The Integrating Chemistry and Earth science (ICE) Project

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Cadre Meeting – June, 2021

NSF #DRL-1721163

ICE Goals

Development Goal – Develop, test and refine lessons and assessments that help teachers and students engage in three-dimensional learning in an integrated Earth science and chemistry context.

Implementation Goal – Develop, test and then provide professional development, in-school support and resources for district-wide adoption of the ICE curriculum.

Research and Documentation Goal - Collect, analyze and present evidence to address hypotheses about learning and teaching, and document ICE outcomes for students and teachers.

Curriculum

Chemistry Curriculum Overview

Unit Topics	ICE Topics
1-Atomic Structure and Patterns - What makes up the world and where did it all come from? – 4 weeks	• The Big Bang Theory • Life cycle of stars
2-Nuclear Chemistry - What happens in the nucleus of an atom? – 5 weeks	• Nuclear fusion in stars • Earth's formation and early history
3-Combining Atoms – Why do we have/need substances that are not just elements? – 5 weeks	• Properties of water
4-Reaction Behaviors – What is happening to our oceans? – 4 weeks	• Ocean acidification
5-Stoichiometry – What determines the yield of a chemical reaction? – 3 weeks	• Earth as a limiting reactant for energy and mineral resources
6-Thermochemistry – What determines the temperature in Baltimore? – 5 weeks	• Urban heat island and related phenomena • Inner earth heat and processes
7-Chemistry and the Life and Death of Baltimore's Mountains – Where did Baltimore's mountains go? – 5 weeks	• Local landforms and rock types, weathering and water quality, and deposition • Plate tectonics, rock and crustal feature formation

ICE-intensive Units

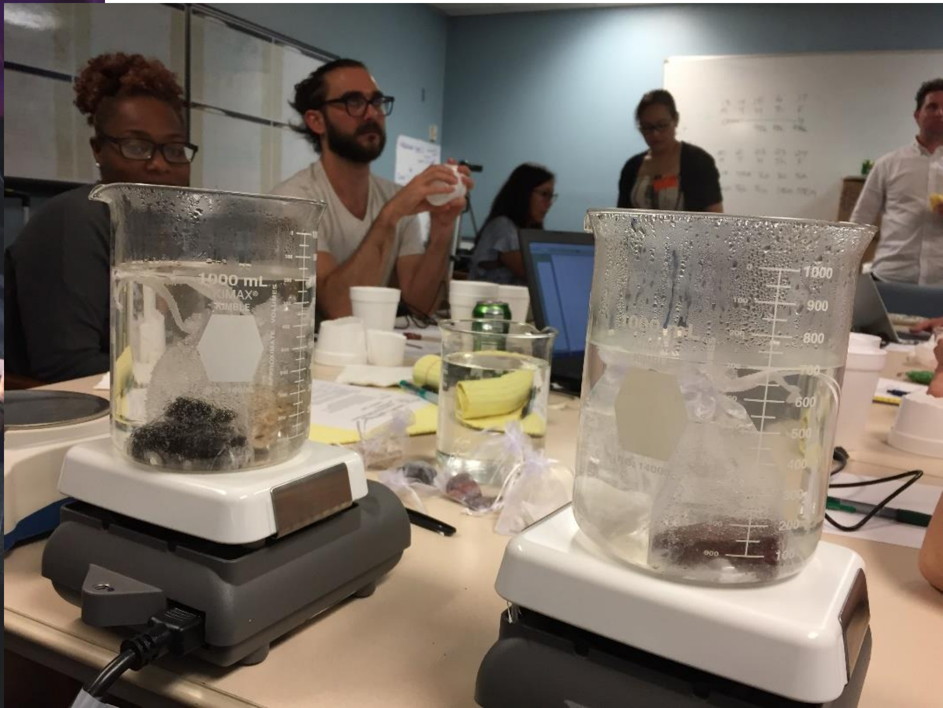
Unit 6 – What Determines the Temperature of Baltimore?

