Research on Effects of Integrating Computational Science and Model Building in Water Systems Teaching and Learning

Comp Hydro

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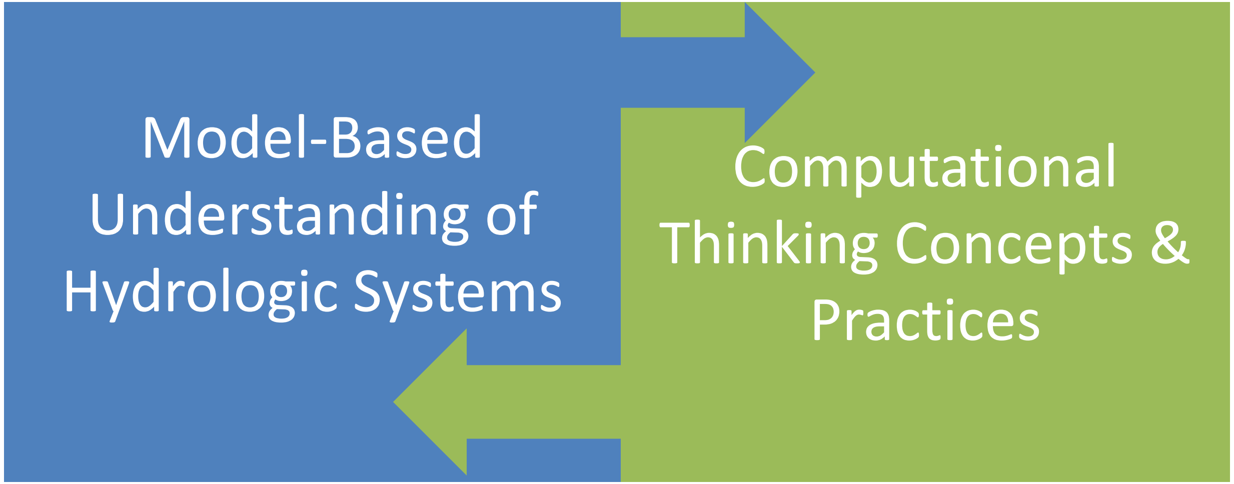
Arizona · Colorado State University · The University of Montana · Cary Institute of Ecosystem Studies · National Computational Science Institute · BEAR Center · NSF

Integrating hydrologic systems knowledge and practice with computational thinking in authentic and innovative ways to support environmental science literacy.



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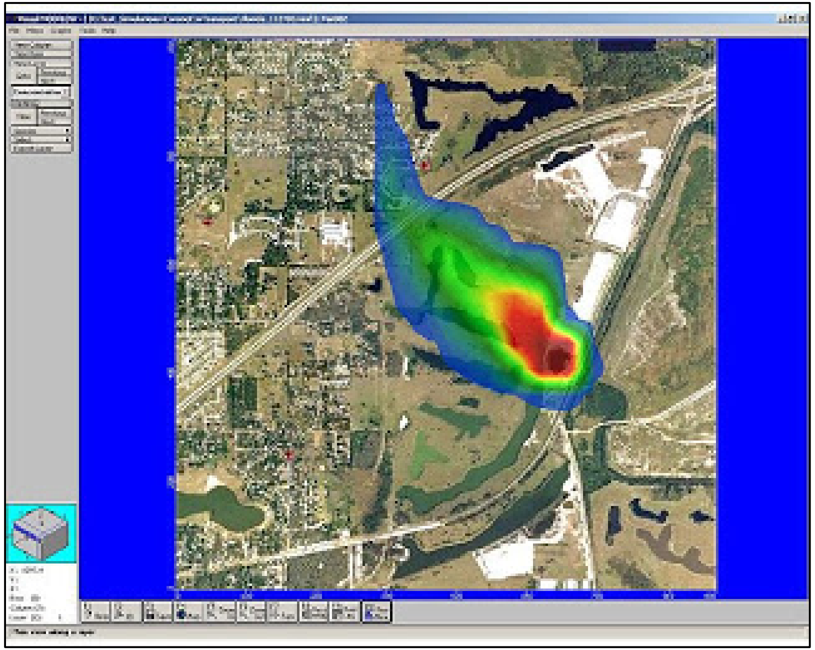
Environmental Science Literacy

Knowledge and practice needed to participate in debates and discussions of socio-environmental problems.

