ICE

Integrating Chemistry & Earth Science

INTEGRATING CHEMISTRY AND EARTH SCIENCE

EXPLORING HOW CHEMISTRY, EARTH PROCESSES, AND PEOPLE SHAPE THE CITY

A National Science Foundation Funded Discovery in Research K-12 Project

THE GEORGE WASHINGTON UNIVERSITY
WASHINGTON, DC

BALTIMORE CITY PUBLIC SCHOOLS

NSF

Cary Institute of Ecosystem Studies

INTEGRATING CHEMISTRY AND EARTH SCIENCE (ICE)

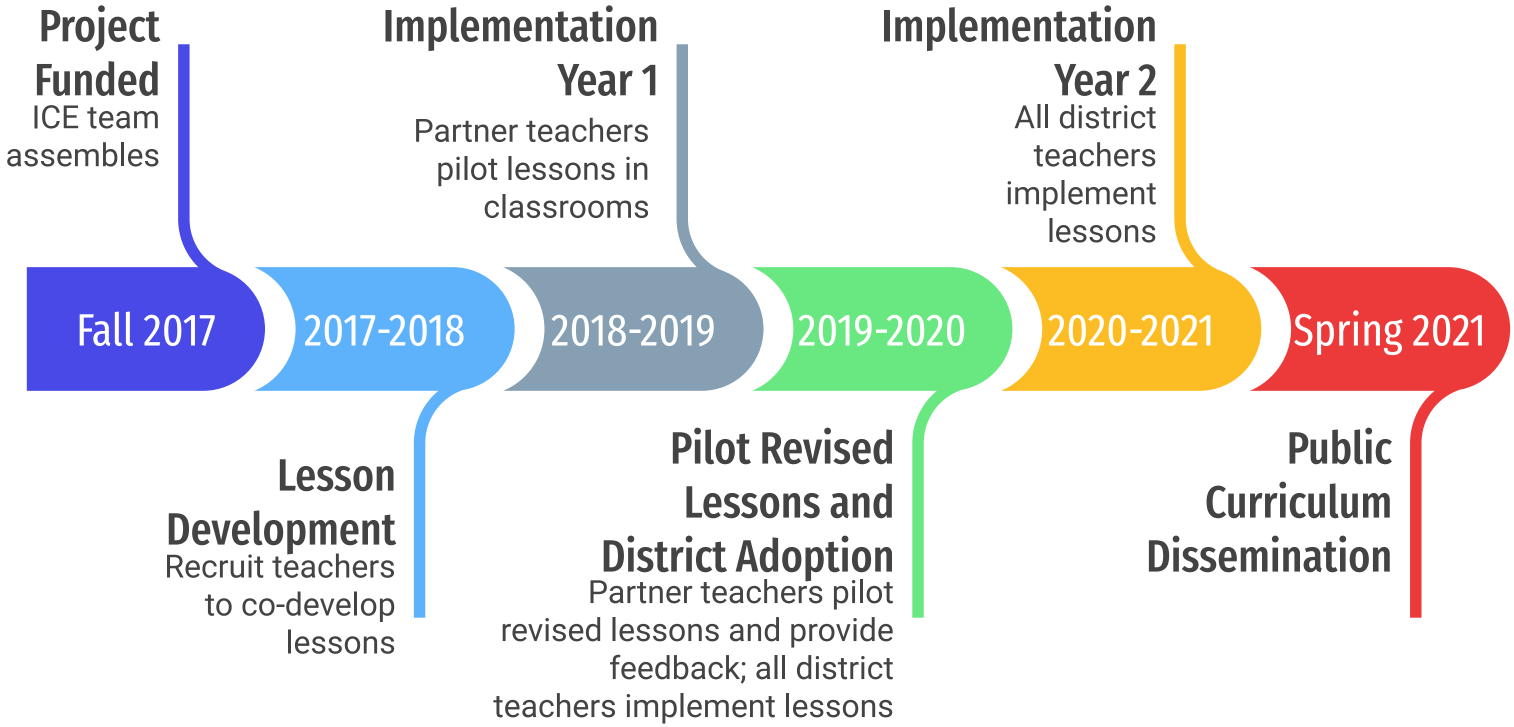
Dear Educators,

The Integrating Chemistry and Earth science (ICE) project is a collaboration between Baltimore City Public Schools (City Schools), Cary Institute of Ecosystem Studies, and George Washington University to infuse Earth science into Baltimore City's high school chemistry course. Funded by the National Science Foundation, ICE brought together experts from Earth science, chemistry and science education to develop an engaging curriculum for students to learn about phenomena in their local environment. ICE lessons cross the Earth-chemistry disciplines, meet NGSS standards in both Physical and Earth/Space sciences, and prepare students to think critically about the world around them.

