Bridging the gap: Using geochemical data to integrate geology and chemistry in K-12 Education

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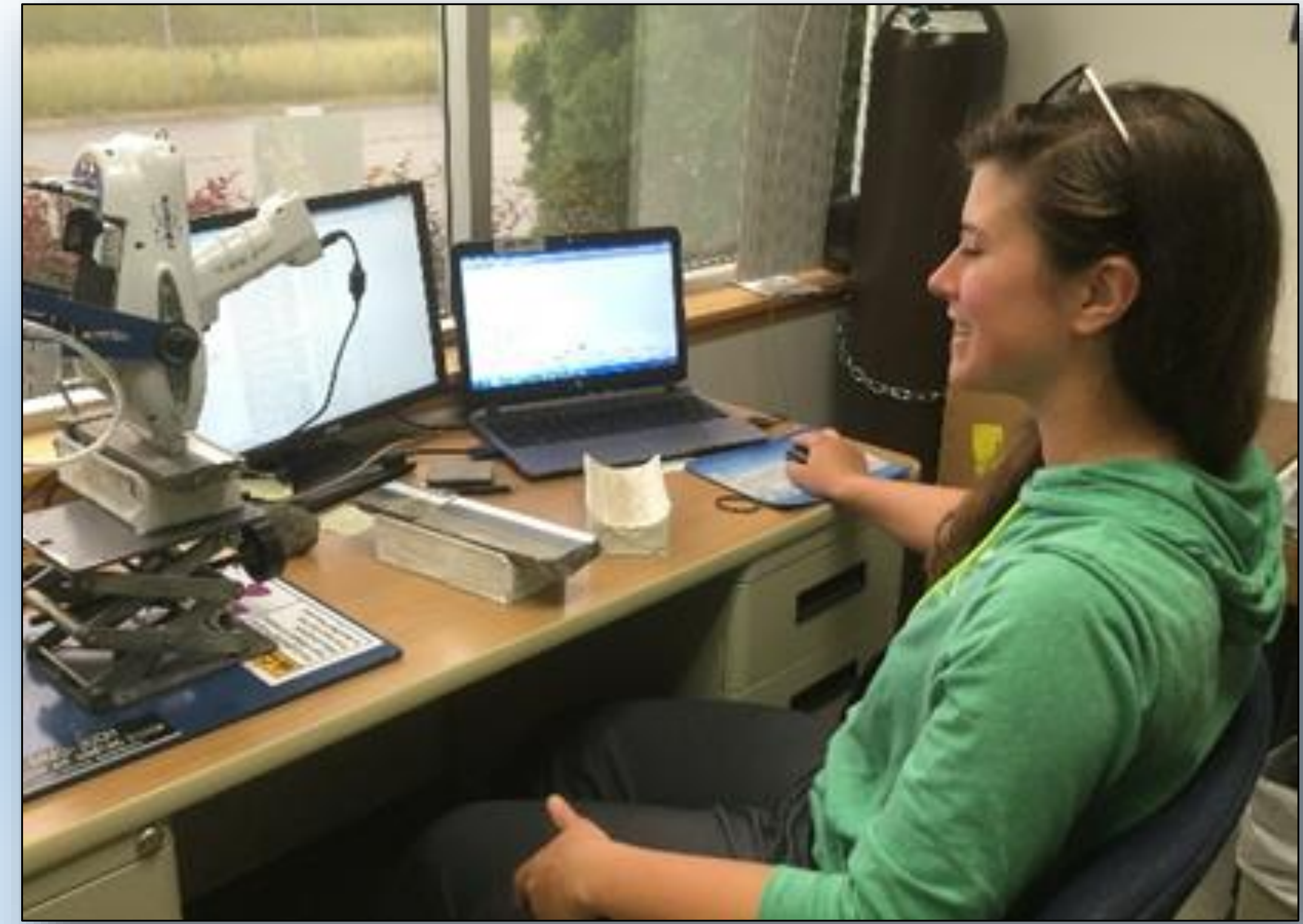
Bridging the Gap Workshop