Today, environmental science literacy requires computational thinking.



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Comp Hydro Sites

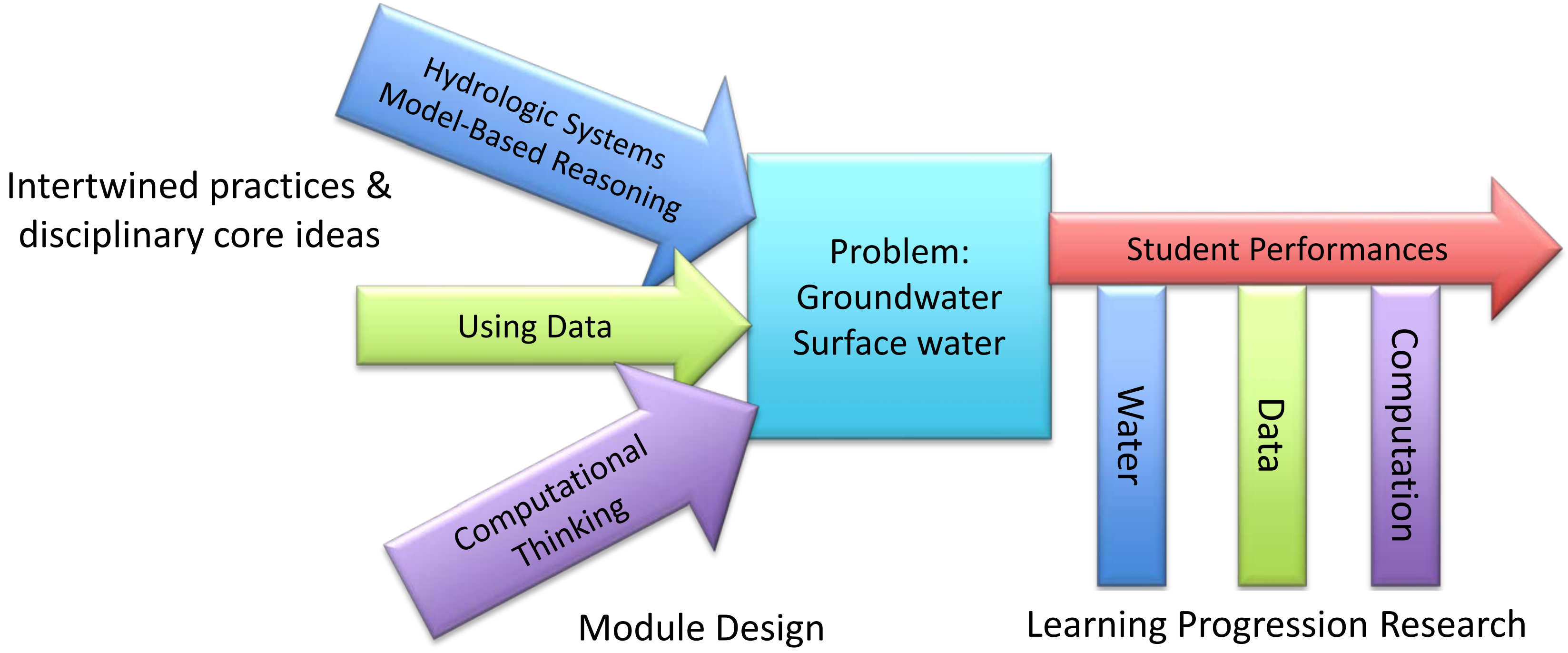
Montana, Univ. of Montana
4 rural, 4 urban districts
Groundwater Contamination