The Chemistry and the Life and Death of Baltimore's Mountains unit, taught as the 7th of 7 total units in the City Schools' Chemistry course, helps students answer the question, "Where did the hills come from and how did they change over time?" The Weathering, Erosion & Deposition module presented here contains a subset of lessons from the Chemistry and the Life and Death of Baltimore's Mountains unit. Now in its final form, we are pleased to share these activities with a broader audience. Thank you for your interest in these educational materials

For more information, contact: Alan R. Berkowitz, Head of Education, The Cary Institute of Ecosystem Studies (berkowitza@caryinstitute.org).

INTEGRATING CHEMISTRY AND EARTH SCIENCE (ICE) - Project Timeline



INTEGRATING CHEMISTRY AND EARTH SCIENCE (ICE) - Acknowledgements

ICE Leadership Team

- Alan R. Berkowitz, Head of Education, Cary Institute
- Joshua Gabrielse, Director of Science, City Schools
- Kevin Garner, Coordinator of Science, City Schools
- Kia Boose, Secondary Science Specialist, City Schools
- Vonceil Anderson, Curriculum Writer, City Schools
- Jonathon Grooms, Assistant Professor of Curriculum and Pedagogy, George Washington University
- Kevin Fleming, Graduate Research Assistant, George Washington University
- Mary Ellen Wolfinger, Doctoral Student, George Washington University
- Bess Caplan, Ecology Education Program Leader, Baltimore Ecosystem Study
- Tanaira Cullens, Education Assistant, Baltimore Ecosystem Study
- Chelsea McClure, Education Assistant, Baltimore Ecosystem Study

Advisory Board

- Jane Wolfson, Professor Emerita, Towson University
- Catherine Manduca, Director, Science Education Resource Center
- Hannah Sevian, Associate Provost and Professor of Chemistry, University of Massachusetts Boston
- Jo Ellen Roseman
- Elie Bou-Zeid, Professor & Director of the Program in Environmental Engineering and Water Resources, Princeton University
- John Hom, Interdisciplinary Scientist, U.S. Forest Service
- Sujay Kaushal, Professor, Department of Geology and Earth System Science Interdisciplinary Center, University of Maryland
- Martin Schmidt, Upper School Science, McDonogh School

This material is based upon work supported by the National Science Foundation under Grant #DRL-1721163*. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.*

INTEGRATING CHEMISTRY AND EARTH SCIENCE

10TH GRADE CHEMISTRY | COURSE OVERVIEW

All high school students in Baltimore City Public Schools (City Schools) are required to complete a three-course sequence of Biology, Chemistry, and Physics in grades 9, 10 and 11. However, with the Next Generation Science Standards adoption and implementation, Earth/space science needed to be addressed within City School's curriculum. The Integrating Chemistry and Earth science (ICE) project supported City Schools in creating a new Chemistry curriculum that met the NGSS requirements for both chemistry and Earth science. This newly revised, seven-unit high school Chemistry curriculum represents a major shift towards providing Next Generation Science Standards-aligned instruction and infusing Earth science performance expectations, concepts and practices across the entire curriculum. Within, there are many opportunities for students to explore Earth science material including in units 4, 6 and 7 which contain extensive ICE content and within the other units where Earth science is infused as small parts of lessons or individual lesson. We deemed these activities "ICEicles." The topics for these infusions are listed on the following slide along with the overall topics for each of the seven units.

INTEGRATING CHEMISTRY AND EARTH SCIENCE

10TH GRADE CHEMISTRY | COURSE UNITS

Unit topics	ICE/ICEicle topics
Atomic Structure and Patterns	• The Big Bang Theory and Life cycle of stars
Nuclear Chemistry	• Nuclear fusion in stars and Earth's formation and early history
Combining Atoms	• Properties of water
Chemical Reactions	• Ocean acidification
Stoichiometry	• Earth as a limiting reactant for energy and mineral resources
Thermochemistry	• Urban heat island and related phenomena and Inner Earth heat and processes
Chemistry and the Life and Death of Baltimore's Mountains *Earth/space science integration	• **Local landforms and rock types, weathering, erosion, water quality, and deposition** • **Plate tectonics, rock and crustal feature formation with a Baltimore focus**

INTEGRATING CHEMISTRY AND EARTH SCIENCE

CHEMISTRY AND THE LIFE AND DEATH OF BALTIMORE'S MOUNTAINS | UNIT SUMMARY

The Chemistry and the Life and Death of Baltimore's Mountains Unit explores the question "Where did the hills in Baltimore come from and how did they change over time?" addressing the concepts of plate tectonics, chemistry of rocks, weathering, erosion and deposition.