Sub-Phenomenon	Student Activities (25 Class Sessions)
• Energy is conserved	• Construct a simple energy exchange model
• Reactions and solvations	• Design a calorimeter, good hand warmer
• Absorption, heat capacity, conduction, emission	• Design study of urban surfaces (asphalt, concrete, brick, Marble, grass) with IR thermometers
• Convection, evaporation/ transpiration	• Observe motion of hot and cold water in a closed system. • Consider temperature data +/- vegetation
• Urban heat island	• Compare urban and rural temperatures and energy budget models
• Albedo	• Consider energy reflected and absorbed by surfaces of different color.
• Inner earth heat, convection	• Consider densities and layers of the earth • Convection in mantle, magnetic fields
• Baltimore and global energy budgets	• Use models to construct arguments for what factors are and are not important for why Baltimore is so hot

Unit 7 – Life & Death of Baltimore's Mountains

Sub-Phenomenon	Student Activities (25 Class Sessions)	NGSS
High places exist	• Observe topographic features near school, in region, and across continent/globe (across scales)	• HS-ESS2-1
Plate tectonics	• GeoBlox exploration of the formation of topographic features	• HS-ESS2-1 • HS-ESS1-5
Rock/mineral formation	• Compare chemistry of rock types • Research local rock types, as found under Baltimore	• HS-ESS2-1 • HS-ESS1-5
Physical weathering	• Weathering evidence in the neighborhood • River rock simulation utilizing a rock tumbler • Storyboarding the formation of potholes	• HS-ESS2-1 • HS-ESS2-5
Chemical Weathering	• Explore local data on precipitation chemistry, pH • Design study of weathering of urban materials • Analyze local data on stream alkalinity, salinity • Construct model of weathering	• HS-ESS2-1 l • HS-ESS2-5 • HS-PS2-1
Physical deposition	• Explore deposition of sand-silt-clay by water	• HS-ESS2-5
Chemical deposition	• Explore the effects of carbon dioxide on the formation of calcium carbonate (limestone) in limewater.	• HS-ESS2-1 • HS-ESS2-5 • HS-PS2-1

Professional Development



Year 3 - Professional Development Activities

- After School Sessions
  - 1.5 hours (previously 2.5 before Covid closure)
  - Open to any chem teacher in the district
  - Required of ICE Fellows
  - Offered 10 sessions per school year
- Saturday Session
  - 7.5 hours
  - Open to any chem teacher in the district
  - Required of ICE Fellows
  - Offered 2 sessions 2019-2020 SY
- Earth-Chem Happy Hours
  - 45 minutes
  - Open to any chem teacher in the district
  - Ongoing sessions after Covid closure beginning in April 2020

Research

ICE Research Questions

1) What is the nature of teachers' instruction during ICE lessons?

2) How are students integrating 3-dimensions in classroom artifacts?

3) What is the nature of student learning related to disciplinary core ideas, scientific practices, and crosscutting concepts that results from students' engagement in ICE lesson sets?

4) What differences emerge in student engagement and learning outcomes for ICE lessons that incorporate local phenomena or data sets as compared to lessons that do not?

5) What contextual factors (i.e., school context, administrative support, time constraints, etc.) influence teachers' implementation of three-dimensional instruction embedded within ICE lessons?

Preliminary Findings - Student Data

Primary data source: Student models of local phenomena that involve integrated chemistry and Earth science concepts (e.g., Urban Heat Islands and pothole formation)

Analysis: model-based explanations framework (Zangori et al., 2017), pre- and post-unit models

Aspects of MBE framework:

Components
- words, symbols, images related to the phenomenon
- e.g., buildings, cars, trees, energy (arrows)

Sequences
- relationships between components, cause/effect relationships
- e.g., reflection, absorption, radiation

Explanations
- Multiple, linked sequences, mechanisms
- e.g., materials behave differently, different temperatures of objects, temperature cycles

Preliminary Findings - Student Data

- Sample models & rubric

Components

Level	Descriptor
0	No relevant components included
1	One component involving the occurrence of precipitation (e.g., rain, snow, ice) OR One component involving a human interaction with the environment (e.g. car, truck, plow) OR One component of a physical change occurring (e.g., cracks, holes, temp)
2	More than one component from any combination of categories (precipitation, human, physical change)
3	At least one component from each of the three categories (precipitation, human, physical change)