Ft. Collins, CO
Colorado State Univ.
1 urban district
Water Allocation

Tucson, AZ
Univ. of Arizona
1 urban district
Groundwater Contamination

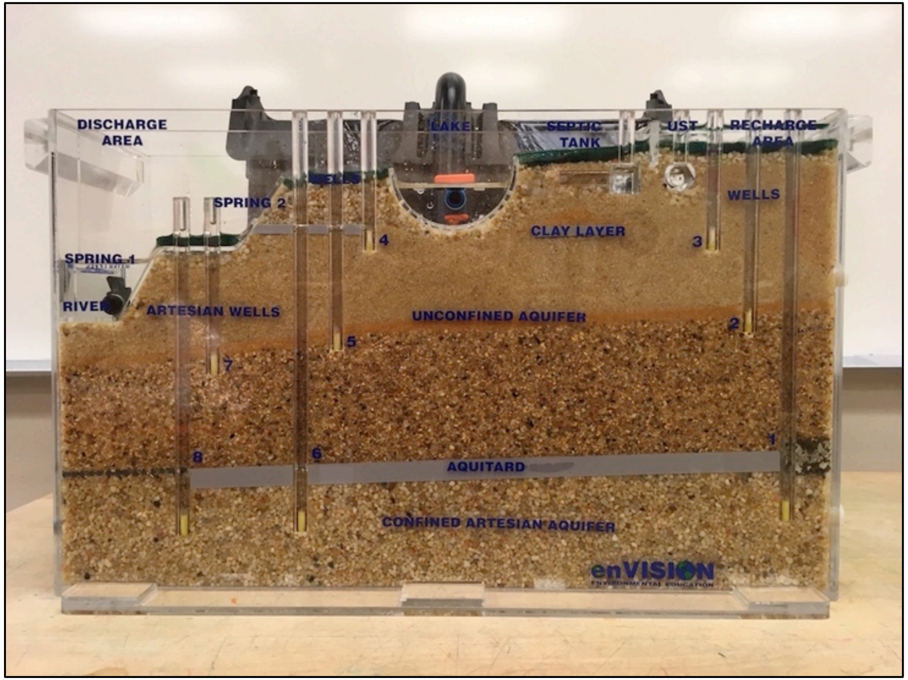
Baltimore, MD
Cary Institute
1 urban district
Flooding

Integrated Instruction & Research



Hydrologic Principles

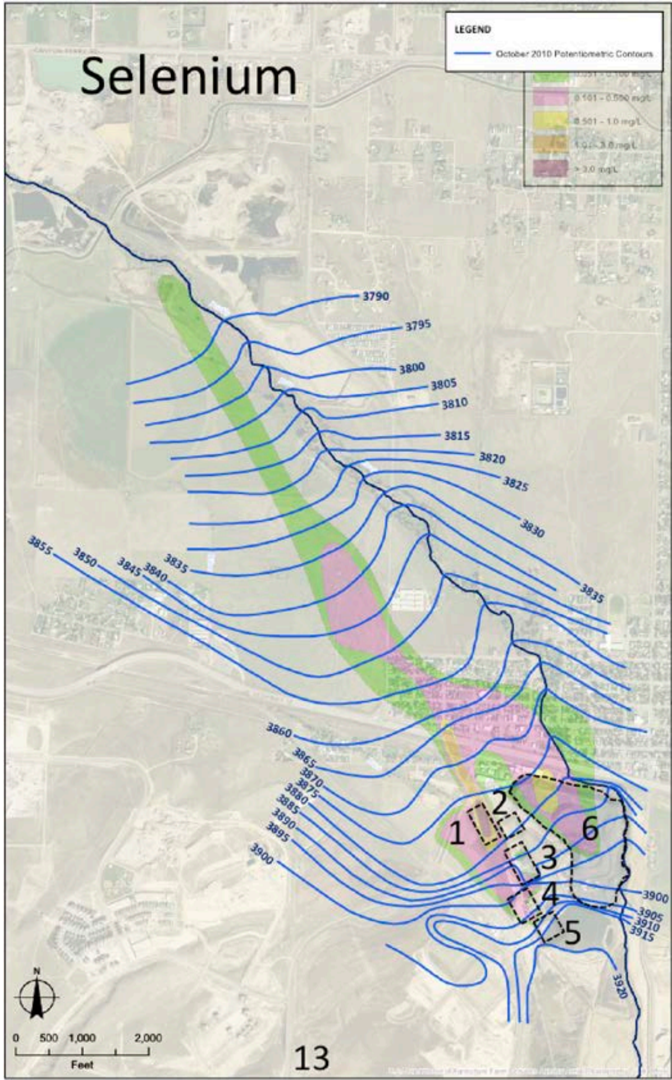
Distribution of potential energy & hydraulic conductivity govern flow of groundwater & contaminants



