Learning Progression-Based Reasoning Tools for Understanding Water Systems

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Presentation Outline

- Intro to Research and PD
- Intro to Water Systems Learning Progression
- Learning Progression-Based Instruction
  - Describe levels of achievement
  - For each level, provide example of Tool use to support student learning
  - Identify affordances of Tools
- Description of Future Directions

Challenges

- Water-related issues (e.g., climate change, population growth, land use patterns) threaten continuing supply of high-quality fresh water
- Collective action is required as citizens play various roles
  - Private: Consumer, worker
  - Public: Voter, advocate, elected official
- Public understanding of science of water systems is thin

Environmental Science Literacy

… is the capacity to understand and participate in evidence-based decision-making about socio-ecological systems.

Informed citizens can…

- Understand and evaluate arguments of experts
- Choose actions consistent with their values

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What We've Done

- Used research to articulate a learning progression (LP) describing span of students' ways of understanding water systems
- Identified that very few students, even by high school, have achieved water systems literacy
- Used LP to develop responsive instructional approaches and tools (e.g., Reasoning Tools) to help students develop water systems literacy

Reasoning Tools Project

- Working w/middle school teachers in AZ & MT
- Summer workshop to introduce teachers to…
  - Learning Progression (LP) Framework
  - LP-Based Formative Assessments to support eliciting, analyzing and responding to students' ideas
  - LP-Based Reasoning Tools to support development of more sophisticated water systems understandings
- During school year, teachers enact water instruction integrating above. We are collecting data as part of exploratory research to test and refine Tools.

Learning Progressions

"…are descriptions of the successively more sophisticated ways of thinking about a topic that can follow one another as children learn about and investigate a topic over a broad span of time (6 to 8 years)." (NRC, 2007)

LPs include…

- **Lower anchor:** Ideas and ways of viewing world that children bring to school
- **Upper anchor:** Scientific knowledge and practices needed for informed decision-making

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LPs Versus Standards

- Focus on students' ideas differs from traditional scope and sequence standards documents
- Traditional standards focus on what students should learn and when
- LPs recognize common conceptions students hold and challenges inherent in learning scientific concepts and discourse
  - Model of learning recognizes primary discourses, views learning science like learning a 2nd language

Lower Anchor: Force Dynamic Reasoning

- Linguistic theory (Pinker, 2007; Talmy, 1988)
- Perspective embedded in grammar that shapes how people talk, think and make sense of world
- Actors with purposes/needs confront antagonists (hindering forces)
- Events determined through interplay of countervailing powers
- Humans have most powers/abilities; non-living entities can be actors too
- Example: Tree's purpose is to grow. Enablers include sunlight, soil, and water. Antagonists include drought and logging.

