Instructional Segment 1 Teacher Background and Instructional Suggestions

The crosscutting concept of ***Systems and System Models*** is a very useful tool that can help learners to connect ideas within a topic and also across science disciplines. Integrated Grade 6 provides ideal opportunities for students to experience the value of this crosscutting concept and to deepen students' abilities to **use and develop system models**. Planet Earth, cells, and organisms are key contexts for the disciplinary core ideas within California Integrated Grade 6. These topics serve as excellent examples of ***systems*** because each of these systems has a fairly well-defined boundary, and each system also has recognizable component parts.

Figure 2 illustrates one of the key NGSS understandings about ***systems*** at the middle school level. As described in NGSS, "Systems may interact with other systems; they may have subsystems and be a part of larger more complex systems." The components of a system are generally themselves systems that are made of parts. Body systems provide great examples of this feature of "systems within systems within systems."

Systems Within Systems Within Systems

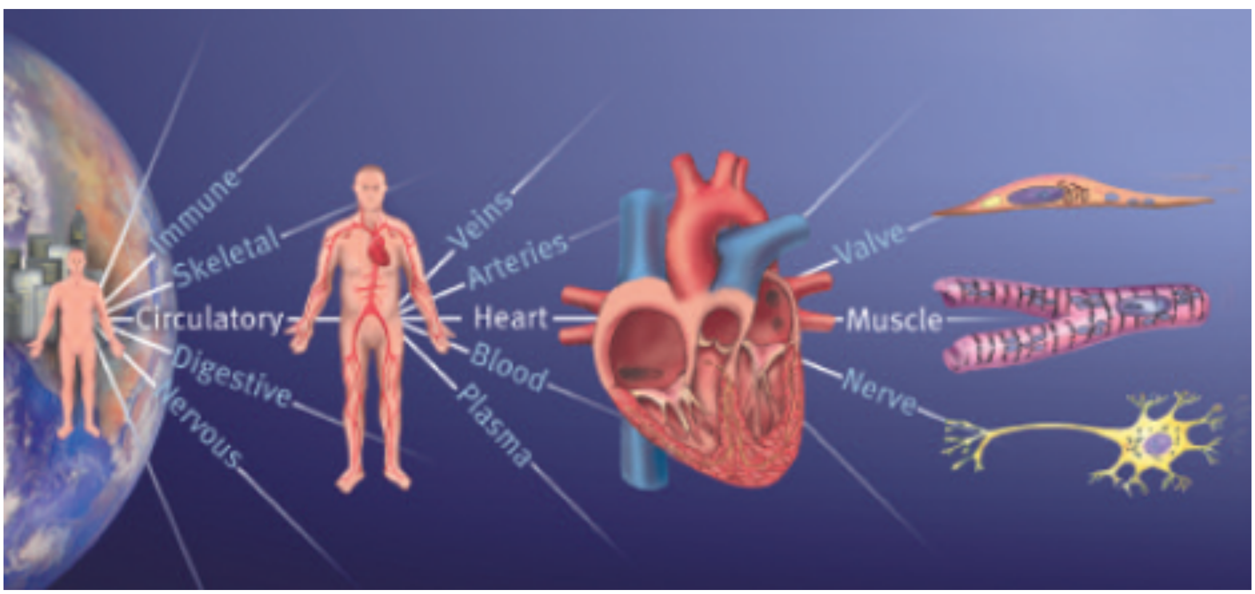

Figure 2: Body systems, such as the circulatory system, are examples of systems within systems within systems. (Illustration from *Dr. Art's Guide to Planet Earth* courtesy of WestEd)

Students can **cite the circulatory system as evidence** that a person consists of body systems that are made of organs (e.g., the heart) that are made of tissues that are made of cells. An analogous situation applies with respect to ***Earth systems***. In Grade 5 students learned that planet Earth has four major systems:

* the geosphere (solid and molten rock, soil, and sediment);

* the hydrosphere (water and ice);

* the atmosphere (air); and

* the biosphere (living things, including humans).