Data Sense Making

Applying scientific (hydrologic) principles in:

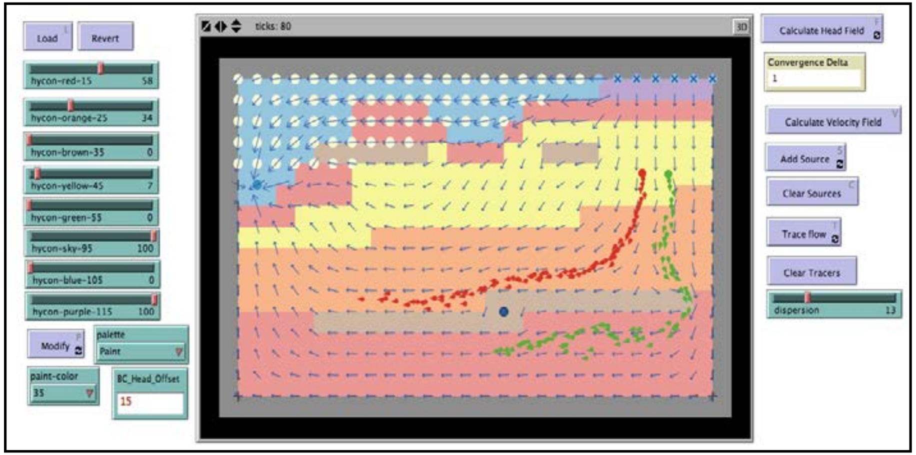
- Connecting levels of abstraction across multiple scales
- Making inferences about 3D systems from 2D representations & vice versa
- Managing uncertainty in data



Computational Thinking

Applying scientific (hydrologic) principles in reasoning concerning:

- Abstraction (including parameterization & discretization)
- Boundary conditions
- Calibration & model validity judgments
- Advantages & limitations of computational modeling



Learning Progression Research Questions

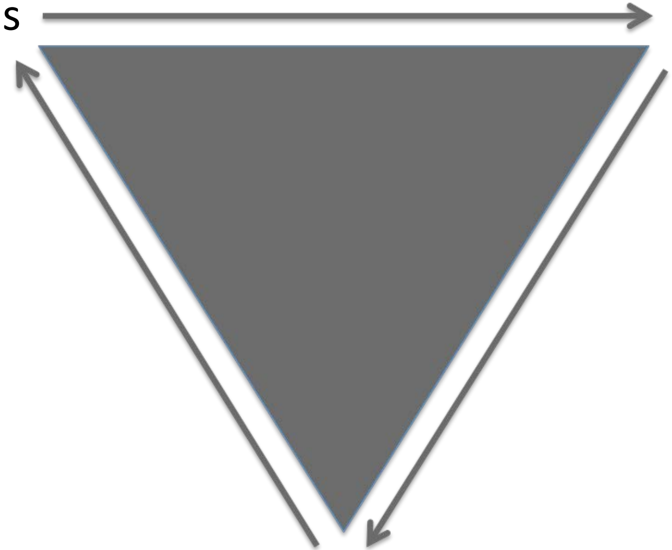
1. What are patterns in increasingly sophisticated ways that students think about and make sense of computational modeling of hydrologic systems?