Upper Anchor: Scientific Model-Based Reasoning

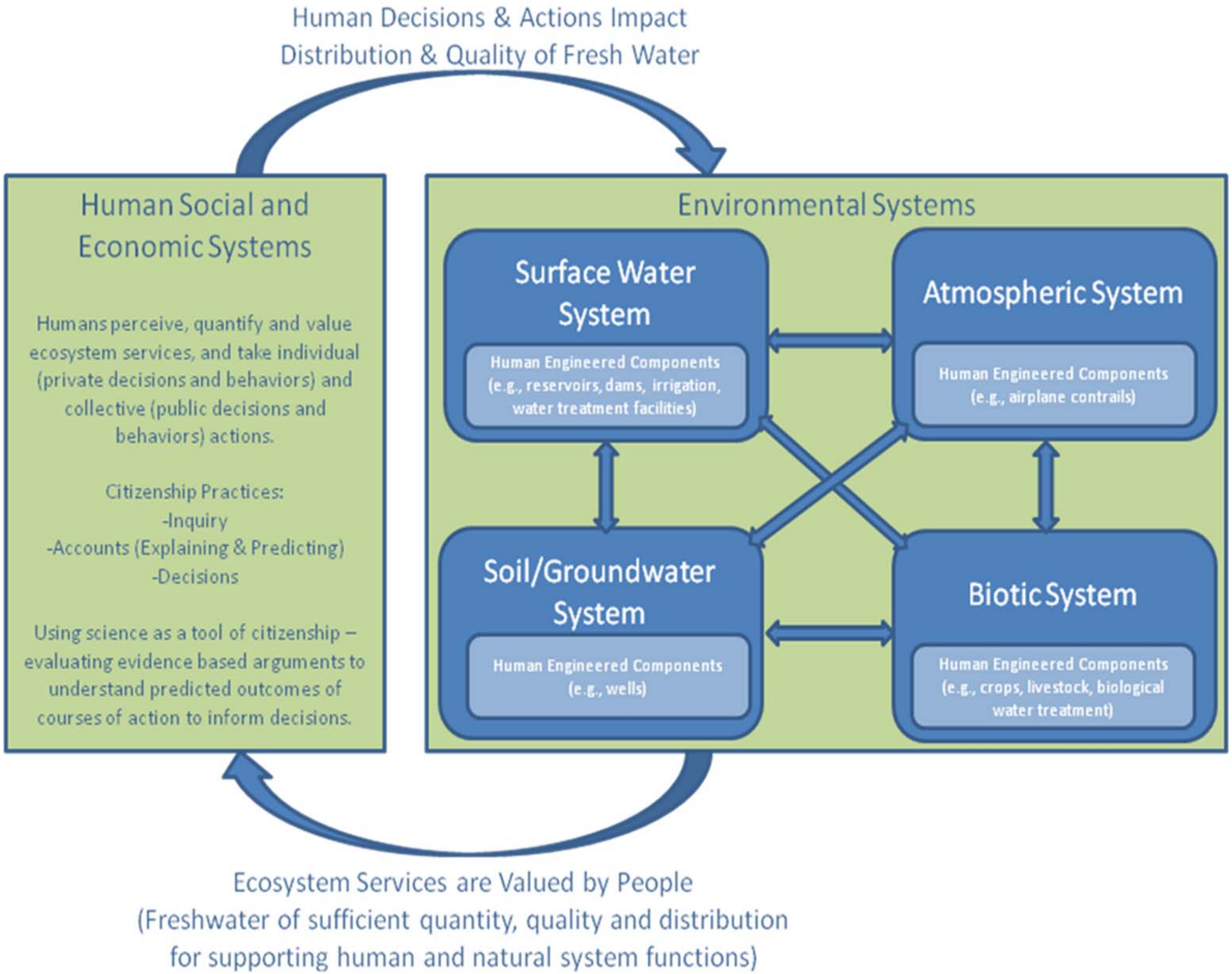
General

- Phenomena are parts of connected, dynamic systems that operate at multiple scales according to scientific principles
- Models are abstractions of systems that focus on key features to explain and predict scientific phenomena

Water

- Water and substances move through connected systems
- Pathways are constrained by
  - Laws (e.g., conservation of matter)
  - Forces (e.g., gravity, pressure)
  - Constraining variables (e.g., permeability, topography, solubility)

Upper Anchor Loop Diagram



Upper Anchor Loop Diagram

Levels of Achievement	Progress Variables	
	Moving Water	Substances in Water
4: Qualitative model-based accounts	• **Traces water through connected systems (multiple pathways/scales)** • **Applies principles that govern movement of water**	• Identifies and traces substances mixing, moving, and unmixing with water (multiple pathways/scales) • Applies principles to reasoning about substances in water
3: "School science" accounts	• **Tells school science narratives** • Has difficulty describing processes at atomic-molecular scale • Does not use principles	• Tells school science narratives • Has difficulty describing processes at atomic-molecular scale • Does not use principles
2: Force-dynamic accounts with mechanisms	• Recognizes water can move and that there are mechanisms moving water • **Uses force-dynamic thinking that invokes actors or enablers**	• Recognizes water quality can change • Thinks of water quality in terms of bad stuff mixed with water • Invokes actors or enablers to change water quality
1: Force-dynamic accounts	• Views water as part of the background setting for actors • **Does not view water in a location as connected to other water**	• Views water quality in terms of types of water (e.g. dirty water)

Level 1: Force Dynamic Accounts*

- Focus on human actions or concerns
- View water in different systems as unconnected
- Provide accounts of first-hand, visible observations
- Water can appear and disappear
- Actors can change/move water without need for mechanisms
- Representations (e.g., maps) viewed literally, rather than as representations of physical systems in world

*Note characteristics identify how students do reason about water, not just what's missing from their ideas

Level 1: Force Dynamic Accounts

Question	How does water get into a river?
Response	It could get into a river by being rained into it. [E]
Indicator	Source of water is immediately visible.