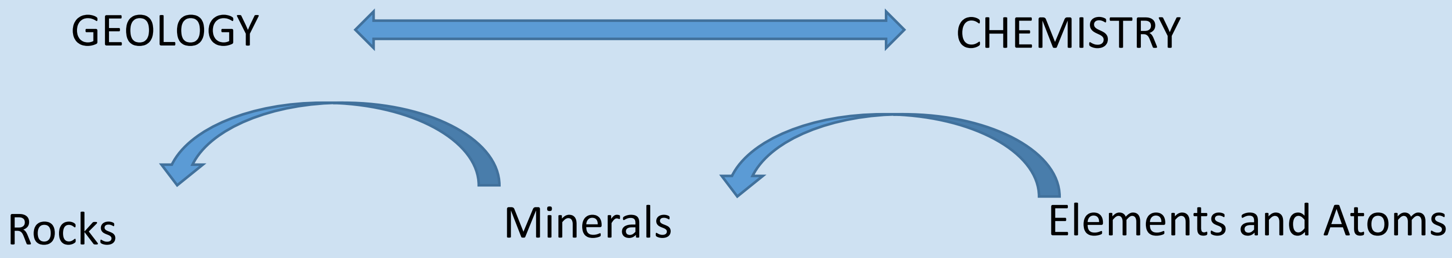
- Funded through a NSF Instrumentation & Facilities Grant
  - Supported purchase of Bruker Handheld X-ray Fluorescence Spectrometer (HHXRF)
  - Training Undergraduate and Graduate students to use the HHXRF to acquire data
  - Develop workshop materials (lesson plans, activities, displays)
  - Travel stipends for teacher participants
- August 2017 Workshop – 15 participants
- August 2018 Workshop – in preparation (37 interested teachers)



One of our students analyzing a core sample with the HHXRF

Workshop Objectives

- Increase familiarity with the concept of using geological materials as sources of quantitative chemical data
- Better appreciate the relationship between common geological materials, their bulk chemical composition, and common societal uses
- Gain a basic understanding of how X-ray fluorescence spectrometry can be used to determine the chemical composition of geological materials



Workshop Agenda

- Short lectures on Earth Materials, Michigan Geology, and X-Ray Fluorescence theory
- Tour of facility
- Hands-on activities – including Pet Rock
- Teacher-led discussion, brainstorming, and lesson plan creation

Teacher Recruitment

- Partnerships with local teachers associations facilitated advertising/recruitment for workshop
- Relationships through existing outreach activities
- 21 teachers interested in 2017 workshop
- 37 for the 2018 workshop

How do we fill the seats????

2017 Workshop Participants

- 15 teachers
- Grade Levels taught – 5 to 12 - mostly at High School level
  - Integrated Science, Earth Science, Biology, Math, Chemistry (Honors, Intro, AP), Physics, Astronomy, STEM, Meteorology, Environmental Science
  - Mix of public, private, and charter schools represented – including a diverse cross section of Urban, Suburban and Rural Schools (primarily Southern Lower Peninsula)
- 53% Female; majority Caucasian/White
- Wide range of experience – 3 to 40 years