1. Does participation in Comp Hydro support students in becoming more sophisticated in their reasoning with respect to the learning progression?

Assessment and Learning Progression Development

Assessment

- Develop/revise items
- Collect data



Interpretation

Analyze data and identify patterns in students' learning performances

Model of Cognition

Develop/revise LP Framework

(NRC, 2006, Systems for State Science Assessment)

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Assessment and Learning Progression Development

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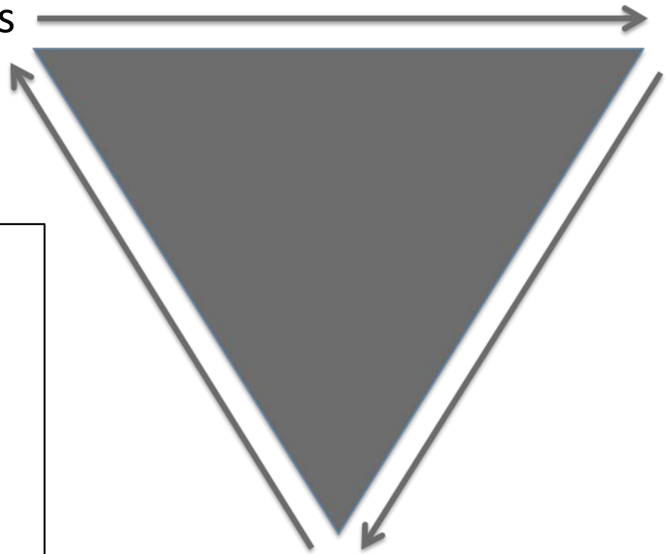

Interpretation

Analyze data and identify patterns in students' learning performances

Pre, post, & embedded constructed response items elicit students' connected knowledge & practice in:

- Hydrologic systems
- Data sense making
- Computational thinking

Model of Cognition

Develop/revise LP Framework

(NRC, 2006, Systems for State Science Assessment)

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Upper Anchor and Assessment Items

Progress Variables and Attributes	Items
Defining the system	
-Employ abstraction to reduce system into fundamental parameters	Parameter ID
-Designate model domain and boundaries	Boundaries 1, 2
-Decompose or discretize model to make it tractable to quant. Approaches	Discretization 1, 2
Sense making with system data and representations	
-How data are abstracted, represented in outputs: graphs, maps	Slope steepness
-How system events/phenomena are represented in multiple, connected spatial/temporal scales & dimensions	Flow direction
-How interpolation and extrapolation may be used	Concentration interpolation
Affordances/constraints of different scales of resolution, discretization	Contour interval
Explaining and predicting events with imperfect data and models	
-Define/employ rules (algorithms) using scientific principles to quantify system processes & computationally reproduce system activities	Model flow explanation
-Calibrate model w/real data (observations) to demonstrate that model outputs can reproduce events in real systems w/some level of confidence	Judging model accuracy
-Judge validity & limitations of computational model & its outputs	Model problems Judging uncertainty
-Use validated model to predict/evaluate system responses	Model uses

