SUPPLEMENTAL MATERIALS

BUILDING INTEREST AND KNOWLEDGE IN GEOSCIENCES THROUGH PLACE- & FIELD-BASED TEACHER PROFESSIONAL LEARNING PROGRAMS: A COMPARATIVE MULTI-CASE STUDY

By

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1 Case Study 1. The Impact of EarthCache™ Development as Part of a Geoscience Field Course for Inservice Teachers

This section includes the supplemental materials for the MiTEP EarthCache Program and subsequent case study.

1.1 Description of Michigan Teaching Excellence Project (MiTEP)

MiTEP was designed to empower urban K-12 teachers to lead their schools and districts through the process of systematically improving science teaching and learning. Michigan Tech University began the 4-year project in 2010 with funding from the National Science Foundation's Math & Science Partnership (MSP). The teacher leadership project had over 40 teachers participating in 4 cohorts. Participating teachers received stipends and credit for participating in the project over a 3-year period and for testing its approach to science education reform. The MiTEP core partners were Michigan Technological University, Grand Rapids Area Pre-College Engineering Program (GRAPCEP), Grand Rapids Public Schools, Jackson Public Schools, Kalamazoo Public Schools, American Geosciences Institute, Grand Valley State University, Western Michigan University and the Midwestern National Parks. MiTEP included both summer and academic-year components, and used a variety of on-site, residential, field, distance, and in-service delivery methods.

1.2 Further Program Details and Course Materials

Earth Science Institute: The field experiences included the Earth Science Institute (ESI), a 2-week summer field-based program that was a requirement during the first and second year of the program for all four cohorts. These field courses were designed to introduce Earth Science content to Michigan science teachers in inquiry form with a focus in applying what they learn to their classrooms. They emphasize the development of participants' problem-solving skills and employ inquiry-based learning techniques. An important part of these courses was to use tools that research scientists use and teach participants to conduct scientific research. The style of the courses was observational, geographical, descriptive, analytical and interpretive. In the field participants repeatedly were asked to apply a sequence of logical questions that could be tested, so that hypotheses could be rejected or refined. To achieve this the teachers visited field sites through the Western Upper Peninsula and Western Lower Peninsula Region of Michigan. These locations were home to the core partner universities and school districts involved in MiTEP. The ESLP Big Ideas were introduced on the first day of the course and then used as a connecting theme for the various field sites visited each day of the 10-day field course. Visit https://pages.mtu.edu/~raman/SilverI/MiTEP_ESI-1/Welcome.html, the MiTEP ESI-1 June-July 2012 website, for the complete schedule. In addition to the course instructors, other content experts joined the teachers to explore the geo-sites and the earth science processes that shape the feature or phenomena. The application of field skills and content varied from site and topic. Common preconceptions were explored in relation to the geoscience content and ESLP big ideas. Additionally, participants worked

individually or together to answer transition questions to reinforce the learning occurring in the field. Participants were asked to create lesson plans for their classroom as product of the program.

National Park Internship: The National Park Internships was an optional capstone project that some teachers participated in during their third and final summer with MiTEP. Teachers spent three weeks connected with a mid-west national park. The expectations of the program included: Developing Earth Science content resources for parks, further development of leadership skills, development of geoscience interpretive skills and to nurture collaboration between public schools and the national parks. This was a much more self-directed learning with deliverables that included creating learning materials for the parks. Some teachers were invited to make EarthCaches as part of this deliverable and engaged in the program that is the topic of this study and would visit sites with content experts and national park staff.

Table S1.1. Cohort 4 MiTEP Schedule

Activity	When?	Status	Description	Location	Cr	Stipend
Earth Systems Institute I	Summer 2012	Required	2-week Field-based professional development experience UP = June 25-29 Lower MI = July 9-13	Michigan Tech. Un. & lower Michigan	4	$1,000 per week
Pedagogy Workshops	2012-2013 School Year	Required	Combine earth science content and pedagogy	lower Michigan	1	Sub Pay
Lesson Study	Spring 2013	Required	Collaborative lesson plan development, teaching, and observation of student learning	lower Michigan	1	$250 Sub Pay
Earth Systems Institute II	Summer 2013	Required	Field-based professional development experience	Michigan Tech. Un. & lower Michigan	4	$1,000 per week
How the Earth Works	Fall 2012	Required	Earth System Science- course includes basic historical and physical geology	On-line	2	$250
Curriculum Scaffolding Workshops	2013-2014 School Year	Required	Focus on system-wide change in science curriculum, connecting curriculum across grade levels	lower Michigan	1	Sub Pay
Science Learning Materials and Assessment	Spring 2014	Required	Examination of learning materials that enable inquiry-based learning as prescribed by state and national standards	On-line	2	$500
Science Leadership Internship	Summer 2014	Required	3-week experience working with National Park interpreters on scientific inquiry based on the natural environment	Midwest National Parks	3	$3,000
Action Research	2013-2014	Select this or Science Leadership Internship	Study of education research methods pertaining to classroom practice, curriculum standards and evaluation; data presentation; action learning and committees of inquirers	On-line	2	$500

