, such as how changes to one component affect other parts of the system. Scaffolds are essential as students engage in this more complex reasoning such as labeled templates, explicit system boundary definitions, and structured group roles. Through modeling a range of systems, including aircraft, bristlebots, and neurons, students recognize common system features across different contexts, such as inputs, internal interactions, outputs, and flows of energy or information. Comparing these systems helped students understand that even small changes in one component can alter the behavior of the entire system. Teaching Systems and System Models after Cause and Effect supports students in

integrating multiple relationships (Andersen, 2013). This sequencing also aligns with learning progression and sense-making (Nordine & Lee, 2021).

Energy and Matter is introduced once students have a clear system model in place, allowing them to trace how energy moves through a system and how matter is conserved as interactions occur. With system boundaries already established, students are positioned to identify inputs, outputs, and transformations in ways that support sense-making rather than treating energy and matter as abstract ideas. Hands-on investigations, such as building a simple barometer, help students visualize processes that are not directly observable by showing how air movement and pressure result in visible change. Graphic organizers support students in identifying energy inputs, transformations, and matter movement, reinforcing that matter is conserved while energy flows through a system. Classroom phenomena such as the DIY barometer activity further reinforce this understanding. In this system, the air inside and outside the jar represents matter, while changes in air pressure represent energy acting on the system. These kinds of visuals are used in classroom phenomena, such as tracking how air pressure affects motion, to support student sense-making (Earth to Space Science, 2018). Teaching Energy and Matter after Systems and System Models helps students understand not only what is happening within a system, but where energy is moving and why those pathways matter, allowing them to move beyond memorizing conservation statements toward explaining real-world phenomena using evidence-based reasoning. This sequencing supports learning progression by building from concrete system interactions toward more abstract conservation principles that students will revisit and deepen in later grades (Nordine & Lee, 2021).

Stability and Change follows Energy and Matter because students now have the conceptual tools needed to explain why systems remain stable under certain conditions and how changes over time can disrupt that stability. At this point in the sequence and learning

progression, students are able to reason about equilibrium, feedback, and rates of change rather than viewing systems as static. Students analyze how balance, feedback, and environmental conditions support stable flight and how changes in mass, fuel, wind, or operating limits can disrupt equilibrium. Scenario cards, sorting activities, and discussion protocols support students in reasoning about gradual versus rapid change and in recognizing that stability is conditional rather than permanent (Nordine & Lee, 2021). This reasoning is extended through environmental and engineering contexts. In examining coral reef bleaching as an anchor phenomenon, students investigate the reef as a system that includes coral, symbiotic algae, ocean temperature, sunlight, and surrounding environmental conditions. When ocean temperatures remain within a tolerable range, this relationship supports system stability. When ocean temperatures rise even slightly for extended periods, the coral becomes stressed and expels its symbiotic algae, disrupting energy flow and leading to bleaching. This change does not occur immediately, helping students understand that systems can appear stable while undergoing slow change before visible disruption occurs. Similar reasoning is applied in aviation examples, where an aircraft may appear stable in flight but relies on continuous feedback such as weight-and-balance calculations and fuel monitoring and maintaining equilibrium only within defined limits. Teaching Stability and Change after Energy and Matter supports deeper sense-making by helping students explain how systems respond to disturbances over time (Andersen, 2013). This sequencing also aligns with research showing that small changes in conditions can lead to large-scale, long-term effects within systems (Nordine & Lee, 2021).

Finally, Scale, Proportion, and Quantity is positioned as a capstone Crosscutting Concept because it requires abstract reasoning that depends on prior understanding of other CCCs. Meaningful engagement with scale, proportional relationships, and quantity is most accessible after students have established conceptual foundations in Patterns, Structure and

Function, Cause and Effect, Systems and System Models, Energy and Matter, and Stability and Change. When numerical relationships tied to scale, proportion and quantity are introduced to early, they can overwhelm students; introduced later, they function as tools for explanation rather than procedural requirements (Nordine & Lee, 2021). Within the aerospace curriculum, students compare model rockets to full-scale rockets, examine proportional relationships between wingspan and lift, and analyze how mass relates to thrust and system constraints. These tasks require students to reason about size, distance, and quantity in relation to real systems rather than applying equations in isolation. Visual representations, ratio language, guided comparisons, and the Scale, Proportion, and Quantity graphic organizer support quantitative sense-making by helping students connect numerical relationships to the structures and systems they already understand. As a capstone, this CCC synthesizes the entire sequence and helps students use numbers to explain how a system works rather than just following steps to get an answer.

In final section, two research-based patterns across instructional strategies stand out for supporting equitable and liberatory science teaching. Patterns are well suited to equitable and liberatory science teaching because they build on ways students already make sense of the world in their homes, communities, and schools. Students notice patterns in everyday life, including changes in weather, how objects move, and how routines repeat over time. Students ask questions like, “Why does this happen?” and “Why does this work this way?” These questions help students make sense of the world around them and lived experiences.

Teaching Patterns as an entry point validates students’ lived experiences as starting points for meaningful and accessible scientific practice.

After students engage in patterns rooted in their lived experiences, Structure and Function supports equitable science learning by helping students turn those observations into explanations. Structure and Function invites students to make sense of systems by asking why

something is shaped the way it is and what purposes its features serve. This approach supports multiple modes of sense-making, including observation, explanation, and connection to everyday objects. For example, the structure of a fork has more than one function, allowing students to consider how shape supports different uses. Similarly, students observe that different birds eat different foods and have different beak shapes, which helps them explain how structure supports function across living systems.

References:

- Andersen, P. (2013, January 16). Crosscutting concept 4: Systems and system models [Video]. YouTube. https://www.youtube.com/watch?v=8kj__V8ehDU
- Andersen, P. (2013, January 17). Crosscutting concept 5: Matter and energy—Flows, cycles, and conservation [Video]. YouTube. <https://www.youtube.com/watch?v=U22h55dHii0>
- Andersen, P. (2013, February 10). Crosscutting concept 7: Stability and change [Video]. YouTube. <https://www.youtube.com/watch?v=EMiHXXUlh6c>
- Andersen, P. (2022, March 28). *Thinking in structure and function – Level 1. The Wonder of Science*. [Video]. YouTube. <https://thewonderofscience.com/mlccc61>
- Andersen, P. (2022a, March 28). *Thinking in structure and function – Level 1: Structure and function* [Video]. YouTube. <https://www.youtube.com/watch?v=PyROFvp7rGk>
- Andersen, P. (2022b, March 28). *Thinking in structure and function – Level 1: Structure and function* [Google Slides]. Google Slides. https://docs.google.com/presentation/d/1PLA95tV_PQXxcjxq_iRzSABFoxaDXP-Jw3iilw18sPY/template/preview
- Andersen, P. (2022, March 29). *Describing scale* [Video]. YouTube. <https://www.youtube.com/watch?v=LgSBGwAOFrk>
- Earth to Space Science. (2018, September 11). *How to Build Your Own Barometer! Easy project to track weather changes* [Video]. YouTube.
- National Science Teaching Association. (2013). *Next Generation Science Standards crosscutting concepts: Cause and effect: Mechanism and explanation* [Video]. YouTube. https://www.youtube.com/watch?v=_Z8JmmJfE7o
- NGSS Lead States. (2013). *MS-ETS1 engineering design*. Next Generation Science Standards. <https://www.nextgenscience.org/dci-arrangement/ms-ets1-engineering-design>
- Nordine, J. & Lee, O. (2021). *Crosscutting concepts: Strengthening science and engineering learning*. NSTA Press; Washington.