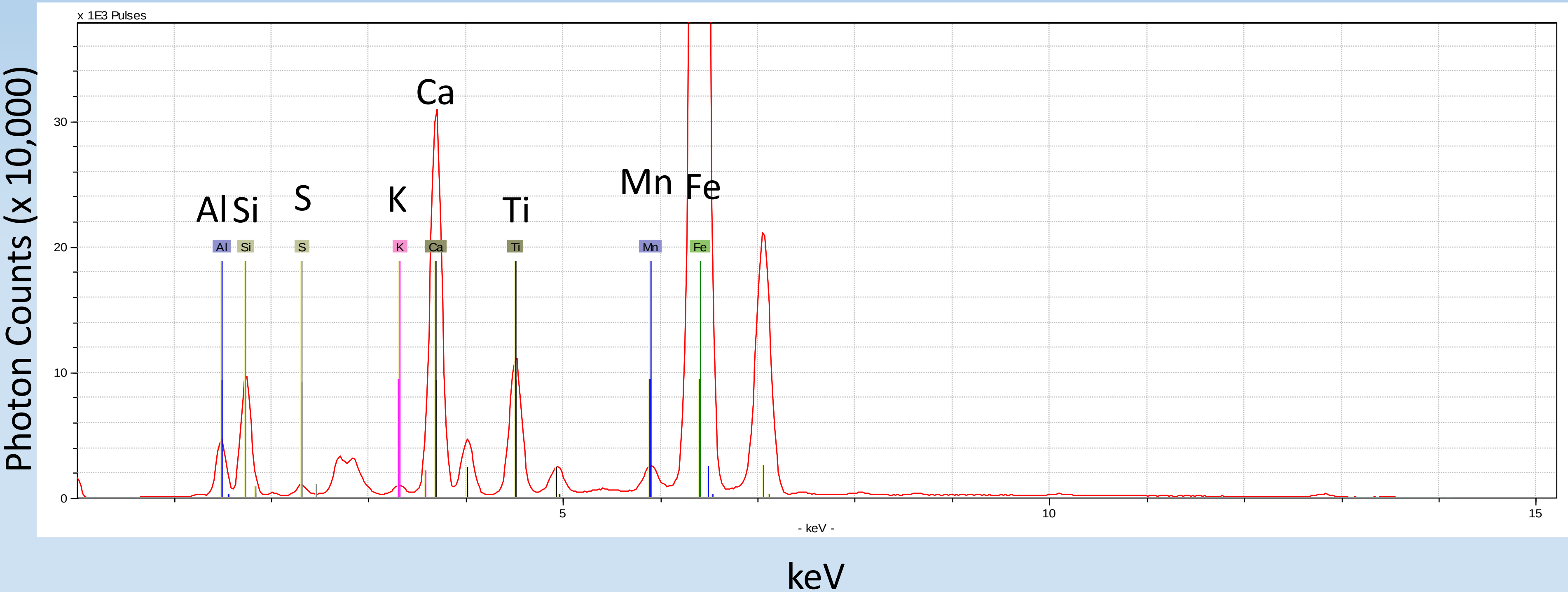
Michigan Geological Repository for Research and Education
Michigan's Rock Archive

560,000 ft. of core, 20 million ft. of cuttings
Well logs, drillers reports for many MI wells
(Hydrocarbons, Water, Mineral)