An emphasis on planet Earth as a ***whole system*** marks a significant progression from middle school beyond the fifth grade level. From the “whole Earth” perspective, each of the Earth systems learned in fifth grade is now viewed as a component or subsystem of the larger scale planet system. Learners of all ages generally expect that definitions, especially in science, should be precise and either/or – that the geosphere, for example, is *either* its own system *or* a component of a larger system, but not both at the same time. Older grade levels in science often mark an advance beyond rigid “either/or” thinking toward “both/and” nuances and complexity. Students can **explain** how the geosphere is an example of being *both* an Earth system made of parts, *and* also a subsystem/component of the planet Earth system.

System models are tools that scientists use to develop and share their understanding of the natural world. In using this tool, scientists, educators and learners have some flexibility in choosing the system boundaries and components depending on the purposes of their investigation. For example, a scientist who specializes in researching glaciers might describe Earth as having five major systems: geosphere, hydrosphere (just liquid water), cryosphere (Earth’s ice), atmosphere and biosphere. A scientist who specializes in researching the effects of human activities on the natural world might describing five Earth systems as: geosphere (solid and molten rock), hydrosphere (liquid and solid water), atmosphere, biosphere, and anthroposphere (human societies and their interactions with the natural world). While this adaptability is one of the strengths of systems modeling, it does present a challenge for learners who are trying to figure out what a system is.

Teaching about ***systems*** can begin by asking students to work individually and then in small groups to describe what systems they know about, and how they might **explain** what a system is. One typical kind of response is to equate systems with cycles such as a life cycle or a collection of circles like the solar system. This view gets broadened when other students provide examples of systems that are linear procedures to accomplish something, such as Emily's daily system for preparing to go to school (see Figure 3).

Emily's School Preparation System

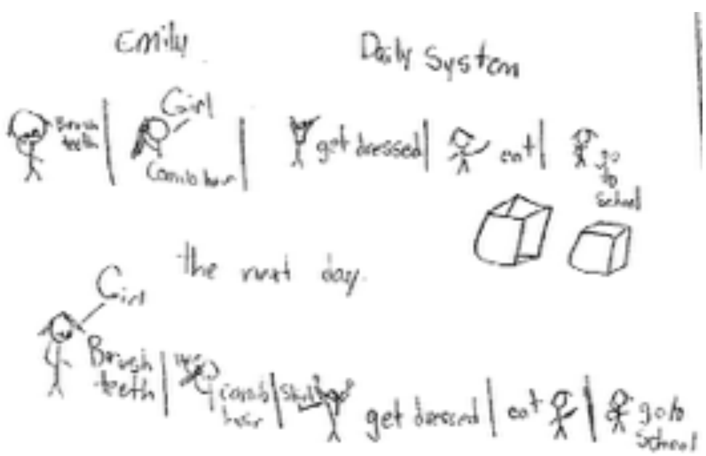

Figure 3: Emily's daily system to prepare for school. (Illustration from Making Sense of Science *Earth Systems* professional development course, courtesy of WestEd)

Student-generated or teacher-seeded examples of sound systems, computer systems, ecosystems, and body systems can help students to transition toward a broader consideration of systems. The teacher can then provide a background reading/writing assignment that establishes a working definition of a system as a group of things that connect or interact to form a whole. That reading also would emphasize five important features of ***systems***: boundaries, components, interactions, inputs/outputs, and one or more system properties.

Figure 4 illustrates these five ***system*** features as applied to a human person. Usually the components of a system are the easiest to identify. Some system boundaries are very obvious, as in this example, while others may require more thought. The systems modeler (scientist, teacher, student) has the most freedom in choosing the boundaries of the system based upon the goal of the modeling. In studying water, Table 3 indicates the boundaries that different people might choose because of the different goals of their investigations.