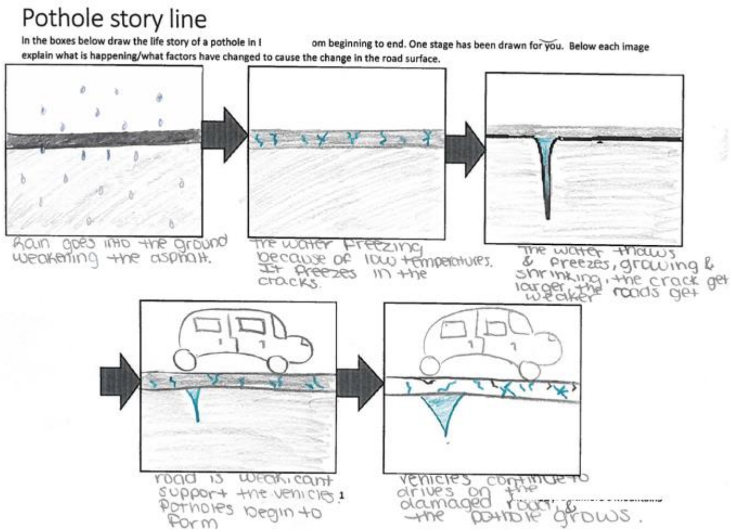
Sequences

Level	Descriptor
0	No sequences included
1	Includes one sequence (link between two components) from either weathering or erosion or human activity
2	Includes two sequences, from more than one category of weathering, erosion, or human activity
3	Includes one sequence from each category of weathering, erosion, and human-related activity

Explanations

Level	Descriptor
0	No links between sequences
1	Repeated sequences (e.g., ice wedging, car traffic) cause potholes to get larger or more potholes to form
2	Interaction between weathering and erosion cycles compounds the formation of more/bigger potholes
3	Interaction between human activity exacerbates natural weather/erosion processes

Figure 1. Pothole model-based explanation rubric



Pothole Formation phenomenon

Urban Heat Island phenomenon

Preliminary Findings- Student Data

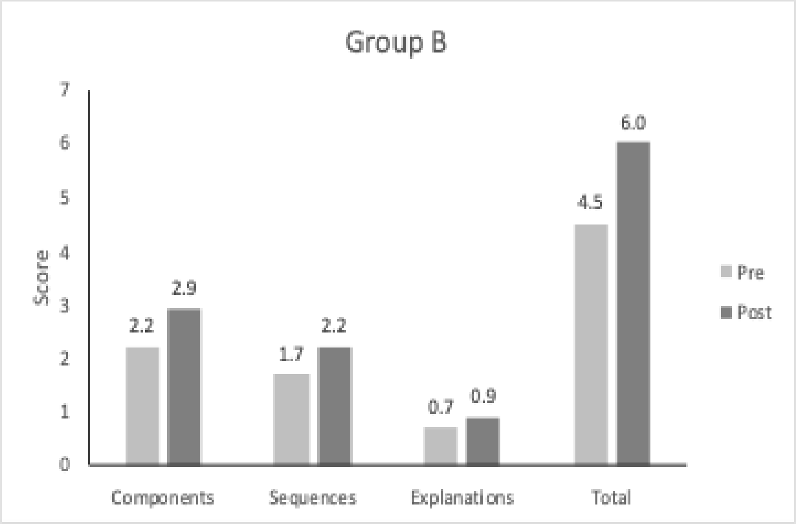
Model-based explanations (UHI phenomenon)

- students demonstrating components and sequences level, but struggle with *explanatory power*
- statistically significant improvement between pre- and post-unit models

	Pre-unit	
Subscale	Components	Sequences
Sequences	$Z = -2.12, p = 0.03$	--
Explanations	$Z = -2.81, p = 0.01$	$Z = -2.24, p = 0.03$
	Post-unit	
Subscale	Components	Sequences
Sequences	$Z = -2.46, p = 0.01$	--
Explanations	$Z = -3.27, p < 0.01$	$Z = -2.88, p < 0.01$

Pair-wise comparisons of model-based explanation subscales for Group B (non-parametric, Wilcoxon signed-rank test)

Pre-Post Comparison
Total Model Score: $Z = -2.3$, $p = 0.02$, r = 0.66
Components: $Z = -3.0$, $p < 0.01$, r = 0.87