1.3 Demographic Information from 2021 Survey

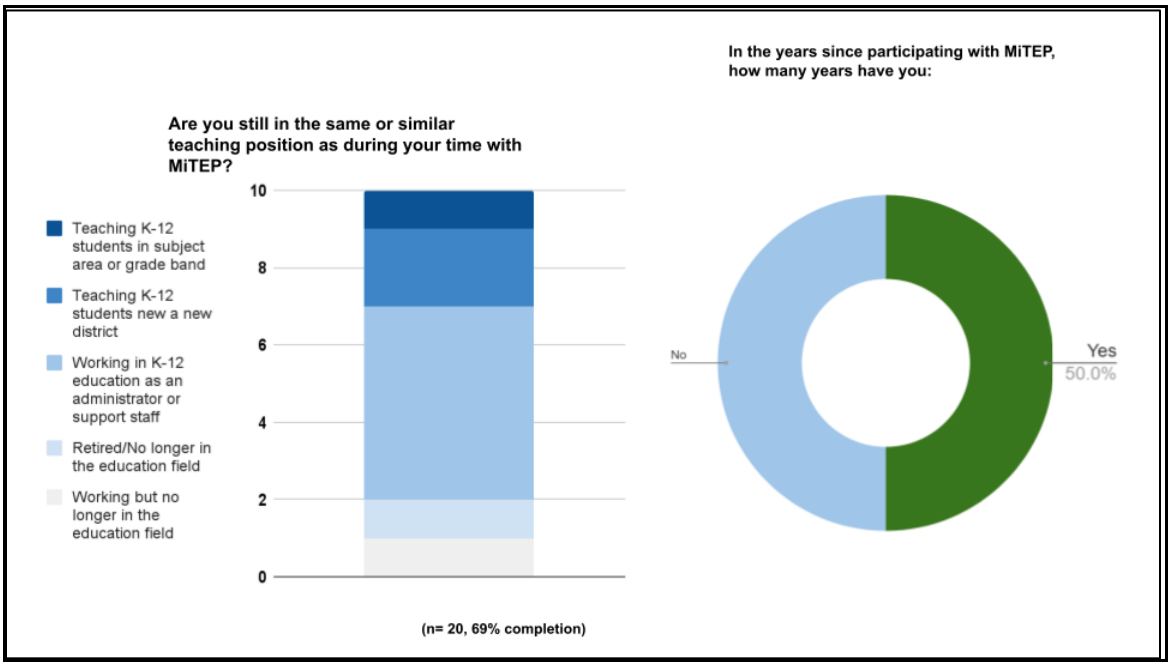

Figure S1. 1. Displays demographic information collected during the 2021 survey.

1.4 Materials Provided to ESI Participants

provide a link to each along with a note about the importance of the materials to the course.

- Published EarthCaches visited during the 2011 course
    - Copper Harbor Conglomerate at Horseshoe Harbor and Stromatolites! at Horseshoe Harbor - developed by MiTEP instructors and provide an example of the type of EarthCache that teachers were expected to create by the end of the course. These included further information beyond those required by EarthCache.
- Published EarthCaches visited during the 2012 ESI II course, many were developed by Cohort 2 participants during the previous summer.
- Geosite Field Collection Form - template of the basic materials that needs to be gathered while in the field. Due to the tight timeline of a field course, it was impractical to revisit or linger in sites. This template served as an important guide to be sure that participants would collect all necessary information while onsite.
- MiTEP EarthCache Format - MiTEP EarthCaches include further information beyond EarthCaches for community members and other educators exploring the geosite lessons. This document outlines all of the components that a MiTEP participant should address as they are creating the EarthCache.
- Landowner permission letter template - Contact information and templates for a letter to the geosite landowner was provided to participants
- Publishing Your EarthCache & Once your EarthCache has been published.
- List of other materials from GSA that were provided as digital or hard copies in participants folders.
    - EarthCaching: An Educator's Guide
    - GSA: Two ways to EarthCache in Schools - Earth Science Week
    - FAQ EarthCaching
    - ES Literacy Principles Brochure

1.5 Research Instruments Applied in Study

1.5.1 2012 Survey Pre/Post Visiting EarthCache Survey

- Pre-Survey Only: Demographic Information
  - What is the name of the district where you teach?
  - What grade level(s) do you teach?
  - What are the main subject area(s) that you teach?
- Pre/Post Survey - Likert-like directions: Please rate the amount of experience that you have with the following on a scale from 1 to 5, with 1 being NONE and 5 being Expert.
  - Using a compass to find my way to a location
  - Using a map to find my way to a location
  - Explaining longitude & latitude to someone
  - Using a handheld GPS device to navigate to a waypoint
  - Using a GPS device to mark waypoints
  - Uploading waypoints to the computer
  - Locating a Geocache
  - Locating an EarthCache
  - Using the geocaching.com website
  - College level coursework in Earth Science
  - Identifying the earth science processes that shape a feature/site
  - Using examples of geo-significant places when teaching students
- Post Survey Only: Open-ended questions
  - Would you consider visiting an EarthCache site again? Why or Why not?
  - Now that you have experienced EarthCaching, in what ways (if any) could you connect your curriculum to a local place to support student learning

1.5.2 2012 Visiting EarthCache Post Site Specific Survey Question

- Likert-type questions:
  - *Directions Read each of the statements below and circle the rating that best describes how the statement relates to you.*
  - EarthCaching improved my ability to navigate using a compass
  - EarthCaching weakened my ability to navigate with a map
  - EarthCaching enhanced my ability to navigate with a GPSr unit
  - EarthCaching strengthened my understanding of Latitude & Longitude
  - EarthCaching did NOT help develop my ability to recognize geo-significant features
  - EarthCaching helped to develop my ability to recognize geologic processes that shape the landscape
  - EarthCaching enhanced my understanding of how to connect the scientific concepts I teach to places of geo-significance
  - I have little experience visiting a place with this type of Earth feature
  - If I visited a place with similar Earth features I would be able to recognize its geo-significance on my own
  - EarthCaching has improved my knowledge of Earth Science processes and concepts
  - I did NOT know that geo-significant places like this EarthCache existed in the state
  - I believe that visiting this EarthCache with my students would support their learning

    - I believe that this EarthCache provides useful Earth Science information for other teachers like me.
- Open-ended questions
    - What was the EarthCache site that you visited today?
    - Circle the answer that best describes who you navigated to the EarthCache site with: Individually, with 1 other person, with 2-3 other people, with 4 or more other people
    - If you had the chance to repeat this experience would you go in the same size group again? Why or Why Not?
    - What was the best thing about visiting the EarthCache?
    - What was the worst thing about visiting the EarthCache?
    - Other comments?