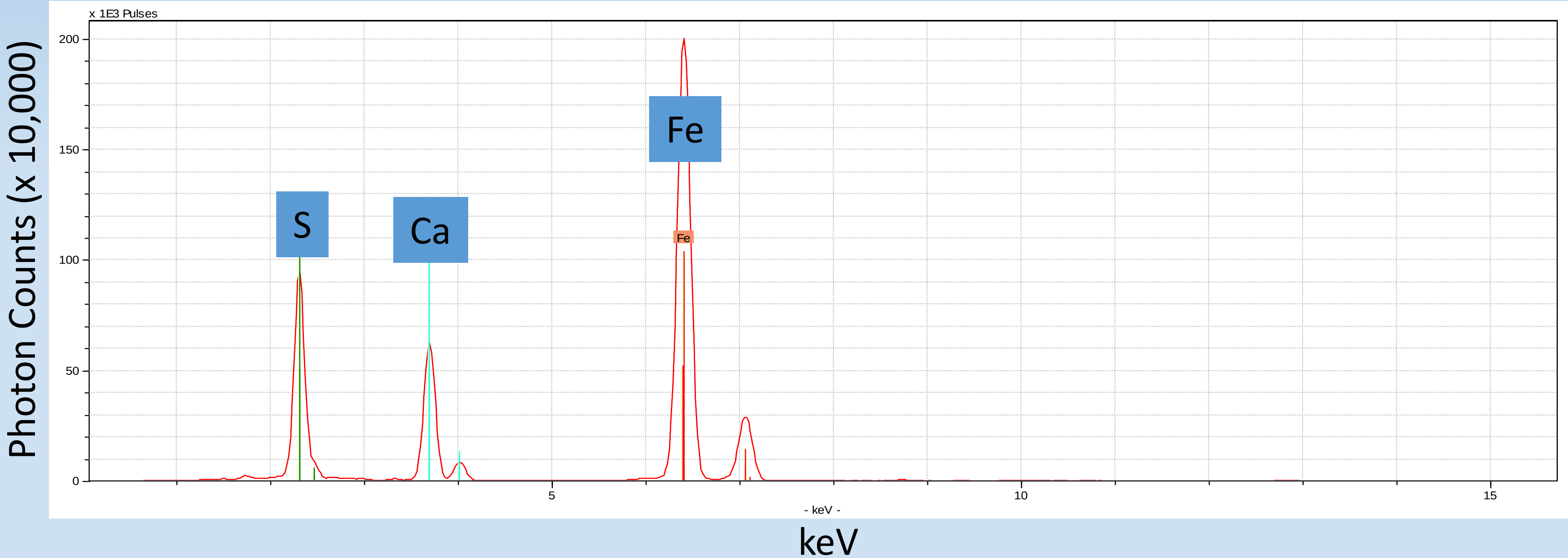
Hands-on Activities

- Variety of Topics
  - Powder Problem
  - Fossilization
  - Pet Rock
  - Forensic XRF
  - Alien Agua

Leslie's Pet Rock – an Icelandic Basalt:



Which Brachiopod is more likely to exhibit the following chemical composition?



Powder Problem

Objectives

The objective of this activity is to identify rock powders based only on their major element compositions as determined by XRF.

Instructions

A set of rocks commonly found in the Michigan Basin has been provided (Table 1). These rocks have been powdered and placed into the vials labeled A-F. The whole rocks are fairly easy to tell apart, but as you can see, it is quite difficult to discriminate between the white powders (except the hematite, of course). Use the raw XRF spectra provided to match the powdered samples to their whole rock counterparts.

XRF – quantitative, quick, analytical technique

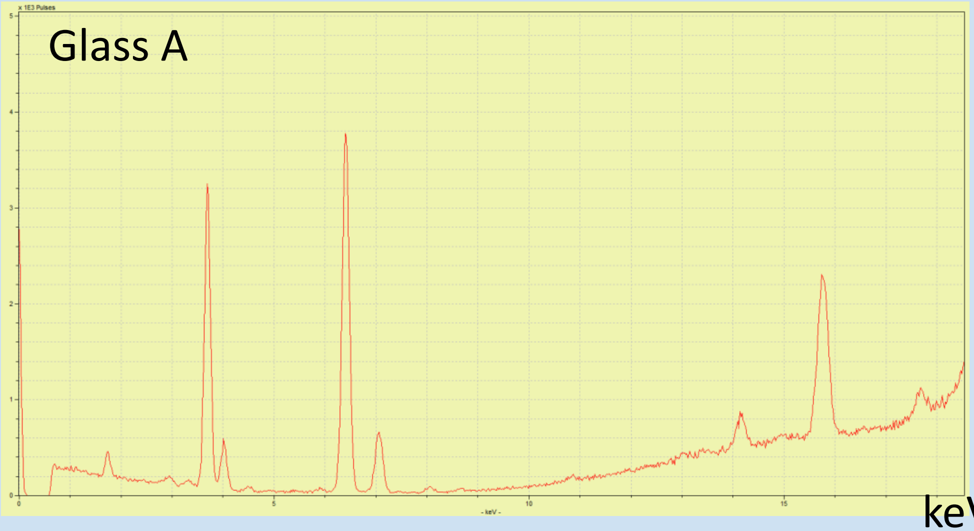
Rock Name	*Mineralogy*	*Chemical Formula*	*Chemical name*
Limestone	calcite, aragonite	$CaCO_3$	calcium carbonate
Dolostone	dolomite	$CaMg(CO_3)_2$	calcium-magnesium carbonate
Rock Salt	halite	$NaCl$	sodium chloride
Rock Gypsum	gypsum	$CaSO_4$	calcium sulfate
Sandstone	quartz	SiO_2	silicon dioxide
Specular Hematite	hematite, mica	Fe_2O_3	iron oxide