What Students Need To Work On…

- Expanding awareness beyond what's immediately visible
- Expanding understanding beyond simple water cycle diagram representation (one circular pathway)
- Experiences with how water systems are connected
- Conserving matter as it moves through systems

Pathways Tool

Before

Before

Before

After

After

After

Instructional Context: Exploration (with maps handy) of where water in the river in our town comes from and goes to

Pathways Tool

Before

Before

In a cloud above Idaho

In the groundwater

Snow on ground in Anaconda

Running off over the ground near Blackfoot River

Before

Falling as rain in E. Missoula

In groundwater near Milltown

Running off over the ground in Clinton

In Rattlesnake Creek

After

In Clark Fork River by Frenchtown

In the atmosphere

In Missoula Aquifer

After

In Clark Fork River near Superior

In a fish in the Clark Fork

In a Mountain Water Well in Missoula

In a cloud above Turah

After

In a Mountain Water pipe heading to my house

In my belly (I caught and ate the fish, but this is not very likely)

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Pathways Tool Affordances

Emphasizes…

- Multiple pathways
- Conservation of matter --- water must come from somewhere and go somewhere
- Invisible pathways
- Connections between systems

Scaffolds…

- Thinking across spans of time and space
- Social construction of understanding
- Opportunities for scientific argumentation

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Level 2:
Force Dynamic Accounts w/Mechanisms

- Describe connections among systems; but may be vague or inaccurate
- Describe simple and/or inaccurate mechanisms to move/change water (e.g., filter, water cycle)
- Use inanimate objects as agents to explain processes (e.g., clouds filter water)
- Water has natural tendencies (e.g., flow to connected places).
- Describe water quality in terms of objects in water (e.g., trash) or vague substances (e.g., pollution, chemicals).

Level 2:
Force Dynamic Accounts w/Mechanisms

Question	Why is there still water flowing in a river even when it hasn't rained recently?
Response	Because it flows from bigger lakes into the rivers. [H]
Indicator	Water has natural tendency to flow from bigger to smaller bodies of water.

What Students Need To Work On…

- Building awareness of system structures, matter, and processes that may be hidden, invisible, or too big to see with eyes
- Shifting from force-dynamic to simple scientific explanations for processes (e.g., gravity as force rather than citing natural tendencies)
- Recognizing scales other than macroscopic (e.g., large, microscopic)

Drivers & Constraints Tool

Where does the water **start**?	Where can the water **go**? What is the **process**?	What **drives or moves** the water? How?	What are the **constraining factors**, and how do they work?
			

Instructional Context: It hasn't rained in Missoula in over a month. Why is there still water in the Clark Fork River?

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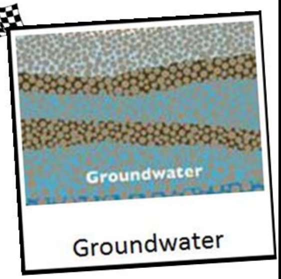
Drivers & Constraints Tool

Where does the water **start**?	Where can the water **go**? What is the **process**?	What **drives or moves** the water? How?	What are the **constraining factors**, and how do they work?
	 Discharge	Gravity	Topography/elevation - water flows to lower areas. Floodgates --- opened or closed to manage flow
	 GW Discharge	Gravity	Topography and permeability – GW flow follows topography of impermeable layer. In river, water table is above ground.
	 Runoff	Gravity	Temperature --- Water won't runoff unless it first melts at temperature above 32°F. Topography – see above.

