

Learning Progressions for Environmental Science Literacy

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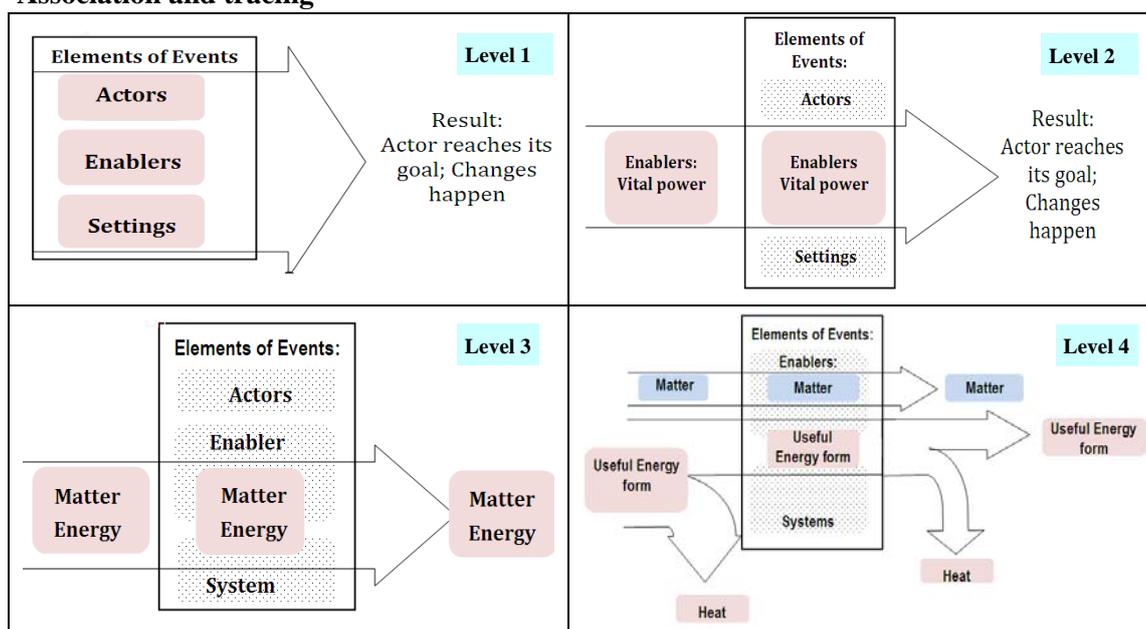
Research Overview

We are developing a learning progression—a sequence of levels of achievement supported by assessments and teaching experiments—extending from upper elementary school through college, focusing on key carbon-transforming processes in socio-ecological systems at multiple scales. These processes: (a) create organic carbon (photosynthesis), (b) transform organic carbon (biosynthesis, digestion, food webs, carbon sequestration), and (c) oxidize organic carbon (cellular respiration, combustion). Our Upper Anchor or learning goal is represented in the Loop Diagram below: linking carbon-transforming processes at atomic-molecular, macroscopic, and global scales with conservation of matter and energy as constraints.

Our products include:

1. A learning progression framework describing increasingly sophisticated ways of reasoning. This framework describes essential transitions in discourse (from force-dynamic to scientific reasoning) and in accounts using concepts of matter, energy, and scale.
2. Associated assessments eliciting students' reasoning, including validated written assessments and clinical interviews.
3. Teaching modules and Tools for Reasoning designed to facilitate the transition from informal reasoning towards scientific reasoning