1.5.3 2012 Post Developing an EarthCache Survey Questions

- Developing an EarthCache Increased my understanding how geologic features provide evidence of Earth Science processes.
- Developing an EarthCache Improved my knowledge of Earth Science concepts.
- Developing an EarthCache expanded my awareness of geologic features that are found in Michigan communities.
- Developing an EarthCache augmented my ability to communicate Earth Science concepts to my students
- Developing an EarthCache improved my understanding of how scientists gather evidence of Earth processes.
- Developing an EarthCache helped me feel more confident collecting observations and data about geologic features.
- Developing an EarthCache helped develop my ability to recognize geo-significant features
- Developing an EarthCache increased the frequency I connect geo-significant places to the science concepts I teach.
- Developing an EarthCache enhanced my ability to connect the scientific concepts I teach to places of geo-significance
- Developing an EarthCache provided a valuable opportunity to participant in the peer review process.
- Developing an EarthCache is a valuable experience for teachers like me.
- The EarthCache I developed provides useful information for other teachers like me.
- Developing an EarthCache provided a valuable resource to the community
- I would visit EarthCaches near my school with my students.
- Most of my students learn Earth Science concepts better if they are linked to geo-significant places.
- Visiting my EarthCache would benefit my students' learning.
- Developing an EarthCache was the only time that I have had my work reviewed by scientists that were not my course instructors.
- Developing an EarthCache was an opportunity to construct inquiry-based questions relating to Earth Science concepts.

1.5.4 2012 Group Interview

Protocol:

During a Pedagogical Content Day, teachers were invited to participate in the group interview after completing a 2012 Developing an EarthCache Post Survey. Participants were randomly assigned to three groups each facilitated by a MiTEP graduate student.

Interview Questions

1. Do you feel that EarthCache is a valuable component of the Summer Earth Systems Institute? Why or Why not?
2. We are interested in what you learned by developing an EarthCache.
    a. What specific knowledge did you gain by developing an EarthCache? How?
    b. What skills did you gain or improve on by developing an EarthCache? How?
3. A geologically significant place is a unique location that can be used to teach others about Earth Science processes and concepts. How do you use geo-significant places in your classrooms?
4. How has developing an EarthCache influenced your use of geo-significant places in your classroom?
5. How did developing an EarthCache affect your ability to communicate science?
6. What value does the EarthCache you developed provide for visitors and the community?
7. What would be the main reason(s): (a) TO do EarthCaching with your students? (b) NOT doing EarthCaching with your students?
8. Based on your experiences, do you anticipate using EarthCaches in your instruction in the future? If so, why? If not, why not?
9. What could be done to improve EarthCaching or the MiTEP EarthCaching program?

1.5.5 2014 Semi-formal Interview

Protocol:

- Teachers will be invited to participate in the interview through individual email requests from Emily
- Gochis. If the teacher agrees to meet for the interview, Emily Gochis and the teacher will arrange to meet at a neutral location for the interview to take place. Otherwise, the interview will take place over the phone at the time designated by the teacher.

Interview questions:

1. Describe your classroom. What subject(s) and age group are you currently teaching?
2. Has your classroom changed since you began participating in the MiTEP program? If so how?
3. Geologically significant places are locations that …. Do you think that visiting and learning about geologically significant places improves your effectiveness as a teacher? Why or why not?
4. Have you visited other geologically significant places in your community or region to continue to study/develop your Earth Science knowledge since the MiTEP program?
    - If yes, which geologically significant places have you visited? Why?
    - If no, what are the main reasons that you have not visited any places since MiTEP?

5. Do you think exploring geologically significant places with your students, either virtually or in the field, benefits their understanding of scientific practices or geoscience knowledge?
6. What are the main reasons that exploring geologically significant places does or does not benefit your students?
7. During the summer field course and/or as part of the National Park Internship MiTEP required you to develop an EarthCache as a deliverable for the program. Describe the experience of developing an EarthCache in comparison to other activities you experienced through MITEP.
8. Have you visited any EarthCaches outside of the MiTEP program?
9. What are the main reasons that you did or did not visit an EarthCache on your own?
10. Have you developed any EarthCaches outside of the MiTEP program? Why or Why not?
11. What are the main reasons that you did or did not develop an EarthCache on your own?
12. Have you developed and/or implemented any EarthCache or EarthCache-like activities with your students?
    - If EarthCache-like activity has been integrated into the classroom
        - Describe the activity that you implemented with your classroom.
        - What were the main reasons you implemented the EarthCache-like activity in the classroom?
        - What were the benefits to your student's learning?
        - Do you expect to repeat this activity in the future? Why or Why not?
    - If EarthCache-like activity has NOT been integrated into the classroom
    - What were the main reasons you DID NOT implemented the EarthCache-like activity in the classroom?
13. Do you feel that EarthCaching was an important part of your MiTEP experience? Why or Why not?

1.5.6 2021 Follow-up Survey

Protocol

- Obtained IRB approval.
- Using available contact information, Emily Gochis contacted the 2011-2013 participants by email in early 2021 to describe the purpose of the study and link to consent form and survey.
- The linked google form was used as an online consent with the following options: If you wish to participate, please select the Accept button below to begin the survey or If you do not wish to participate in this study, please select the Decline button, and your session will end.
- The teachers who agreed were asked to respond to a series of questions about their EarthCache experiences through a google form survey designed for this purpose - see below.
- Analysis of data collected through the survey process was conducted by coauthors

Questions:

1. Do you consent to participate in this research?
2. Which MiTEP Cohort did you participate in (please note that the first cohort was prior to the activities being surveyed here, which is why this survey is starting with the 2nd cohort)?
3. When you participated in MiTEP, which district did you work for?
4. In the years since participating with MiTEP, how many years have you:
    - worked directly with students?
    - taught courses that included earth science concepts?