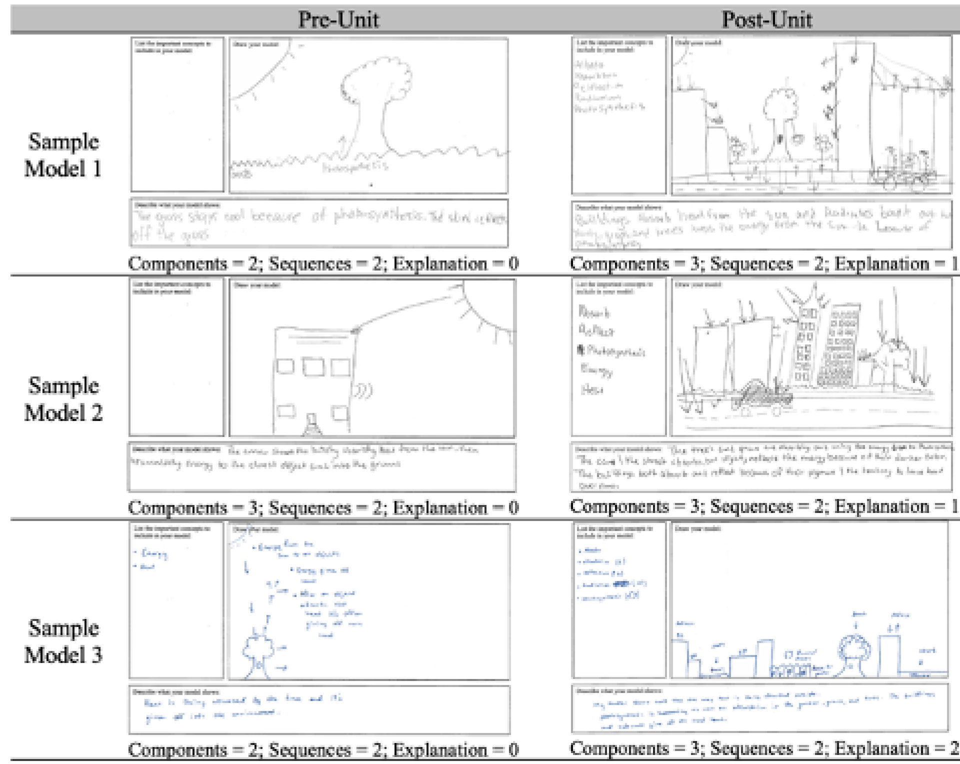


Pre- and Post-unit

Preliminary Findings- Student Data

Model-based explanations (UHI phenomenon)

- Increasing and more diverse components included in models
- Increasing number and types of “arrows” related to energy flow and/or transfer between objects
- Differential behavior between natural components and human components within the system
- Recursive aspects of UHI are missing



Preliminary Findings - Teacher Data

Primary data sources: Teacher interviews from each year of the project, video recordings of PD sessions with development team teachers

Analysis: Qualitative analysis of teachers interviews grounded in the Teacher-Centered Systemic Reform model (Woodbury & Gess-Newsome, 2002); and video analysis using the Episodes of Pedagogical Reasoning framework (Horn, 2005)

Teacher interviews

Perceptions of curriculum reform effort:

- initially: hesitation with integration, need to balance depth/breadth of new E.S. content
- more recently: agency in integrating chemistry & Earth science, recognize implications for student learning
- Ts began with focus on ‘getting through curriculum’ and desired to learn necessary E.S. content being integrated into curriculum
- With time, Ts have moved to a focus of ‘problematizing and refining curriculum’ based on their experiences and observations of student success and challenges

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Professional Development Video Analysis

In their engagement with the curriculum and PD, Teachers exhibit multiple levels of pedagogical reasoning with their peers:

1. Micro level - discussion and collaboration around instructional approaches related to a particular lesson;
2. Meso level - discussion and consideration of the role of science practices within or across lesson sequences; and,
3. Macro level - reflection and consideration of the goals and nature of the district's systemic reform

We are working to understand the impacts of these levels of pedagogical reasoning and how the distribution of these levels changes (or not) from year to year of the project.