The Unit addresses such big ideas as the role of plate tectonics in mountain formation and the geologic evolution of North America. Students explore the chemistry of rocks types and understand how the Earth acts as a chemical refinery. The second part of the unit focuses on breaking down mountains through the processes of weathering, erosion and deposition. Students investigate both physical and chemical weathering and the impacts of weathered urban materials on stream water quality. The culminating student project requests students to design a page for the new *Visit Baltimore* website that explains the origin of the hills and "mountains" within Baltimore.

The Weathering, Erosion & Deposition module is a subset of lessons from Chemistry and the Life and Death of Baltimore's Mountains Unit. These lessons bring together important concepts from Earth science and chemistry to help students build an understanding of what happened to Baltimore's hills and where did the material go?

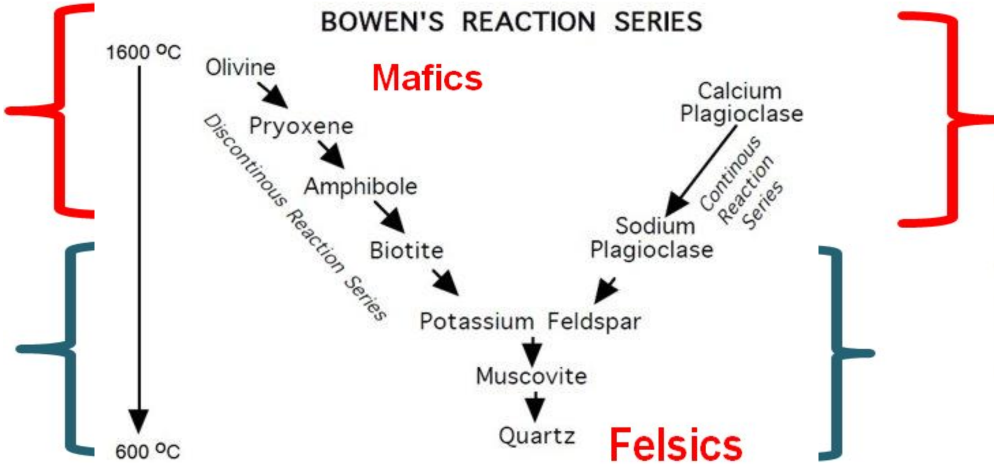
INTEGRATING CHEMISTRY AND EARTH SCIENCE

CHEMISTRY AND THE LIFE AND DEATH OF BALTIMORE'S MOUNTAINS

ANCHORING PHENOMENON: Plate Tectonics and the chemical composition of the Earth.

DRIVING QUESTION: Where did the hills in Baltimore come from and how did they change over time?

DESIGN CHALLENGE: Design a page for the new *Visit Baltimore* website that will explain the origin of the hills and "mountains" within Baltimore.



Mafic minerals often chemically weather faster than felsic ones. Quartz is physically hard and chemically almost inert, so it always weathers slowly.

INTEGRATING CHEMISTRY AND EARTH SCIENCE

CHEMISTRY AND THE LIFE AND DEATH OF BALTIMORE'S MOUNTAINS | UNIT LESSON SEQUENCE

Weathering, Erosion & Deposition Module

1. Unit Introduction:
2. Exploring Landform Patterns - Global Scale:
3. Evidence of Plate Boundaries:
4. The History of North America, Maryland, Baltimore:
5. Global Composition:
6. Chemistry of Rock Types:
7. Agents of Change:
8. Physical Weathering (3 Days):
9. Chemical Weathering:
10. Weathering and Water Quality (2 Days):
11. Weathering Erosion, and Deposition in the Local Environment:
12. Landforms and Physical Deposition:
13. Chemical Deposition:
14. Final Activity (2 Days):
15. End of Unit Assessment:

INTEGRATING CHEMISTRY AND EARTH SCIENCE

CHEMISTRY AND THE LIFE AND DEATH OF BALTIMORE'S MOUNTAINS | TARGETED PERFORMANCE EXPECTATIONS

HS-ESS2-1: **Develop a model to illustrate how Earth's internal and surface processes operate at different spatial and temporal scales to form continental and ocean-floor features.** [Clarification Statement: Emphasis is on how the appearance of land features (such as mountains, valleys, and plateaus) and sea-floor features (such as trenches, ridges, and seamounts) are a result of both constructive forces (such as volcanism, tectonic uplift, and orogeny) and destructive mechanisms (such as weathering, mass wasting, and coastal erosion).] [Assessment Boundary: Assessment does not include memorization of the details of the formation of specific geographic features of Earth's surface.]
HS-ESS2-2: **Analyze geoscience data to make the claim that one change to Earth's surface can create feedbacks that cause changes to other Earth systems.** [Clarification Statement: Examples should include climate feedbacks, such as how an increase in greenhouse gases causes a rise in global temperatures that melts glacial ice, which reduces the amount of sunlight reflected from Earth's surface, increasing surface temperatures and further reducing the amount of ice. Examples could also be taken from other system interactions, such as how the loss of ground vegetation causes an increase in water runoff and soil erosion; how dammed rivers increase groundwater recharge, decrease sediment transport, and increase coastal erosion; or how the loss of wetlands causes a decrease in local humidity that further reduces the wetland extent.]
HS-ESS2-5: **Plan and conduct an investigation of the properties of water and its effects on Earth materials and surface processes.** [Clarification Statement: Emphasis is on mechanical and chemical investigations with water and a variety of solid materials to provide the evidence for connections between the hydrologic cycle and system interactions commonly known as the rock cycle. Examples of mechanical investigations include stream transportation and deposition using a stream table, erosion using variations in soil moisture content, or frost wedging by the expansion of water as it freezes. Examples of chemical investigations include chemical weathering and recrystallization (by testing the solubility of different materials) or melt generation (by examining how water lowers the melting temperature of most solids).]

INTEGRATING CHEMISTRY AND EARTH SCIENCE

CHEMISTRY AND THE LIFE AND DEATH OF BALTIMORE'S MOUNTAINS | SCIENCE AND ENGINEERING PRACTICES

Developing and Using Models. Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system. Develop and/or use a model (including mathematical and computational) to generate data to support explanations, predict phenomena, analyze systems, and/or solve problems. Develop and/or use multiple types of models to provide mechanistic accounts and/or predict phenomena, and move flexibly between model types based on merits and limitations.

Planning and Carrying Out Investigations. Plan an investigation or test a design individually and collaboratively to produce data to serve as the basis for evidence as part of building and revising models, supporting explanations for phenomena, or testing solutions to problems. Consider possible variables or effects and evaluate the confounding investigation's design to ensure variables are controlled.

Analyzing and Interpreting Data. Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution.

Engaging in Argument from Evidence. Make and defend a claim based on evidence about the natural world or the effectiveness of a design solution that reflects scientific knowledge, and student-generated evidence.

Obtaining, Evaluating, and Communicating Information. Communicate scientific and/or technical information or ideas (e.g. about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically).

INTEGRATING CHEMISTRY AND EARTH SCIENCE

CHEMISTRY AND THE LIFE AND DEATH OF BALTIMORE'S MOUNTAINS | DISCIPLINARY CORE IDEAS

ESS2.A HS1: **Earth Materials and Systems.** Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes.

ESS2.B HS2: **Plate Tectonics and Large-Scale System Interactions.** Plate tectonics is the unifying theory that explains the past and current movements of the rocks at Earth's surface and provides a framework for understanding its geologic history.

ESS2.C HS1: **The Roles of Water in Earth's Surface Processes.** The abundance of liquid water on Earth's surface and its unique combination of physical and chemical properties are central to the planet's dynamics. These properties include water's exceptional capacity to absorb, store, and release large amounts of energy, transmit sunlight, expand upon freezing, dissolve and transport materials, and lower the viscosities and melting points of rocks.

ESS2.BHS3: **Plate Tectonics and large-Scale System Interactions.** Plate movements are responsible for most continental and ocean-floor features and for the distribution of most rocks and minerals within Earth's crust.