- taught courses that included other sciences?
- taught elementary students?
- taught middle school students?
- taught high school students?
- taught post-secondary students or adults?

5. Are you still in the same or similar teaching position as during your time with MiTEP? If no, which of the following best describes how your situation has changed?
    - Working but no longer in the education field
    - Retired/No longer in the education field
    - Working in K-12 education as an administrator or support staff
    - Teaching K-12 students new a new district
    - Teaching K-12 students in subject area or grade band
6. Did you develop an EarthCache as part of your time at MiTEP? Please, choose the response that best fits your experience. Note: please choose 'yes' even if your EarthCache was published to the MTU website but not the official GSA website.
7. Choose the response that best describes how often you included each of the following in your classroom practice since participating in MiTEP.
    - Connect geo-significant places to the concepts you teach.
    - Encouraged students to explore classroom content through an educationally significant place at or near the school yard either as an individual or a group.
    - Used Google Earth as a tool to explore significant places with your students.
    - Encouraged students to visit an official EarthCache outside of the classroom either as an individual or a group activity.
    - Discussed the EarthCache that you made during MiTEP with your students.
    - Had students use Google Earth as a tool to explore concepts.
    - Encouraged students to visit a geosite or an official EarthCache to explore classroom content either as an individual or a group.
    - Encouraged students to research a geosite for a classroom assignment or to build public educational materials.
    - Included activities or information from a published EarthCache in your class.
    - Encouraged students to research a geosite to develop an official EarthCaches as a group or individual.
8. If you indicated that you have implemented any of the activities above could you please elaborate on the experience further (optional).
9. Responses to previous group interviews and surveys indicated that there were many barriers to integrating EarthCaching or similar activities into many classroom settings. To which extent do you agree that the following are barriers to current barriers to implementation
    - Lack of funding for classroom field trips
    - Limited time due to strict curriculum requirements
    - Lack of information about the significance of local or regional places
    - Limited local or regional sites that connect to the curriculum you teach
    - Lack of equipment to have students to develop EarthCaches
10. Please elaborate further on any challenges or barriers that were not listed above (Optional).
11. Choose the response that best describes how often you personally conducted each of the following activities since participating in MiTEP.
    - Interacted with visitors that logged your EarthCache on the website.
    - Visited the EarthCache Website site
    - Visited an EarthCache in your own community or region

- Visited an EarthCache outside your region
- Developed an EarthCache and published it on the website

12. Please elaborate further on your experience participating in any of the activities above activities.
13. Check all of the boxes that describe how each statement relates to your EarthCache experiences following your participation in our program.
    - I gained knowledge from developing my EarthCache
    - Participating in MiTEP activities expanded my ability to use Google Earth and Features as a classroom method vehicle for virtually exploring significant geosites.
    - Visiting and developing EarthCaches increased my ability to teach earth science through a particular place.
    - Participating in MiTEP activities expanded my ability to use Google Earth to explore geosites virtually.
    - Developing an EarthCache increased my confidence to use geo significant examples in the classroom.
    - Developing an EarthCache increased my confidence to use Michigan relevant examples in the classroom.
    - I think about the EarthCache site that I developed.

1.6 Survey and Artifact Results

1.6.1 Archival Analysis of Published Geosite Lessons

The geosites were distributed throughout the state of Michigan including: 7 sites in 3 National Parks, 16 within the communities of Houghton-Hancock Area near MTU, 20 in the surrounding Keweenaw Peninsula, and 4 in the Lower Peninsula. It should be noted that the six 6 geosites that were not published on the official geocaching.com website. While the scientific content and importance of the geosite successfully passed through the review process, the specific location could not be published online due to lack of landowner permission or safety concerns. For example, the Blue Ridge Esker contains glacial, fossil and sedimentary features however is an active gravel pit and the owners need to be contacted before entering, a problem for the geocaching community. Another geosite features Segregation Cylinders that contain evidence of glacial directional movement through Segregation Cylinders, however is located on the playground of a local school. While this is an important story, the safety considerations of geocaching visitors visiting without prior notice would be problematic.