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Drivers & Constraints Tool Affordances

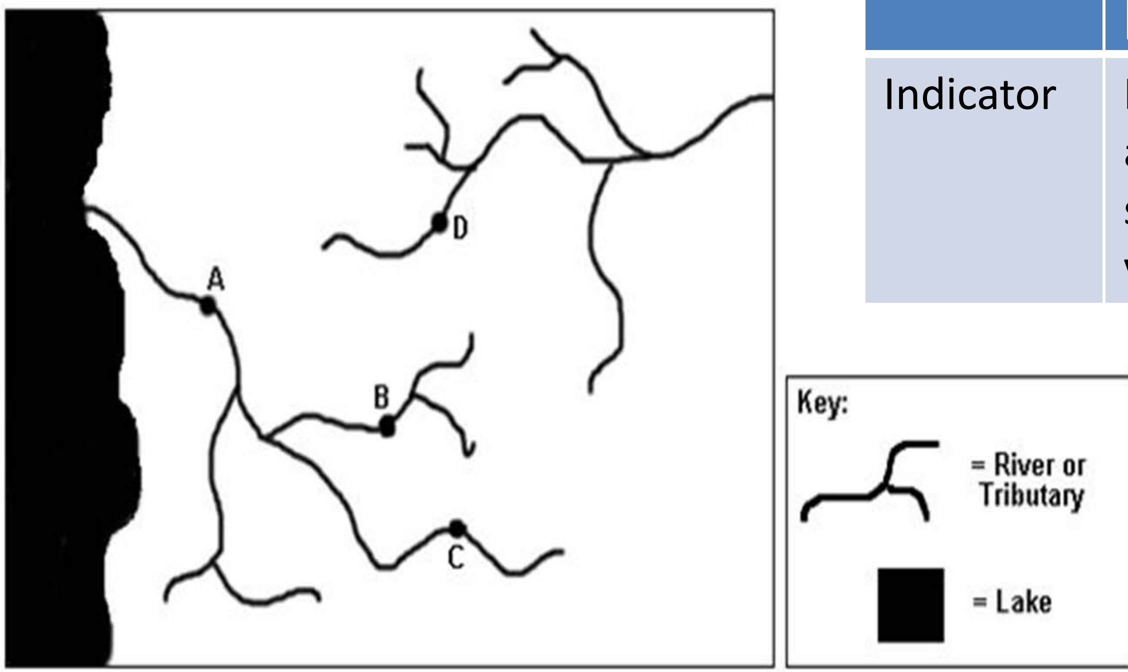
- Focuses students on scientific explanations for pathways, especially driving forces and constraining variables
- Supports developing awareness of system structures, pathways, and processes
- Scaffolds social construction of understanding
- Scaffolds students in scientific argumentation (e.g., debating processes/likelihoods of possible pathways)

Level 3: School Science Accounts

- Retell stories about water cycle learned in school
- Put multiple events in order, but do not rely on driving forces or constraining variables to move or change water
- Trace water into hidden/invisible places (e.g., groundwater, water vapor) and describe invisible processes
- Describe systems and paths with moderate detail and some errors, especially in human-engineered systems
- Aware of atomic-molecular scale, but understands as “small particles” --- no electrostatic forces
- Identify different types of substances in water and some processes for mixing/unmixing substances

Level 3: School Science Accounts

If a water pollutant is put into the river at Town C, which towns (if any) would be affected by the pollution?



Response	**[A] The pollution would get into the towns because the poluted [sic] water go [sic] down the river and ends up in a different town. [E]**
Indicator	Identifies which way rivers flow on a map but does not identify forces such as gravity or constraining variables such as topography.