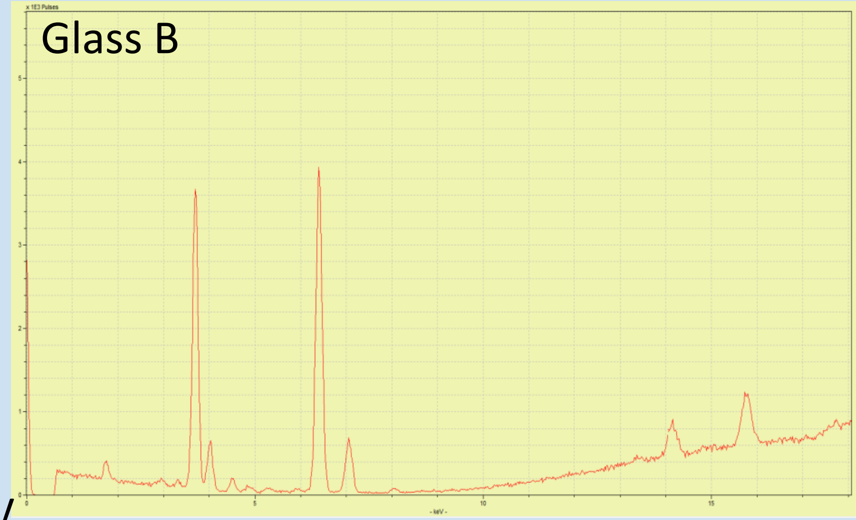
Forensic X-ray Fluorescence: Hit-and-Run

Image that you're a forensic scientist whose task it is to determine what happened in a hit-and-run car accident. At the crime scene, microscopic glass fragments from the car's windshield are found on the victim's body (Glass A). The police locate an abandon car with serious damage that fits a witness's description. The owner of the vehicle (i.e. suspect #1) claims his vehicle was stolen earlier that night and he wasn't involved with the accident. After obtaining a search warrant, your team searches the suspect's home and collects a small glass fragment embedded in the suspect's jacket (Glass B).

Both glass samples have been analyzed with the handheld XRF to determine their trace element compositions. Here are the resulting spectra

Photon Counts (x 10,000)