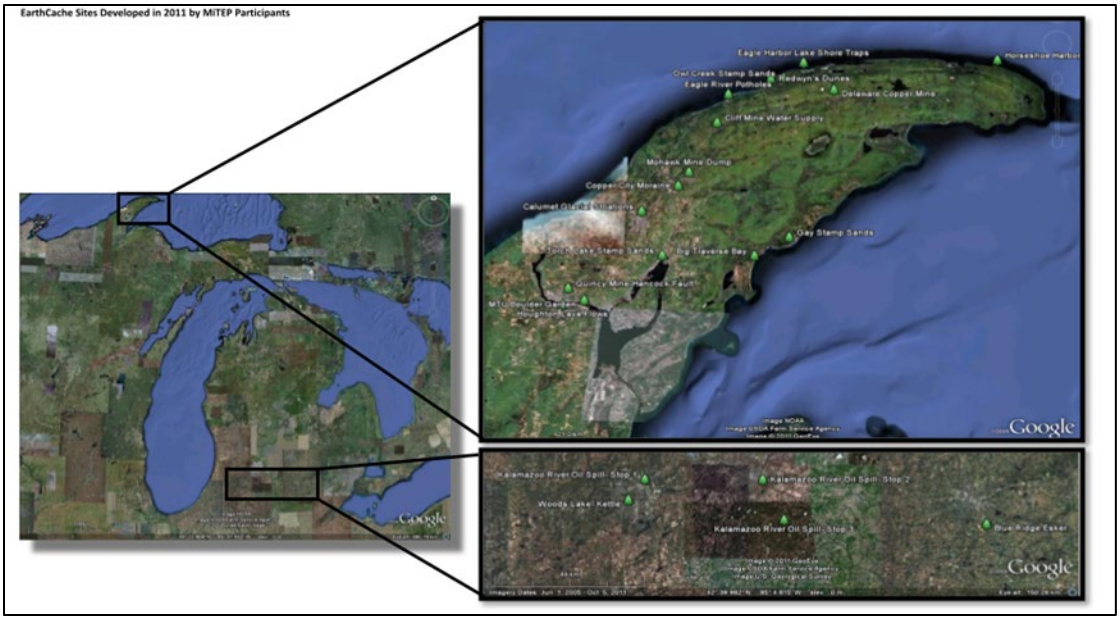

Figure S1.2. Displays the location of the EarthCache and other geosite lessons developed by MiTEP Participants.

Table S1.2. Provides the full list of EarthCaches and geosite lessons. Title include the hyperlink to the websites.

A'a Lava Glacial Erratic	Volcanoes in Michigan!? Giant mile high ice fields!? There is evidence of both found in giant boulders, right in Downtown Houghton's Franklin Square. How can they help explain our geologic past and why these resources are important to humans?
Allouez Conglomerate	The Allouez Conglomerate Boulder EarthCache is located in the business district of Houghton. The cache can be accessed by parking along Sheldon Street in the designated parking spaces. There is also a parking area behind the business district on East Lakeshore Drive. At the Allouez Conglomerate Boulder visitors will gain an understanding of how sedimentary rocks, like those found throughout the Keweenaw, can provide clues about past conditions on Earth.
Beware of Bent Trees	Bent trees give us a clue that this hill is on the move. This site is located on Michigan Tech University's hilly campus in Houghton, Michigan. The slope is between Phoenix and Cliff Drive. Park in the parking lot across the street.
Credit Union Petrology	In the city of Houghton, many buildings are being built and developed and recently among these is the Michigan Tech Employee's Federal Credit Union. Here you can see different types of rocks that have been cut and cemented together to form pillars and a decorative façade. By exploring this EarthCache, visitors can observe different rock types and infer about their origin.

Dolerite Layers in a Lava Flow	An excellent and easily accessible example of Dolerite can be seen in a large basalt boulder within the city limits of Houghton, Michigan.
Glacial Grooves	Houghton's hilltops are a good place to find glacial striations where rocks in glaciers left their mark on the basalt outcrops. On this hilltop, under a large survey maker, you will see how sediment mixed in with moving glacial ice cut grooves, scars, and scratches into the bedrock.
Houghton Outwash Boulders???	On the southeast side of Houghton EarthCache visitors are able to find a variety of boulders that have been left behind long ago by melting glaciers. Some of these boulders are examples of local rocks and some are ‘strangers ‘to the area, carried here from far away. Visitors will learn how this diverse group of boulders came to rest at this site and will be able to distinguish between ‘locals ‘rocks and those that are ‘strangers‘.
Houghton Lava Flow	This site which is behind a strip mall in the Keweenaw Peninsula provides a great opportunity to readily see volcanic flow from the Keweenaw Rift.
Huron Creek Waterfall	There are few natural beautiful places left within city limits across the developed world. Huron Creek falls, behind the Northern Foot Care Center in the far north west of Michigan's Upper Peninsula, is one of them. It is tucked between residential neighborhoods and the fast-developing Houghton, Mi. business district. Upstream and down from this natural fragment, the Huron Creek has been greatly impacted by direct and indirect human interactions. It is also one of the few spots in the watershed where the bedrock peaks out from the Quaternary glacial till that covers much of its area. This peak into the past will give us a look at how water works together with geologic history to shape the features we see in our landscape today.
Jacobsville Sandstone Buildings	Jacobsville Sandstone buildings are found throughout downtown Houghton and the Upper Peninsula. These sandstones were taken from the Lake Superior region, and used as building stones throughout the UP and other places in the United States.
Jacobsville Sandstone Churches	Jacobsville sandstone is a red sandstone found in the Upper Peninsula and portions of Ontario. There were 32 quarries in the Upper Peninsula which operated between 1870 and 1915. It was named Jacobsville sandstone after the town notable for its production, Jacobsville, Michigan. The Jacobsville sandstones contains mysterious white spots in the red sandstone. Scientist have proposed two theories to the causes of the white color which will be explored in this EarthCache.
The Keweenaw Boulder Garden	When you visit the Keweenaw Boulder Garden, you get the opportunity to go back in time and experience the geological history of Michigan. The garden was created so that it could be used to tell the geological story of these native Michigan rocks. The three basic rock groups are represented here, igneous, sedimentary and metamorphic. The rocks found here are approximately one billion years old! Every rock has its story to tell and the rocks in this garden are waiting for you to come and learn their story.