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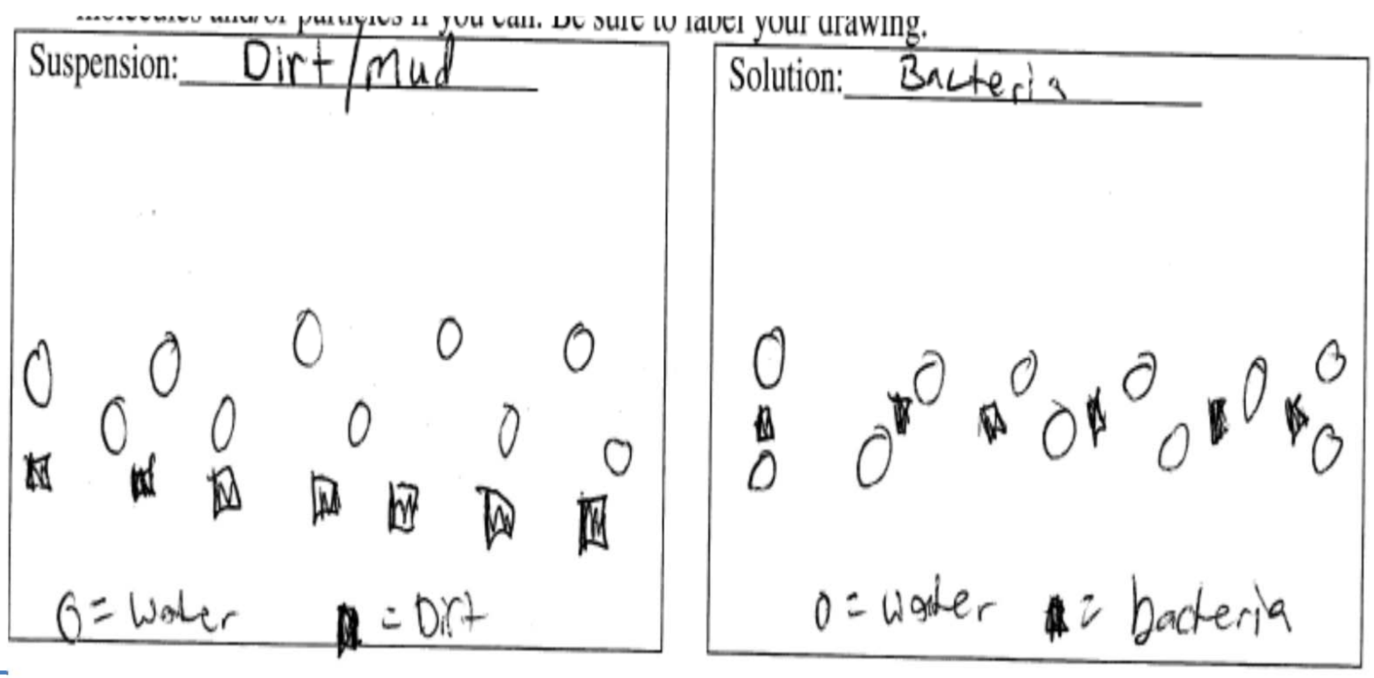
Level 3: School Science Accounts

Question	Identify one thing that would be in suspension and one thing that would be in solution in water. Draw a picture of each thing showing molecules and/or particles if you can.
Indicator	Aware of smaller than visible matter. Confusion between microscopic and atomic-molecular scales.



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Level 3: School Science Accounts

What Students Need To Work On Developing…

- The need and knowledge to rely on principles and constraining variables to trace water and substances
- Detailed awareness of system structures and chemical identities
- Capacity to distinguish between microscopic and atomic-molecular scales, and to reason about these scales

Scale Tool

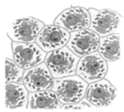
Atomic-Molecular

Not visible
Nanometer or smaller
($<10^{-9}$m)

Molecule

Microscopic

Visible with microscope
(10^{-8}m to 10^{-4}m)



Cells

Macroscopic

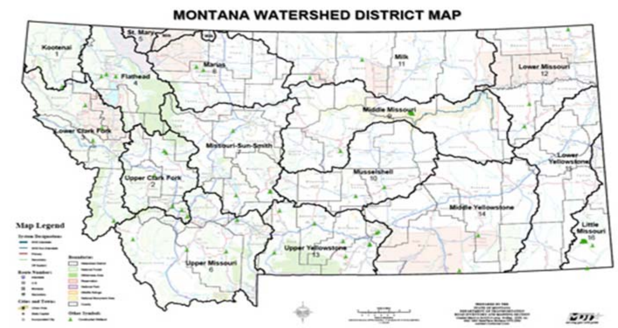
Visible with naked eye
Millimeter (10^{-3}m) to Meter (10^{0}m) to Hectometer (10^{2}m)

Water Drop

Football Field

Landscape

Larger than what you can see at once
Kilometer or more ($>10^{3}$m)



Watersheds

Instructional Context: At a school, there is a football field near a creek. If fertilizer was applied to the field and then it rained, where could the fertilizer end up? In the creek? In groundwater? Evaporated with water and came down as fertilizer mixed with rain? In the grass on the field?

