Educator Resource: Students' Learning Progressions for the *Decomposers* Unit

The *Carbon TIME* curriculum is based on learning progression research. Learning progressions are descriptions of the informal and then successively more sophisticated (scientific) ways that students reason about phenomena. *Carbon TIME* researchers have investigated how students understand and learn to make sense of carbon-transforming processes. You will find many of our publications and presentations under the Research Tab on the *Carbon TIME* website. (See, for example, Learning Progressions and Climate Change, by Joyce Parker, et al.)

Here, we offer a brief overview of the specific learning challenges that your students are likely to face as they study the *Decomposers* Unit. We focus on students' practices associated with their roles as questioners, investigators, and explainers.

Students as Questioners

Some students are curious about decomposers and decay and have lots of questions, other students less so. But even curious students must learn how to ask scientifically productive questions. Students' questions play an essential role as they work on the Expressing Ideas and Questions Tool and the Evidence-based Arguments Tool.

The Expressing Ideas and Questions Tool asks students for their questions, and consensus questions are an important outcome for this discourse routine. These questions will drive later activities and discussions. However, you may find few productive questions among the questions that students initially pose. The most productive questions for the unit ask about *mechanisms* (e.g., What's happening inside the bread mold?) and about *tracing matter and energy* (e.g., How are materials moved around and changed when bread molds?). In contrast, many students start with "wondering questions" about health and diet (e.g., Is it dangerous to eat moldy bread?) or about conditions for decay (e.g., How can you keep bread from getting moldy?).

Though you do not want to discourage students' "wondering questions," there are ways to help students identify productive questions on mechanisms and tracing matter and energy. For example:

- Students at Learning Progression Level 2 are likely to think of decomposition as a natural process that "uses up" or destroys food and dead organisms. You can remind students about conservation principles that lead to productive questions: The matter in the bread *must* go somewhere. Where might it be going? The matter in the mold *must* come from somewhere? Where is it coming from and how is it changing?
- Students may have ideas about whether decomposers exchange O_2 and CO_2 like animals and plants, but students rarely identify questions to ask about how this process works. You can encourage students to refine their questions by thinking about the Three Questions and accompanying rules that they studied in *Systems and Scale, Animals,* and *Plants:* If atoms last forever, then O_2 can't just change into CO_2. Where did the carbon atoms come from?
- It can be helpful to draw students' attention to questions about what obviously must be chemical changes as decaying materials go away and as mold grows.

Later in the unit, students completing the Evidence-based Arguments Tool generally need help identifying questions that result from limitations in their investigations and results. For example, the investigation provides evidence about matter and energy that go into or come out

of the moldy bread (macroscopic scale), but not about how they are being changed inside the moldy bread (atomic-molecular scale). Encouraging as-yet unanswered questions about how matter and energy change inside the moldy bread prepares students to answer those questions through the subsequent molecular modeling activities.

Students as Investigators

Students are naturally inclined to pursue "engineering investigations" about how different conditions affect how fast and what kinds of molds grow on bread, but not "matter-tracing investigations" about how matter and energy are moving through and transformed in the bread-mold system. In fact, it will be hard for many students to see how their investigations can answer questions about mechanisms or tracing matter and energy. It is especially important for students to figure out how their tools—the digital balances, BTB, and their senses—can be used to trace movements and changes in matter and energy.

- The digital balance is a *matter movement detection tool:* The rules on the Three Questions say that matter (solids, liquids, or gases) MUST be moving out of a system that loses mass and MUST be moving into a system that gains mass. Most students are pretty good at applying this reasoning to solids and liquids: They notice that the moldy bread loses mass. But they struggle to interpret evidence about movement of gases: If the bread-mold system loses mass, then gases MUST be leaving the system.
- BTB is a *matter change detection tool:* If the amount of CO_2 in the air goes up, then it is probably coming from the bread mold, so there must be a chemical change that is producing the CO_2.
- The students' senses are *energy change detection tools:* Student can see the mold growing; this can lead to questions about whether there is chemical energy in the mold, and where it might have come from.

When students are using the Predictions and Planning Tool to plan their investigations, they need help to see how they can use the digital balance, BTB, and their senses to provide evidence that addresses the Three Questions about matter movement, matter change, and energy. And when they are using the Evidence-based Arguments Tool, they need help to see how their evidence provides them with partial, but not complete, answers to the Three Questions.

Students as Explainers

Our learning progression research shows three levels as students become more scientifically sophisticated in their explanations:

- *Force-dynamic explanations* (Learning Progression Level 2) do not attempt to trace matter and energy at all and pay more attention to decaying materials than to the decomposers that cause the decay. They explain decay as a natural process that happens when actors such as plants and animals die and gradually disappear. In the Big Idea Probe about what happens to a leaf pack in the soil, Jessie ("I think the leaf pack will lose mass because the leaves will naturally break down and the mass will disappear.") and Mei ("I think the leaf pack will lose mass to the soil because the leaves are dead, so they'll decay into the soil over time.") express Level 2 ideas.
- *Incomplete matter-tracing explanations* (Learning Progression Level 3) recognize that decomposers are growing and causing decay. They may try to trace matter and energy, but without following all the rules of the Three Questions. You will likely see students' Level 3 explanations on the Expressing Ideas Tool, where students agree with Marco ("I think the leaf pack will gain mass because decomposers from the soil will grow on the leaves.") or Kara ("I think the mass of the leaf pack will stay about the same because the

decomposers will gain mass while the leaves will lose mass."). Level 3 explanations commonly focus on solids and liquids, but not gases. So they recognize that decay returns nutrients to the soil, but not that carbon from decaying materials goes into the atmosphere in CO_2.

- *Complete matter and energy-tracing explanations* (Learning Progression Level 4) answer the Three Questions while following the rules. On the Big Ideas Probe, students who understand Level 4 explanations will agree ONLY with Andre ("I think the leaf pack will lose mass to the air because decomposers under the rock will use the leaves for cellular respiration.").

The activities and tools in Lessons 4, 5, and 6, including the molecular modeling activities, the Explanations Tools, and the readings and worksheets in Lesson 6, are all designed to scaffold the students' explanations as they make the difficult progression from Level 2 to Level 4 explanations.