Features of Systems

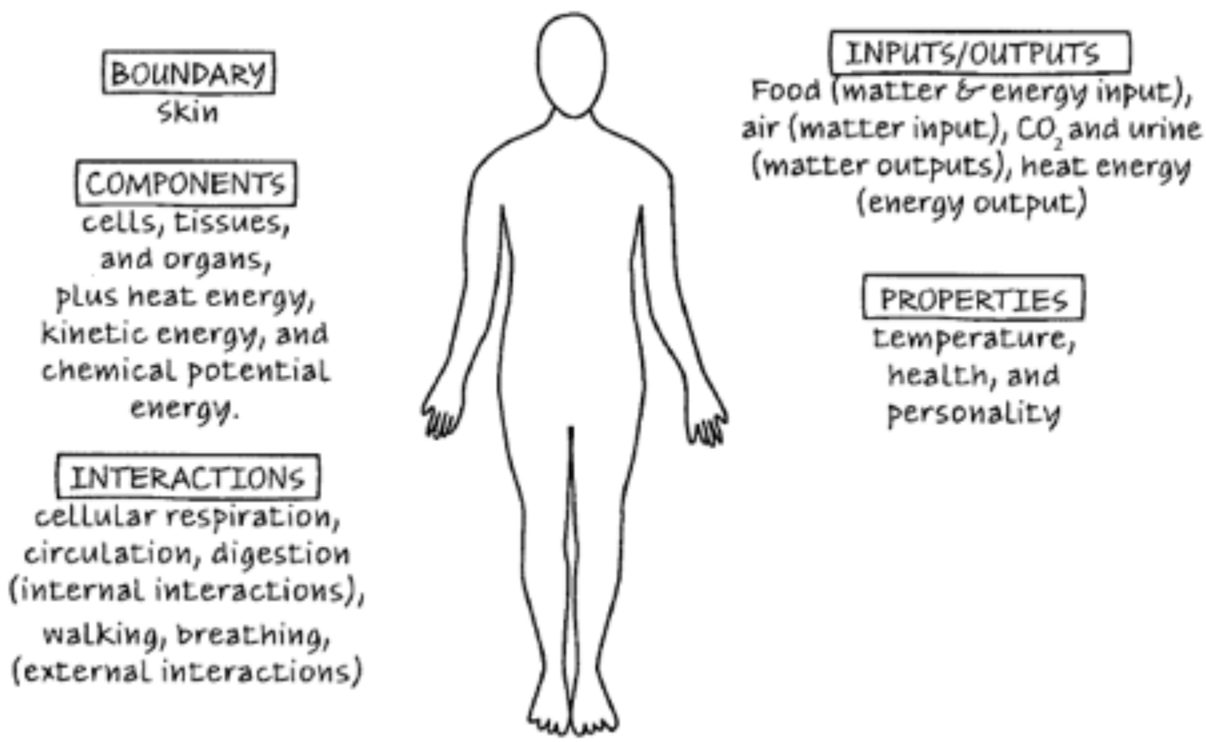

Figure 4: Features of a human person system. (Illustration adapted from Making Sense of Science *Weather and Climate* professional development course, courtesy of WestEd)

TABLE 3: Different System Boundaries for Investigating Water on Earth	
Investigation Topic	**System Boundary**
Changes in the water cycle due to global warming	Planet Earth
Using solar power to desalinate ocean water	A sunny beach on an island
Getting freshwater for a farm	Underground wells on the farm
Cleaning a city's sewage before it drains into the ocean	Output from city sewage facility
Surfing at the beginning and end of the day	Wave patterns on local beaches

(Table 3 by Dr. Art Sussman, Courtesy of WestEd)

Using the guidelines provided by the working definition of a ***system*** and the five highlighted system features, the teacher can guide students to work in groups on **analyzing** and **modeling** different kinds of systems. These groups can then share with each other through gallery walks and other pedagogical methods to extend and deepen student proficiencies with respect to systems modeling. In IS 1, life science can provide many examples based on cells and on body systems. IS 2 provides additional detailed examples with respect to the water cycle and weather systems that then deepen student understanding of systems and system modeling as a crosscutting concept that applies in multiple disciplines. (The EEI Curriculum unit, Changing States: Water, Natural Systems, and Human Communities provides a variety of resources that can support this instruction.)