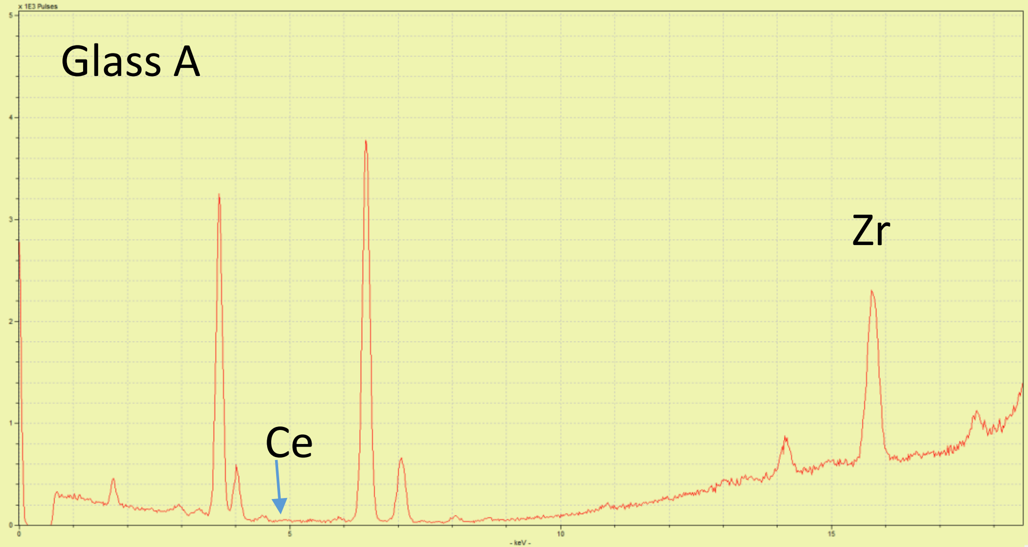
keV

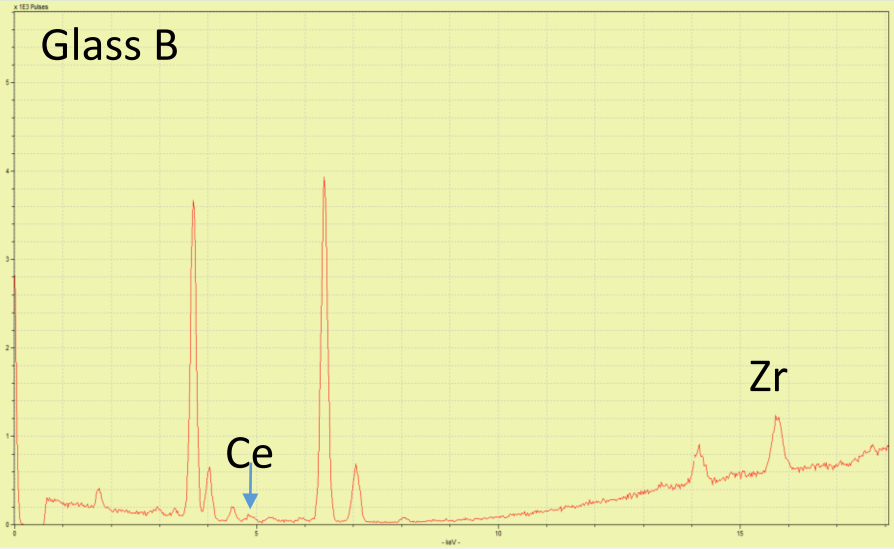
Forensic X-ray Fluorescence: Hit-and-Run

What elements do the glass samples have in common? What elements are unique? Do these samples have the same origin?
These samples likely do not have the same origin due the presence of Ce in Glass B. The samples are also different in their relative amounts of Zr, with Glass A having more Zr than B. Both samples are the same in the amount of all other elements.

Is there enough forensic evidence to say the suspect was or wasn't involved in the crime?

These data do not support the claim that the glass on the suspect's jacket was the same as the glass from the crime scene and on the victim. It doesn't rule out the involvement of the suspect.





Afternoon Hands-on Activities


MQ-153
158A
131
Horse Tooth
Wood
Brachiopod
Brachiopod

Discussion Sessions

- Teacher-mediated discussion in small groups
  - Discussion of how activities/lesson plans fit into NGSS
  - Discussion of multidisciplinary/integrated science – using examples from geosciences to reinforce chemistry and physics concepts

HS-ESS3 Earth and Human Activity

HS-ESS3 Earth and Human Activity

Students who demonstrate understanding can:

HS-ESS3-1. **Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity.** [Clarification Statement: Examples of key natural resources include access to fresh water (such as rivers, lakes, and groundwater), regions of fertile soils such as river deltas, and high concentrations of minerals and fossil fuels. Examples of natural hazards can be from interior processes (such as volcanic eruptions and earthquakes), surface processes (such as tsunamis, mass wasting and soil erosion), and severe weather (such as hurricanes, floods, and droughts). Examples of the results of changes in climate that can affect populations or drive mass migrations include changes to sea level, regional patterns of temperature and precipitation, and the types of crops and livestock that can be raised.]