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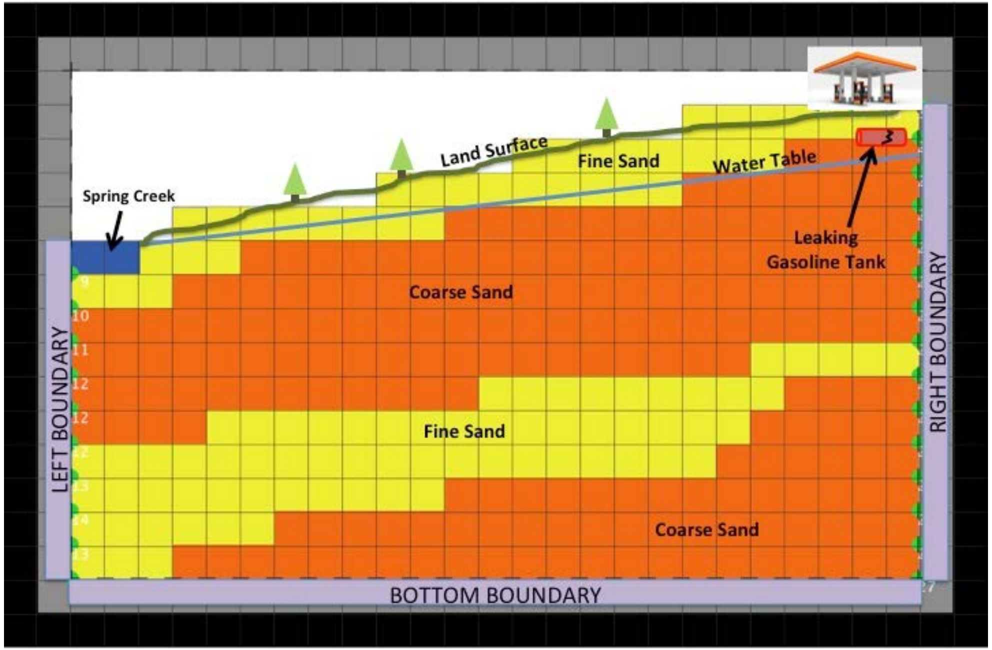
Parameter ID

What info about each cell in the grid would be needed to compute and predict flow of water and MTBE through the system?

Explain why each type of info (parameter) you listed is important.



Analysis

1. Work with sets of item responses
2. Identify patterns of indicators in responses
3. Group indicators into proposed LP levels
4. Iterations of coding, interrater reliability, and refinement
5. Sets of coded data subjected to IRT analysis
   a. Wright maps
   b. Learning evidence

Three learning progression levels emerged that are consistent across the progress variables.

CT for Hydrologic Systems Modeling Learning Progression*

Levels	Defining the system	Sense-making w/data & representations	Explaining & predicting w/models
Upper: Principle-based model users	Understands how abstraction, parameterization, boundaries, & discretization are used to define system model.	Makes sense of model outputs that employ abstractions across scales & dimensions w/ interpolation & extrapolation.	Understands how algorithm, calibration, & validation are used to develop, refine, & judge models used to explain & predict.
Middle: Procedural model users	Views model as connected to world, but novice at connecting CT & hydro principles to define system model.	Sense-making simplifications leads to incomplete &/or inaccurate inferences.	Understands models are used to explain/predict but w/black box approach.
Lower: Literal model users	Views model as “player” using graphical user interface (GUI). Model is “it,” rather than a representation.	Makes informal literal and proximity-based interpretations of representations.	Indicates models can’t represent world or possible to change world by changing model.

*Upper anchor represents environmental science literacy for participating in debates and discussions – a social participation goal.

How can a scientist judge if a computer model is accurate?

Level	Explaining & Predicting With Models	Indicator	Example Student Response
Upper: Principle-based model users	Understands how algorithm, calibration, & validation are used to develop, refine, & judge models.	Use calibration and/or iteration.	They can test it and go back to the actual site and take more tests… to make sure that it is right. And if not they will calibrate it and keep fixing it until it is accurate.
Middle: Procedural model users	Understands models are used to explain/predict, but w/black box approach.	If model matches known info, past research, expected results.	They could check the research and information they already have.
Lower: Literal model users	Indicates model can't represent world or possible to change world by changing model.	It's not possible to judge model accuracy.	They can't.