Association and tracing



Learning Progression Framework

Explaining			Naming	
	Association	Tracing		
Level 4	<p>Energy</p> <ul style="list-style-type: none"> Associate energy with energy indicators consistently; Identify energy sources correctly Energy clearly and consistently distinguished from matter and from other enablers such as conditions 	<p>Trace energy at atomic-molecular and global scales successfully</p> <ul style="list-style-type: none"> Trace energy with degradation and separately from matter in carbon-transforming processes across scales. 	Level 4	<p>Scientific statements</p> <ul style="list-style-type: none"> MATTER: scientifically appropriate names for both reactants and products; both gases and solids/liquids named as material reactants or products ENERGY: all forms of energy involved in the chemical change; heat as byproduct
Level 3	<p>Energy</p> <ul style="list-style-type: none"> Associate energy with energy indicators including unobvious indicators such as familiar organic molecules, but may identify other substances as energy sources or do not distinguish energy and organic molecules. 	<p>Trace energy at atomic-molecular and global scales unsuccessfully:</p> <ul style="list-style-type: none"> Trace energy without degradation in large-scale systems such as ecosystems (e.g., energy recycles). Trace energy and matter but with confusion about labels (e.g., glucose is energy; ATP is energy) and or matter-energy conversions (e.g., fuel is converted to heat and light in flame) Describe energy transformation correctly but cannot connect that to matter transformation in chemical reaction 	Level 3	<p>Scientific words of organic molecules, energy forms, and chemical change</p> <ul style="list-style-type: none"> MATTER (organic molecules): glucose, C₆H₁₂O₆, monosaccharide, glycogen, lipid, ATP, ADP, carbohydrate, hydrocarbon, octane; ENERGY (bonds, energy forms): C-C bond, C-H bond, light energy, <i>kinetic energy (American version)</i>, electrical energy, chemical energy, heat energy PROCESS (chemical reaction): <i>cellular respiration (American version)</i>, <i>combustion (American version)</i>, oxidation, light reaction, dark reaction
			Level 2.5	<p>Easier scientific words with mixed meanings</p> <ul style="list-style-type: none"> MATTER: Fat, sugar, starch, organic matter, carbon, molecule, atom ENERGY: stored energy, motion energy/□□ PROCESS: photosynthesis, decomposition/decomposer, chemical reaction/change, □□□□□□ OTHERS: chloroplast
Level 2	<p>Vital power:</p> <ul style="list-style-type: none"> Recognize that actors cannot create vital power and that they must gain vital power from enablers Recognize that enablers contain vital power (the notion of vital power is indicated in a list of words that students use such as energy, vitamin, nutrients, combustible, etc.) Associate energy with obvious indicators, but also hold the idea that all enablers are energy sources 	<p>Trace the power-result chain in uphill and downhill events:</p> <ul style="list-style-type: none"> Trace power/energy backwards but not forwards Actor gaining vital power/energy through hidden processes Vital power triggers hidden processes Actor losing vital power through hidden processes Can trace “energy” through food chains 	Level 2	<p>Hidden mechanism words</p> <ul style="list-style-type: none"> MATTER: carbon dioxide, oxygen, nutrients, gas (as in gas, liquid, and solid), ENERGY: calories, electricity PROCESS: digestion, digest, digestive system, break down OTHERS: bacteria, fungi, micro organisms), cell, power plants
			Level 1.5	<p>Easier hidden mechanism words</p> <ul style="list-style-type: none"> ACTOR: organs (e.g., lung, stomach, heart, etc.), machine parts (e.g., engine, cylinder, piston), material ENABLER: fuels (e.g., gasoline, diesel, oil, coal, petroleum), heat
Level 1	<p>Natural Ability:</p> <ul style="list-style-type: none"> Associate natural ability with elements of events such as actors, enablers, settings, aspects of processes, and so on. 	<p>Trace the macroscopic action-result chain in uphill and downhill events:</p> <ul style="list-style-type: none"> The actor uses its enablers to take action. As the result, it reaches its goals to keep alive, to grow, to keep burning, and so on. When the actor loses its natural ability or loses enablers, it changes towards the downhill direction. Do not trace any scientific entities behind the action-result chain. Actors and settings endure over time, but not materials (in chemical changes) or energy. 	Level 1.5	<p>Easier hidden mechanism words</p> <ul style="list-style-type: none"> ACTOR: organs (e.g., lung, stomach, heart, etc.), machine parts (e.g., engine, cylinder, piston), material ENABLER: fuels (e.g., gasoline, diesel, oil, coal, petroleum), heat
			Level 1	<p>Words about actors, enablers, and results</p> <ul style="list-style-type: none"> ACTOR: body parts (e.g., leaves, roots, leg, etc.) ENABLER: water, air, sunlight, food (e.g., food, milk, bread, etc.), bugs, wind, lighter, etc. RESULT: strong, healthy, grow, run, warm, etc.