Pilgrim River Delta	The Pilgrim River Delta is located off of US 41, Townsend Dr. There is a parking area and visitors will have to take a stroll over the Pilgrim River Bridge and down the boardwalk to get to the delta. By exploring this EarthCache visitors will be able to make observation on how the delta formed and make predictions on how the delta is changing.
Pilgrim River Fault	Many river valleys are strongly influenced by faults, the Pilgrim River is located along the great Keweenaw fault. Visitors will park in the Nara Parking Lot. From here it is a short walk along a paved trail. Visitors will need to cross highway M41 as the river flows on the opposite side of the parking lot (N 47° 6.085′ W 88° 31.029′). There is not a cleared path so do not be afraid to walk through the vegetation to see a better view! This cache is part of the MiTEP program in Houghton, check out some of our other caches!
Scales Creek Lava Flow	In the middle of a neighborhood in Houghton, nestled around houses, is a large basaltic outcrop showing evidence of the Scales Creek lava flow dating approximately 1 billion years in age.
Waterfront/Canal in Houghton	The Keweenaw waterway cuts through the Keweenaw Peninsula between the cities of Houghton and Hancock. This allows for a shorter shipping route, and gives ships a safe passage between two sections of Lake Superior. This canal is a natural formation, but also has been shaped and changed by humans over the years. The canal was dredged in the 1860's, increasing the depth and size of what had previously been a small river. This dredging allowed for larger ships to pass through the canal and more efficiently distribute the native copper that was mined in this area.
Owl Creek Stamp Sands	Just North of Copper Falls off Highway 41, you will find a winding series of two tracks that few travels. Those that succeed will be impressed as you make your approach. When you arrive at the Owl Creek Sands, you will be above the actual sands and you will notice a sea of grey, surrounded by a sea of green vegetation. This absolutely breathtaking landform has only been seen by the humans that make the rough voyage.
Torch Lake Stamp Sands	This EarthCache site displays several pieces of historical information from the copper mining era in the Keweenaw. After finding this site visitors will understand a little more about what part Torch Lake played in the mining era and how it became an Area of Concern.
Eagle River Bridge Potholes	This EarthCache will take you to a pedestrian bridge overlooking the Eagle River in the Keweenaw Peninsula not far from Great Sand Bay. The site has several geological features of interest: a waterfall, a geological contact, and several potholes.
Big Traverse Bay Stamp Sands	Along the eastern shore of the Keweenaw Peninsula lies Big Traverse Bay. Visiting here gives a great picture of how the past activities of humans can have an effect on the environment in the future. It will provide a vivid picture of how waves and currents are a powerful force that can change the Earth's surface.
Redwyn's Dune Vernal Ponds	Located on the coast of Lake Superior in the Keweenaw Peninsula, Redwyn's Dunes display evidence of recent glaciations and forestation. Visitors can observe vernal pools at this location created by the unique geologic conditions present.

Mohawk Mine and Mohawkite	In Allouez Township, Michigan, near Mohawk Mine, there are piles of waste rock where Mohawkite might be found.
Great Sands Bay	Great Sands Bay is a beautiful white sands beach on the Keweenaw Peninsula. It rests between Eagle Harbor and Eagle Bay and is a great place for swimming and enjoying an expansive shoreline. It is also a perfect stop to observe the geological phenomenon of longshore drift.
Copper Harbor Conglomerate at Horseshoe Harbor	Located at the tip of the Keweenaw Peninsula on Lake Superior, Horseshoe Harbor has a beautiful outcrop of the unique rock, Copper Harbor Conglomerate. Like all sedimentary rocks, the Copper Harbor Conglomerate formed in a four-stage process- erosion & transport, deposition and cementation. EarthCache visitors will "read the rocks", examining the features of the Copper Harbor Conglomerate to understand the conditions present 1.1 billion years ago at the time of its formation.
The Beach at Horseshoe Harbor	Horseshoe Harbor is located on the northern shore at the tip of the Keweenaw Peninsula. This pristine beach is a prime location for understanding the Earth's past, and how the Earth constantly changes to create its present.
Eagle Harbor Lake Shore Traps	Perched at the northern edge of the Keweenaw Peninsula, this red brick lighthouse continues to guide ships safely across the harbor and nearby waters of Lake Superior. The rocky shore here provides visitors with an opportunity to view Lake Shore Traps and the syncline formed by the Mid-Continental rift found in Lake Superior's basin.
Cliff Mine Water Supply	The Cliff Mine was the first copper mine in Michigan that paid dividends to its owners. This demonstrated that money could be made from the syncline caused by some of the oldest rocks in the world. The place I have selected is the spring, where water emanated and was used to wash the stampings. The question is – is this an adit or a spring?
Stromatolites! at Horseshoe Harbor	At the tip of the Keweenaw Peninsula, Horseshoe Harbor features excellent examples of ancient stromatolites within the dipping layers of Copper Harbor Conglomerate rock. These unique geologic features provide a glimpse 1.1 billion years into the Earth's history when cyanobacteria such as these ruled the world. By exploring this EarthCache visitors will make geologic observations and predictions of the past conditions.
Stamp Mill Ruins	At this site you will see a mill stamper. These were used during the mining years to crush rock that was pulled up from the mines. The rock was then separated into poor rock, left over or waste rock, and ore, the rock that contained copper.
Hancock Fault at the Quincy Mine	In this EarthCache visitors will explore the Hancock fault and its effects on the copper miners at the Quincy Mine. This feature will be explored above ground at various points along the fault line or, for an optional closer look, at a below ground exposure during the Quincy Mine Tour.
Copper City Moraine	This EarthCache site features a terminal moraine landscape. The area is privately owned and managed for its timber, a common land use in the Keweenaw for the rocky deposits left behind by the retreating glaciers.