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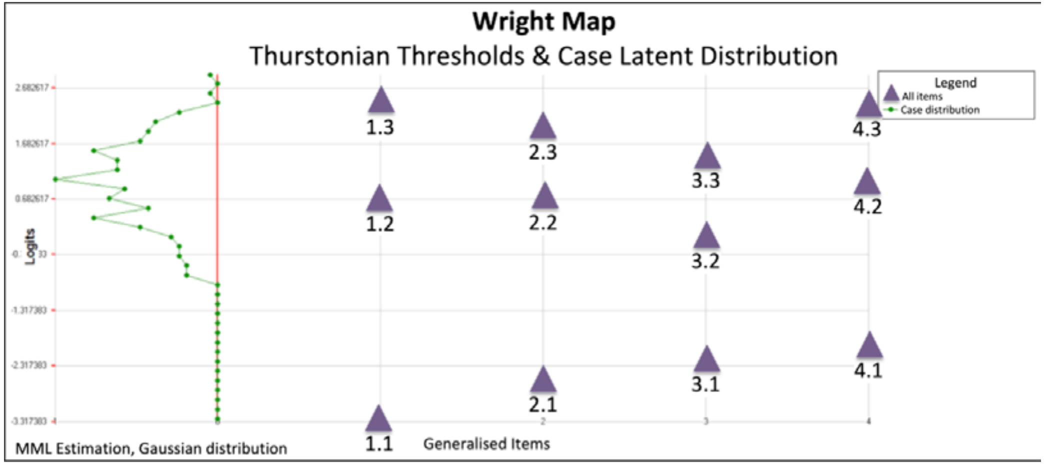
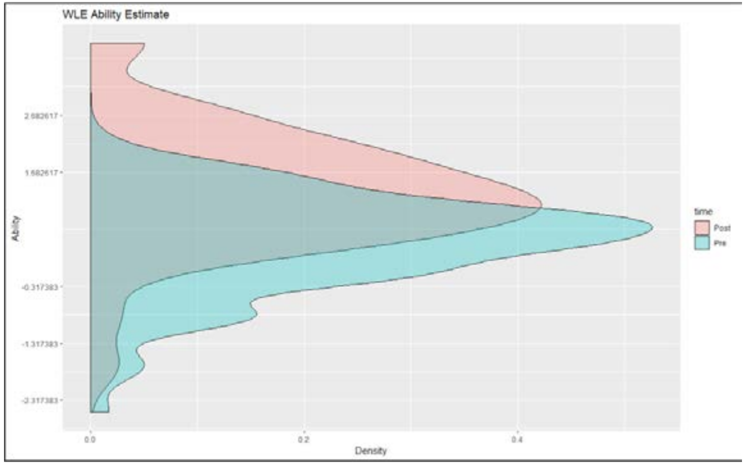
Learning Evidence

- Evidence below: 91 MT students, "explaining & predicted w/models" items
- Currently working on analysis with 1400 MT and AZ students w/all progress variables



Wright Map

- Green graph: distribution of student proficiency scores
- Purple triangles: difficulty thresholds for LP levels for each item



Latent regression w/fixed pre/post dummy variable

- Beta = 0.93, s.e. = 0.11, $p < .001$
- Students' post mean ability (pink) higher than pre (blue)

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Contact Info

Website

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Research Products

Past Conference Products (and in preparation for publication submission)

Available on website:

- *Students Ideas about Computational Thinking Concepts When Learning to Model Hydrologic Systems*, Gunckel
- *High School Students' Developing Ideas about Computational Modeling of Earth and Environmental Systems*, Podrasky
- *Teacher Perspectives of Teaching Computational Thinking*, Cooper
- *High School Students' Sense Making with Contour Maps When Learning to Model Hydrologic Systems,* Covitt
- *Student Empowerment in an Environmental Science Literacy Unit about Groundwater Contamination*, Moreno

In preparation for NARST and publication submission

- *Developing and Validating a Learning Progression for Computational Thinking in Earth and Environmental Systems*, Covitt
- *Intertwining Three Dimensions: Levels of Performance for Computational Thinking While Using Models of Hydrologic Systems*, Gunckel

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