HS-ESS3-2. **Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios.*** [Clarification Statement: Emphasis is on the conservation, recycling, and reuse of resources (such as minerals and metals) where possible, and on minimizing impacts where it is not. Examples include developing best practices for agricultural soil use, mining (for coal, tar sands, and oil shales), and pumping (for petroleum and natural gas). Science knowledge indicates what can happen in natural systems—not what should happen.]

HS-ESS3-3. **Create a computational simulation to illustrate the relationships among the management of natural resources, the sustainability of human populations, and biodiversity.** [Clarification Statement: Examples of factors that affect the management of natural resources include costs of resource extraction and waste management, per-capita consumption, and the development of new technologies. Examples of factors that affect human sustainability include agricultural efficiency, levels of conservation, and urban planning.] [Assessment Boundary: Assessment for computational simulations is limited to using provided multi-parameter programs or constructing simplified spreadsheet calculations.]

HS-ESS3-4. **Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.*** [Clarification Statement: Examples of data on the impacts of human activities could include the quantities and types of pollutants released, changes to biomass and species diversity, or areal changes in land surface use (such as for urban development, agriculture and livestock, or surface mining). Examples for limiting future impacts could range from local efforts (such as reducing, reusing, and recycling resources) to large-scale geoengineering design solutions (such as altering global temperatures by making large changes to the atmosphere or ocean).]

HS-ESS3-5. **Analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth's systems.** [Clarification Statement: Examples of evidence, for both data and climate model outputs, are for climate changes (such as precipitation and temperature) and their associated impacts (such as on sea level, glacial ice volumes, or atmosphere and ocean composition).] [Assessment Boundary: Assessment is limited to one example of a climate change and its associated impacts.]

HS-ESS3-6. **Use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity.** [Clarification Statement: Examples of Earth systems to be considered are the hydrosphere, atmosphere, cryosphere, geosphere, and/or biosphere. An example of the far-reaching impacts from a human activity is how an increase in atmospheric carbon dioxide results in an increase in photosynthetic biomass on land and an increase in ocean acidification, with resulting impacts on sea organism health and marine populations.] [Assessment Boundary: Assessment does not include running computational representations but is limited to using the published results of scientific computational models.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Analyzing and Interpreting Data
Analyzing data in 9–12 builds on K–8 experiences and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data.
- Analyze data using computational models in order to make valid and reliable scientific claims. (HS-ESS3-5)

Using Mathematics and Computational Thinking
Mathematical and computational thinking in 9-12 builds on K-8 experiences and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.
- Create a computational model or simulation of a phenomenon, designed device, process, or system. (HS-ESS3-3)
- Use a computational representation of phenomena or design solutions to describe and/or support claims and/or explanations. (HS-ESS3-6)

Constructing Explanations and Designing Solutions
Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific knowledge, principles, and theories.
- Construct an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. (HS-ESS3-1)
- Design or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (HS-ESS3-4)

Engaging in Argument from Evidence
Engaging in argument from evidence in 9–12 builds on K–8

Disciplinary Core Ideas

ESS2.D: Weather and Climate
- Current models predict that, although future regional climate changes will be complex and varied, average global temperatures will continue to rise. The outcomes predicted by global climate models strongly depend on the amounts of human-generated greenhouse gases added to the atmosphere each year and by the ways in which these gases are absorbed by the ocean and biosphere. *(secondary to HS-ESS3-6)*

ESS3.A: Natural Resources
- Resource availability has guided the development of human society. (HS-ESS3-1)
- All forms of energy production and other resource extraction have associated economic, social, environmental, and geopolitical costs and risks as well as benefits. New technologies and social regulations can change the balance of these factors. (HS-ESS3-2)

