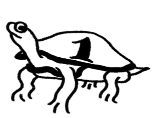
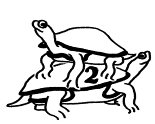
Carbon Time Turtle Trails

One of the core goals we aim to meet as K-12 science educators is to help students develop the capacity to understand and use scientific explanations to make sense of the world. While not an easy goal, it seems like this should at least be a straightforward goal. For example, *NGSS* boils it down to four words in the practice, “construct explanations for science.” However, when we dig into the question of exactly *which* scientific explanations students should be able to construct, things can get very complex very quickly!

Part of the problem has to do with the fact that phenomena in the material world can be understood and explained in less and more “deep” ways. For instance, we can very simply categorize states of matter as solids, liquids and gases. Or, we could describe characteristics of states of matter at the atomic-molecular scale. Or, we could delve even deeper and talk about matter using ideas about subatomic particles, wave-particle duality, and string theory!

The *Carbon TIME* project addresses this problem of identifying the appropriate level of complexity of scientific explanations in two ways. First, the project has designated a set of content simplifications that are applied consistently throughout *Carbon TIME* instruction. These simplifications are based on extensive research on student understanding and learning and are designed to meet four instructional criteria including: comprehensibility, efficiency, consistency and productivity for future learning. An explanation of the general simplifications made in the project may be found in the document, *Carbon TIME* Content Simplifications.

Our second approach to addressing levels of complexity in *Carbon TIME* content involves Turtle Trails, which designate several instructional pathways (less and more complex) that teachers may choose to follow with their classes. As you review and use the 2016-17 versions of *Carbon TIME* units, you will notice that some activities are identified with one, two or three turtles. As a teacher, it will be up to you to use your knowledge of your students and of your district-adopted standards to decide which turtle trail to follow. (Note if there are no turtles attached to a lesson or activity, then there is only one version for all students.)

	**1 Turtle Activities** designate a less complex instructional trail. All students engaged in *Carbon TIME* learning should be held responsible for explanations and performances in 1 Turtle Activities. These activities may be appropriate for middle school students who don’t have much experience constructing explanations at the atomic-molecular scale. 1 Turtle Activities often aim for atomic-molecular scale explanations that stop at the depth of distinguishing between small and large organic molecules.
	**2 Turtle Activities** designate a more complex instructional trail. These activities are appropriate for more advanced classes and students. 2 Turtle Activities generally go beyond distinguishing small and large organic molecules to, for example, differentiating polymers including starches, proteins and fats. In 2 Turtle Activities, biosynthesis is modeled as a 2-step process.
	**3 Turtles** designate information that goes beyond what is reasonable to hold high school students responsible for. An example is the Metabolic Pathways Poster, which provides a sense of the great complexity with which science can explain carbon-transforming processes in living organisms. 3 Turtle information may pique students’ interests in delving deeper into topics in the future. When providing *Carbon TIME* students with glimpses of 3 Turtle information, it will be important to make clear that they won’t be held accountable for such information on a test.

Are you wondering, “why turtles?” That’s a good question! The use of turtles to designate more and less complex pathways in the Carbon TIME curriculum comes from a metaphorical story illustrating the concept of *Anavastha* in Indian philosophy. *Anavastha* is a Sanskrit expression meaning that which is ungrounded or without a definite foundation (Drummond & Lal, 2006). The turtle story has many different versions. Here is one from anthropologist Clifford Geertz’s 1973 (pp. 28-29) book, *The Interpretation of Cultures.*

> “There is an Indian story – at least I heard of it as an Indian story – about an Englishman who, having been told that the world rested on a platform which rested on the back of an elephant, which rested in turn on the back of a turtle asked (perhaps he was an ethnographer; it is the way they behave), what did the turtle rest on? Another turtle. And that turtle? ‘Ah, Sahib, after that it is turtles all the way down.’”

The Indian wise man makes a point. The Englishman wants him to tell about the solid foundation on which everything rests, but the wise man suggests that he is looking in the wrong direction – there is no foundation more solid than what we see and experience here on the surface. We can dig deeper and deeper, through those “turtles all the way down,” but we will never get to a foundation underneath the last turtle.

So, science is like that. We can extend our experience by collecting more precise data using more powerful instruments, and we can reduce it to order by developing deeper and more comprehensive laws and theories, but we never will get to that last turtle – the law or theory on which everything else is based.

The implication of “turtles all the way down” for science teaching is that there is no absolute definition of understanding. Children arrive in school already understanding some important things about the material world, based on their experiences with objects, materials, plants and animals. Our task as science teachers is to help them “extend their experience and reduce it to order” (Bohr quoted in Hawkins, 1990, p. 100). In the process, we can help them see and understand the “next turtle down” in the great edifice of laws and theories that modern science has constructed.

While it is often enticing as science educators to try to delve “another turtle down” in our lessons, there can be negative consequences to going deeper than students are ready for. For example, going too many turtles down can lead to things like procedural display (e.g., students memorizing without understanding, or doing what the teacher says in order to get a good grade) and/or the belief that science isn’t about the normal world we live in and experiences in our everyday lives.

Thus, while there will always be more turtles to explore, as science teachers we can seek to do two important things. We can help students develop deeper understanding than what they begin with when they enter our classrooms, AND we can help prepare students to examine deeper layers of turtles in future science learning experiences in later grade levels, higher education, and their personal and/or professional lives beyond.

References

Drummond, M. & Lal, Y. (2006). *Buddhist thought and applied psychological research*. London: Routledge.

Geertz, Clifford. (1973). *The interpretation of cultures: Selected essays*. Vol. 5019. Basic books.

Hawkins, D. (1990). Defining and bridging the gap. In E. Duckworth, J. Easley, D. Hawkins & A. Henriques (Eds.), *Science education: A minds-on approach for the elementary years* (pp. 97-139). Hillsdale, NJ: Erlbaum Associates.