Gay Stamp Sands – The Happiest Place on Earth?	This area that was created by the dumping of stamp mill waste is known as the Gay Stamp Sands and covers around 350 acres. In this EarthCache you will explore the history and effects of this human created landscape.
Gay Stamp Sands Coriolis Effect	The main features that visitors will observe are the massed amounts of Stamp sands that were placed in Lake Superior, using water from the Tobacco River to transport a slurry of stamp sand and water via the sluices. Longshore drift has moved the sands from the vicinity of Gay, MI along the coast.
Delaware Copper Mine	Located in the town of Delaware 12 miles south of Copper Harbor lays a mine that operated from 1847 to 1887 mining the Allouez conglomerate. Eight million pounds of copper were removed from this mine. The mine had 5 shafts that reached a depth of 1400 ft with 10 different levels. As you walk the ground level area of the mine evidence remains of waste discarded by the mine.
Calumet Glacial Striations & Segregation Cylinders	This site presents glacial striations (or grooves) that were formed when the glaciers moved across the Keweenaw Peninsula in the last ice age. It is estimated that the ice may have been one to two miles thick in this region. While looking at the grooves, you will be able to determine the direction that the glacier was moving. It is important to remember that glaciers only advance, they do not move backwards.
Ripples at the Ledges	Visitors will find a cast of ripple marks in the outcrop located on the ledges trail at Fitzgerald Park. Learn how these ripple marks were formed and what clues they give us about Michigan's past.
Blue Ridge Esker (1 of 3)	The Blue Ridge Esker provides two interesting stories that can be told that involve orange-brown sandstone boulders or fragments found within it. These boulders tell a story of when climatic conditions were vastly different than what they are today in Michigan.
Blue Ridge Esker (2 of 3)	The Blue Ridge Esker provides two interesting stories that can be told that involve orange-brown sandstone boulders or fragments found within it. These boulders tell a story of when climatic conditions were vastly different than what they are today in Michigan.
Blue Ridge Esker (3 of 3)	The Blue Ridge Esker provides two interesting stories that can be told that involve orange-brown sandstone boulders or fragments found within it. These boulders tell a story of when climatic conditions were vastly different than what they are today in Michigan.
Kalamazoo River Oil Spill	This is a multistep EarthCache exploring the effects of July 26, 2010 Enbridge 6B Pipeline break and resulting oil spill on the Kalamazoo River.
Woods Lake – A Neighborhood Kettle Lake	Woods Lake is a 26-acre kettle lake with public access through the Kalamazoo Park system that provides an excellent example of cultural eutrophication in an inland lake. EarthCache visitors will be able to observe this inland water feature created by glaciers of the past.

The Ancient Shoreline	The Ancient Shoreline location for this EarthCache is found on the Scoville Point Lava Flow. This lava flow is one of the 100 flows that make up the Portage Lake Volcanic Formation that create the northeast end of Isle Royale. The paleoshoreline that will be the cache site is a location that correlates to the Nipissing stage of the Isle Royale shoreline, found at a higher elevation than the current shoreline. Visit the cache to find out why!
Glacial Striations on a Basalt Outcrop	Striations on a basalt outcrop mark the path of thick glaciers that advanced on Isle Royale over 10,000 years ago. Hard rocks, frozen into the bottom of these moving rivers of ice scratched out their pathways as they slowly glided over the exposed basalt surfaces.
Trough Cross-Bedding in the Jacobsville Form	The Jacobsville Formation is the oldest exposed bedrock in Pictured National Lakeshore Park. It is easily identifiable by its bold red color mottled with white. Over the years it has been quarried in the area and used in the construction of buildings in this area. It is exposed along Lake Superior's south shore for about 150 miles and is usually just under or slightly above the water plane of Lake Superior.
The "Painted" Pictured Rocks	This is a water (boat or kayak) accessible EarthCache! By visiting this location, you will be able to view and identify the minerals “painting” the “Rainbow Cave” and Pictured Rocks cliffs. You will also be able to see a sea cave up close and learn about its formation.

1.6.2 MiTEP Style EarthCaches - Review of Published Sites

A review of the teachers' geosites shows that participants were able to develop lessons that included information such as lesson connections to the classroom standards and common misconceptions, and engaged pedagogical practices such as integration of place-based and scientific inquiry with Earth Science Curriculum that address misconceptions (see image below).

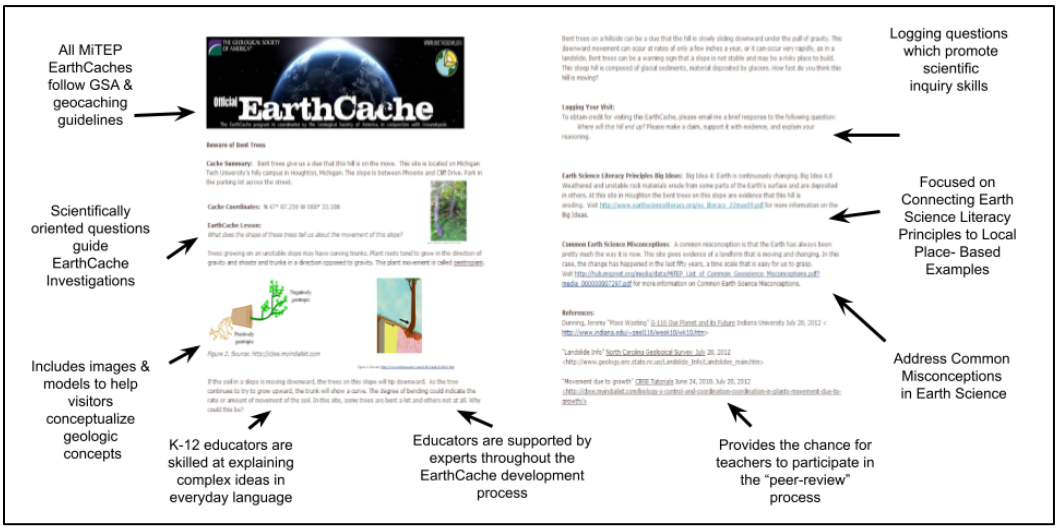

Figure S1.3. Displays some added features of a "MiTEP" style EarthCache

1.6.3 2012 Developing an EarthCache Post Survey

Table s1.3. Full results for the Likert-type questions on the 2012 Post Developing an EarthCache Survey taken by both cohort 3 and 4 (n=31; 97% completion rate). Results from questions that were part of a grouping are reported together.