ESS3.B: Natural Hazards
- Natural hazards and other geologic events have shaped the course of human history; [they] have significantly altered the sizes of human populations and have driven human migrations. (HS-ESS3-1)

ESS3.C: Human Impacts on Earth Systems
- The sustainability of human societies and the biodiversity that supports them requires responsible management of natural resources. (HS-ESS3-3)
- Scientists and engineers can make major contributions by developing technologies that produce less pollution and waste and that preclude ecosystem degradation. (HS-ESS3-4)

ESS3.D: Global Climate Change
- Though the magnitudes of human impacts are greater than they have ever been, so too are human abilities to model, predict, and manage current and future impacts. (HS-ESS3-5)
- Through computer simulations and other studies, important discoveries are still being made about how the ocean, the atmosphere, and the biosphere interact and are modified in response to human activities. (HS-ESS3-6)

ETS1.B: Developing Possible Solutions
- When evaluating solutions, it is important to take into

Crosscutting Concepts

Cause and Effect
- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (HS-ESS3-1)

Systems and System Models
- When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models. (HS-ESS3-6)

Stability and Change
- Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible. (HS-ESS3-3),(HS-ESS3-5)
- Feedback (negative or positive) can stabilize or destabilize a system. (HS-ESS3-4)

Connections to Engineering, Technology, and Applications of Science

Influence of Engineering, Technology, and Science on Society and the Natural World
- Modern civilization depends on major technological systems. (HS-ESS3-1),(HS-ESS3-3)
- Engineers continuously modify these technological systems by applying scientific knowledge and engineering design practices to increase benefits while decreasing costs and risks. (HS-ESS3-2),(HS-ESS3-4)
- New technologies can have deep impacts

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice or Disciplinary Core Idea.

The section entitled "Disciplinary Core Ideas" is reproduced verbatim from A Framework for K-12 Science Education: Practices, Cross-Cutting Concepts, and Core Ideas. Integrated and reprinted with permission from the National Academy of Sciences.

Participant	1. This workshop increased my familiarity with how geoscientists use geological materials as sources of quantitative chemical data.	2. This workshop allowed me to better appreciate the relationship between common geological materials, their chemical composition, and common societal uses.	3. This workshop gave me a basic understanding of how X-ray fluorescence spectrometry can be used to determine the chemical composition of geological materials.
P1	5	5	5
P2	5	5	5
P3	5	5	5
P4	5	5	5
P5	5	5	5
P6	5	5	5
P7	5	5	5
P8	5	5	5
P9	5	5	5
P10	4	4	5
P11	5	5	5
P12	3	4	4
P13	5	5	5
P14	5	4	5
P15	5	4	5

Post-Workshop Surveys – Feedback opportunity

9. How much do you think you now understand about using XRF spectroscopy to study the elemental composition of geologic materials as a result of participating in this workshop?	10. To what extent did the lessons and teaching materials provided in this workshop align with state science standards?	11. I plan to use the lessons and teaching materials provided in this workshop in my classes.
4	5	5
5	5	5
4	5	5
4	5	4
5	5	5
5	5	5
4	4	4
5	5	5
4	5	5
4	5	4
5	5	5
3	3	3
4	4	4
4	4	4
4	4	4

The Workshop was effective:

1. It increased teacher knowledge
2. The materials provided were aligned with MI Science Standards
3. Teachers were willing to use the materials in their classrooms

Post-Workshop Surveys – Feedback opportunity

Conclusions

- Emphasize connections between Geosciences, Chemistry and Physics
  - Better alignment with NGSS
  - Provide examples across disciplines that teachers can use
- Hands-on activities – more engaging to students and teachers
- Data sets authentic and quantitative: math literacy, graph comprehension, statistical analysis of geological data
  - More rigorous approach to outreach and K-12 education – portable tech and “instantaneous testing”