Question: Say you mixed some fertilizer with water. How small of particles do you think the fertilizer would break down into? Would the fertilizer in water form a solution or a suspension?

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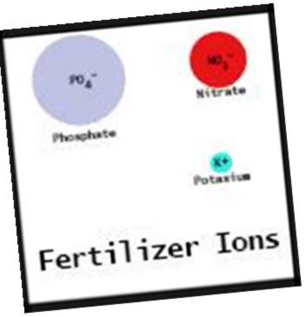
Scale Tool

Atomic-Molecular

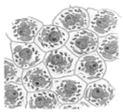
Not visible
Nanometer or smaller ($<10^{-9}$m)

Molecule



Microscopic

Visible with microscope (10^{-8}m to 10^{-4}m)



Cells

Macroscopic

Visible with naked eye
Millimeter (10^{-3}m) to Meter (10^{0}m) to Hectometer (10^{2}m)

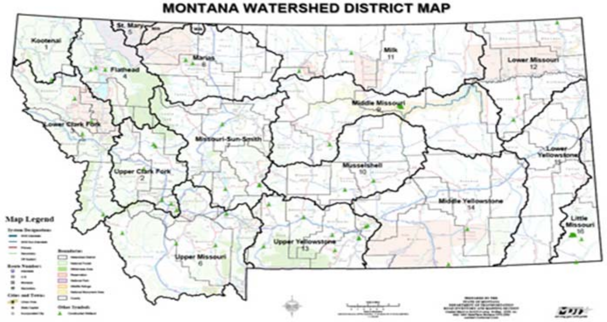
Water Drop

Football Field

Landscape

Larger than what you can see at once
Kilometer or more ($>10^{3}$m)

MONTANA WATERSHED DISTRICT MAP



Watersheds

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Tracing Mixtures With Water Tool

Substances mix and unmix with water and water moves through systems. How does this work?

Tracing Back

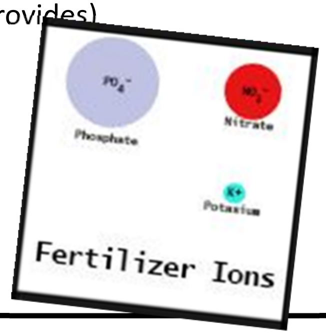
Where did the substance come from?

Where did the water come from?

How did the substance get into the water?

The Mixture

What's mixed in the water?
(Teacher provides)



Where is the mixture now?
(Teacher provides)

Football Field

What kind of mixture is it?
Suspension or Solution

How do you know?

Tracing Forward

If the water moves (new place) ____________________, will the substance stay mixed with the water?
Yes or No

If no, how and why will it separate?

- Groundwater
- Creek
- Grass
- Atmosphere

Where will the substance end up next?

Scale Tool Affordances

Scaffolds…

- Distinguishing scales for matter and systems
- Reasoning about how scale is important for tracing water and substances (e.g., solution versus suspension)
- Quantitative reasoning skills (e.g., converting units for different scales, estimating, working with scientific notation)

Tracing Mixtures w/Water Tool Affordances

Scaffolds…

- Reasoning about how scale impacts movement of substances (e.g., solution or suspension)
- Deeper reasoning about processes that mix, unmix and move substances with water (not just telling a story of where stuff goes --- have to explain WHY and HOW)
- Social construction of understanding and scientific argumentation

Future Directions

Help teachers use Water Systems Learning Progression to inform instruction including…

- Test and refine Reasoning Tools with teachers and students
- Test and refine Formative Assessment materials designed to help teacher elicit, analyze, and respond to students' ideas
- Develop and share productive examples of how Tools and Formative Assessments can be used in school contexts

Questions? / Comments?

Contact

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