Properties of Whole Systems

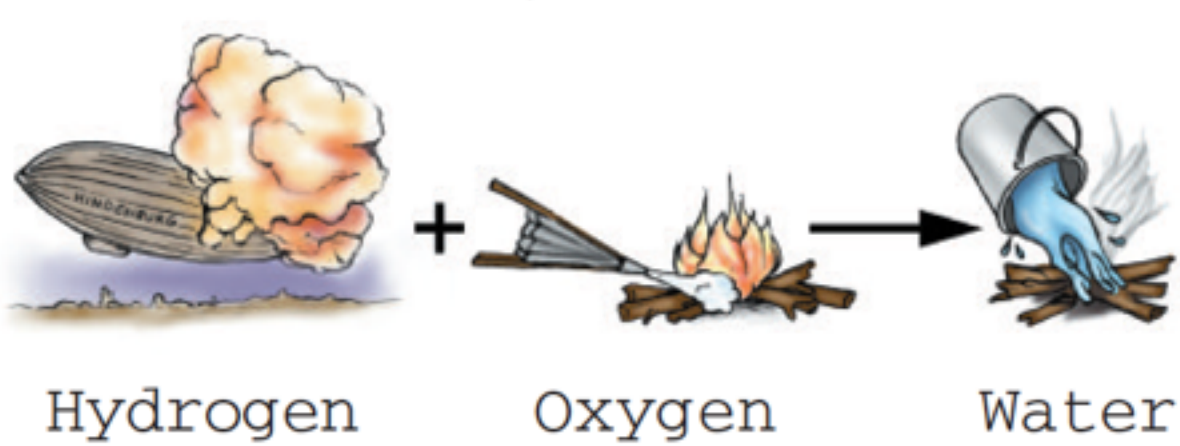

Figure 5: A whole system can have properties that are qualitatively very different than the properties of its parts. (Illustration from *Dr. Art's Guide to Planet Earth* courtesy of WestEd)

Students may initially struggle in describing a property of the ***whole system***. In part this difficulty can arise because the property of the whole system is often very different from the property of any of its parts. H_2O, the star of the water cycle, is a particularly good example of how different a whole system can be from its parts (Figure 5). The component parts of H_2O are hydrogen and oxygen. Hydrogen is a gas that explodes. Oxygen is a gas that is necessary for fire. Combining these two gases produces a new system, a liquid that extinguishes fires.

Cells provide interesting examples of ***systems*** to study. The boundary of a cell is obvious, and the presence of a cell wall provides a useful way to differentiate plant cells from animal cells. For NGSS middle school, the assessed components are limited to the outer boundary, the nucleus, the chloroplast (site of photosynthesis) and the mitochondria (site of cellular respiration). The interactions, inputs and outputs vary depending on whether the cell is a unicellular organism, or a specialized cell within a multicellular organism.

The cell is often described as the building block of life. Students can be challenged to **describe and explain** a whole system property of a cell. Perhaps they will need prompting, but students should be able to explain that being alive is a property that the whole cell has that none of the cell parts by themselves have. The property of being alive ***arises from the interactions*** of all the parts of the cell with each other and with the environment. This system property of life is equally true for a multicellular organism. That organism's property of being alive is ***caused by*** and depends upon the interactions of its vital body systems with each other and with the environment.

Engineering Connection

Teaching about organ and tissue donation provides opportunities to connect learning about body ***systems*** with a socially beneficial topic that also has strong connections with engineering and technology. Donate Life California has an informative website that includes educator resources, notably an Interactive Body Tour (http://www.donatelifecalifornia.org/education/how-donation-works).

Students can work in groups to **research** and learn about organ and tissue donation related to different body systems and diseases. They can **create *system diagrams*** related to the different diseases and transplantation remedies as well as representing the system for soliciting donors, identifying recipients, and getting the organs/tissues to the patients in excellent condition and within the necessary **criteria and time constraints**.

If motivated in this direction, students can also **analyze** the outreach with respect to educating and motivating people to become donors. This enrollment of donors can also be analyzed as a system wherein students identify constraints and **propose solutions** to increase the number of people who volunteer to become donors. This kind of ***system modeling*** extends the crosscutting concept beyond physical science and engineering into applications of science intermixed with social science perspectives.