INTEGRATING CHEMISTRY AND EARTH SCIENCE

CHEMISTRY AND THE LIFE AND DEATH OF BALTIMORE'S MOUNTAINS | CROSS CUTTING CONCEPTS

Patterns. Mathematical representations are needed to identify some patterns. Empirical evidence is needed to identify patterns.

Cause and Effect. Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system.

Scale, Proportion, and Quantity. Some systems can only be studied indirectly as they are too small, too large, too fast, or too slow to observe directly.

Systems and System Models. Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales.

Energy and Matter. Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system.

Structure and Function. The functions and properties of natural and designed objects and systems can be inferred from their overall structure, the way their components are shaped and used, and the molecular substructures of its various materials.

Stability and Change. Much of science deals with constructing explanations of how things change and how they remain stable. Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible.

INTEGRATING CHEMISTRY AND EARTH SCIENCE

CHEMISTRY AND THE LIFE AND DEATH OF BALTIMORE'S MOUNTAINS | MODELING TASKS FOR STUDENT SENSE MAKING

Throughout the ICE curriculum, lessons bring together disciplinary core ideas, crosscutting concepts, and science and engineering practices to support three-dimensional teaching and learning.

Within the Chemistry and the Life and Death of Baltimore's Mountains and the Weathering, Erosion & Deposition module, particular emphasis is placed on supporting students' development of model-based explanations of the process of pothole formation in roads. The modeling tasks within the module prompt students to illustrate their understanding of how mechanical and/or chemical processes of weathering and erosion cause changes in natural and human-made surfaces. Additionally, students are able to highlight how interactions between natural and human systems have reciprocal impacts on phenomena like pothole formation.

The students' models also make their thinking visible so teachers are able to build upon the current understanding of their students and document the changing complexity of their models.

INTEGRATING CHEMISTRY AND EARTH SCIENCE

WEATHERING, EROSION & DEPOSITION
OVERVIEW

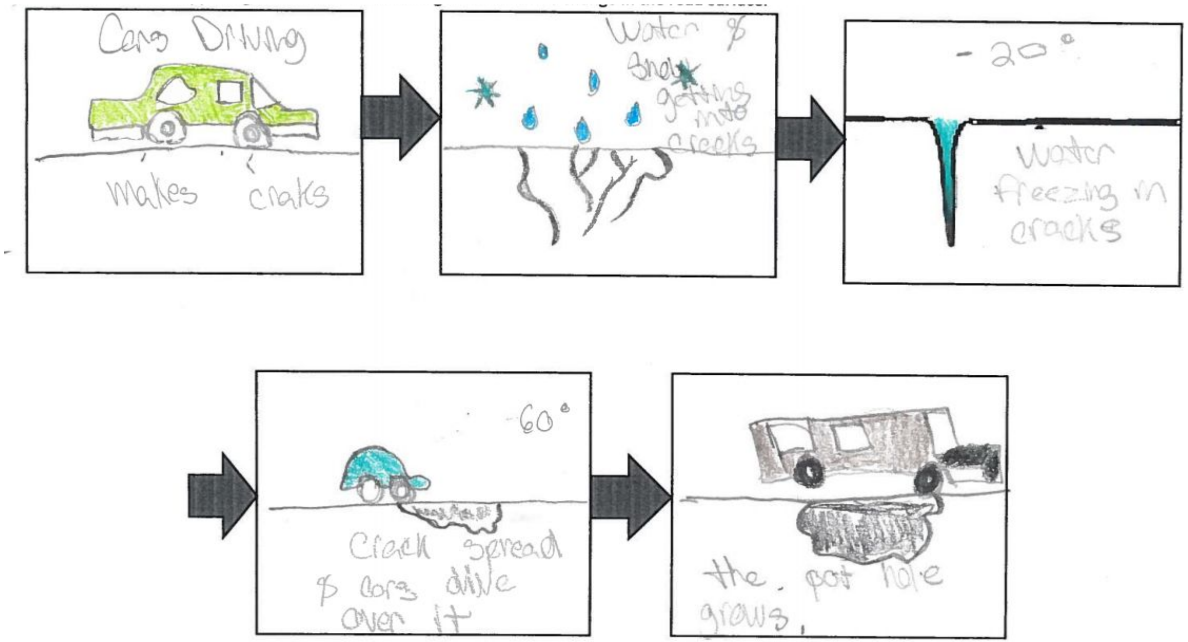
Near-Surface Fracturing

Plate tectonic forces can make a pattern of parallel cracks called *joint sets*. Gunpowder Falls State Park, Baltimore County, MD. Photo by Martin Schmidt.

WEATHERING, EROSION & DEPOSITION MODULE

The Weathering, Erosion & Deposition Module includes 7 lessons derived from the Chemistry and the Life and Death of Baltimore's Mountains Unit of Baltimore City Public School's high school chemistry course. These lessons guide students in learning about and developing an understanding of the processes of physical and chemical weathering and the role of chemical compounds in preventing or accelerating the forces that cause the breakdown in natural and human-made materials. Students examine how potholes form and the consequences of the erosion of urban building materials on stream water quality.

A student description of how potholes form.



INTEGRATING CHEMISTRY AND EARTH SCIENCE (ICE)

WEATHERING, EROSION & DEPOSITION | LESSONS

1) Agents of Change

2) Physical Weathering (3 Days)

3) Chemical Weathering

4) Weathering and Water Quality (2 Days)

5) Weathering, Erosion & Deposition in the Local Environment

6) Landforms and Physical Deposition

7) Chemical Deposition

Marble stairs showing signs of weathering in Baltimore City, MD.

INTEGRATING CHEMISTRY AND EARTH SCIENCE

WEATHERING, EROSION & DEPOSITION

Lesson 1: Agents of Change	Lesson 2: Physical Weathering (3 Days)
Driving Question: What can move/change mountains?	**Driving Question:** How does freezing water break down mountains?
Summary: Students will learn about the basics of weathering, erosion and deposition. They will have the opportunity to debate and defend claims as teams, describe cause and effect relationships, and examine models while classifying phenomena. Go To Lesson	**Summary:** Students will experiment with factors that lead to the weathering process ice-wedging and develop a **cause and effect** understanding of how it contributes to the formation of potholes in our streets. By the end of the lesson sequence students will **"storyboard" the process of pothole formation** which will demonstrate their understanding of the concept. They will also complete the rock tumbler activity that **models** weathering of natural and urban materials. Go To Lesson

INTEGRATING CHEMISTRY AND EARTH SCIENCE

WEATHERING, EROSION & DEPOSITION

Lesson 3: Chemical Weathering	Lesson 4: Weathering and Water Quality (2 Days)
Driving Question: How do chemical processes break down mountains?	**Driving Question:** How do we measure chemical weathering?
Summary: Students should have an idea of the following: Physical weathering breaks objects into smaller pieces but does not change the identity of the object. Water is a major component of Physical weathering due to its ability to expand when it freezes and through flowing water aiding in abrasion. These two processes are a significant component in the formation of potholes in city streets as well as the natural landscape. Questions they should be considering, at this point, include how can weathering change the composition of the rocks?	**Summary:** Students will examine how scientists measure chemical weathering through the chemical composition of runoff in streams. They will analyze local stream data and use that data to make and defend a claim regarding the impact of impermeable surfaces (such as cement) on water quality. Teacher note: This activity requires two days.
Go To Lesson	Go To Lesson

INTEGRATING CHEMISTRY AND EARTH SCIENCE

WEATHERING, EROSION & DEPOSITION

Lesson 5: Weathering, Erosion & Deposition in the Local Environment	Lesson 6: Landforms and Physical Deposition
Driving Question: Where do we find evidence of weathering, erosion, and deposition in the local environment?	**Driving Question:** Where does the moving material go?
Summary: Students will apply their knowledge of cause and effect relationships of weathering, erosion, and deposition to their local environment. As weather permits, students will go outside to collect and analyze evidence of weathering in the “Schoolyard Weathering and Erosion Treasure Hunt.”	**Summary:** Students will examine the changes in matter within a simulated stream to develop an understanding of the process of settling. Students will analyze data and observations collected during class investigations and apply their understanding to the natural world through student created models.
Go To Lesson	Go To Lesson

INTEGRATING CHEMISTRY AND EARTH SCIENCE

WEATHERING, EROSION & DEPOSITION

Lesson 7: Chemical Deposition

Driving Question: What happens to dissolved minerals?

Summary: Students will simulate the process of limestone formation in a chemical deposition lab activity by blowing through limewater.

Go To Lesson

INTEGRATING CHEMISTRY AND EARTH SCIENCE

SOURCES

Grooms, J., Fleming, K., Berkowitz, A.R., and Caplan, B. (2021). Exploring modeling as a context to support content integration for chemistry and Earth science. *Journal of Chemical Education*, 98(7), 2167-2175.