Item/Measure (# of questions)	Strongly Agree/ Agree	Neutral	Disagree/Strongly Disagree	Descriptive Details
Developing an EarthCache Increased my understanding how geologic features provide evidence of Earth Science processes.	87%	10%	3%	Strongest favorable response with low prior ES levels
Developing an EarthCache Improved my knowledge of Earth Science concepts.	94%	3%	3%	The person that strongly disagreed had taken more than 15 earth science courses
Developing an EarthCache expanded my awareness of geologic features that are found in Michigan communities.	97%	0%	3%	The person that strongly disagreed had taken more than 15 earth science courses
Developing an EarthCache improved my understanding of how scientists gather evidence of Earth processes.	81%	13%	6%	
Developing an EarthCache helped me feel more confident collecting observations and data about geologic features.	87%	6%	6%	Lower levels shown with low prior ES, perhaps helpful to have some prior experience in field skills to feel comfortable
Developing an EarthCache helped develop my ability to recognize geo-significant features	94%	3%	3%	
Developing an EarthCache increased the frequency I connect geo-significant places to the science concepts I teach.	74%	10%	13%	Slightly Higher ratings from those that use geo-sig lessons in most/every lesson than those who use in some/never
Developing an EarthCache augmented my ability to communicate Earth Science concepts to my students	81%	16%	3%	
Developing an EarthCache enhanced my ability to connect the scientific concepts I teach to places of geo-significance	84%	10%	6%	
Developing an EarthCache provided a valuable opportunity to participant in the peer review process.	81%	16%	3%	
Developing an EarthCache is a valuable experience for teachers like me.	90%	10%	0%	The responses are more agreeable here than "the EC I developed would be useful for a teacher like me"
The EarthCache I developed provides useful information for other teachers like me.	77%	23%	0%	Those with 5 or fewer courses do not consider EC as valuable as those that had more than 5.
Developing an EarthCache provided a valuable resource to the community	97%	3%	0%	
I would visit EarthCaches near my school with my students.	84%	6%	6%	The different districts show strong differences in responses- though JPS teachers rated almost all questions higher than KPS teachers.
Most of my students learn Earth Science concepts better if they are linked to geo-significant places.	87%	13%	0%	
Visiting my EarthCache would benefit my students' learning.	84%	13%	3%	
Developing an EarthCache was the only time that I have had my work reviewed by scientists that were not my course instructors.	84%	6%	10%	
Developing an EarthCache was an opportunity to construct inquiry-based questions relating to Earth Science concepts.	90%	10%	0%	

Table s1.4. Displays the three questions centered on Developing an EarthCache effects on Content Knowledge. All are self-reported response to Likert-type questions (n=31; both C3 & C4; 95% completion rate).

Item/Measure (# of questions)	**Strongly Agree/ Agree (# of responses)**	**Neutral**	**Disagree/ Strongly Disagree**
Increased my understanding how geologic features provide evidence of Earth Science processes.	87% (27)	10% (3)	3% (1)
Improved my knowledge of Earth Science concepts.	94% (29)	3% (1)	3% (1)
Expanded my awareness of geologic features that are found in Michigan communities.	97% (30)	0% (0)	3% (1)
Development of EarthCaches Improved Content Knowledge & Awareness	92% (86)	4% (4)	3% (3)

Table s1.5. Displays the two questions centered on Developing an EarthCache effects on Foster Observational/Interpretive Skills. Both are Self-reported response to Likert-type questions (n=31; both C3 & C4; 95% completion rate).

Item/Measure (# of questions)	**Strongly Agree/ Agree**	**Neutral**	**Disagree/ Strongly Disagree**
Developing an EarthCache helped me feel more confident collecting observations and data about geologic features.	27	2	2
Developing an EarthCache helped develop my ability to recognize geo-significant features	29	1	1
Development of EarthCaches Foster Observational/Interpretive Skills	90% (56)	5% (3)	5% (3)

Table s1.6. Displays the three questions centered on Developing an EarthCache effects on Improve Pedagogical Skill. All are Self-reported responses to Likert-type questions (n=31; both C3 & C4; 95%).

Item/Measure (# of questions)	Strongly Agree/ Agree	Neutral	Disagree/ Strongly Disagree
Developing an EarthCache augmented my ability to communicate Earth Science concepts to my students	25	5	1
Developing an EarthCache enhanced my ability to connect the scientific concepts I teach to places of geo-significance	26	3	2
Development of EarthCaches Improves Pedagogical Skill	84% (51)	13% (8)	5% (3)

Table s1.7. Displays the response frequencies on the Developing an EarthCache survey, to the question: The EarthCache I developed provides useful information for other teachers like me. Those with 5 or fewer courses do not rate this as high as those that had more than 5.

Response	> 11 Courses			6 to 10 Courses			0 to 5 Courses		
Strongly Agree (5)	3	60%	100%	3	33%	100%	5	31%	56%
Agree (4)	2	40%		6	67%		4	25%	
Neutral (3)	0	0%	0%	0	0%	0%	7	44%	44%
Disagree (2)	0	0%	0%	0	0%	0%	0	0%	0%
Strongly Disagree (1)	0	0%		0	0%		0	0%	
Total	5	100%	100%	9	100%	100%	16	100%	100%

Table s1.8. Displays the response frequencies on the Developing an EarthCache survey, to the question: I would visit EarthCaches near my school with my students. The various districts show strong differences in responses.

Response	**Kalamazoo**			**Jackson**		
Strongly Agree (5)	*3*	*16%*	*79%*	*6*	*55%*	*100%*
Agree (4)	*12*	*63%*		*5*	*45%*	
Neutral (3)	*2*	*11%*	*11%*	*0*	*0%*	*0%*
Disagree (2)	*1*	*5%*	*11%*	*0*	*0%*	*0%*
Strongly Disagree (1)	*1*	*5%*		*0*	*0%*	
Total	*19*	*100%*	*100%*	*11*	*100%*	*100%*

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Table s1.9. Displays Grade Level Response for Effects of Developing an EarthCache Survey on Pedagogical Ability. The average agreement with the statement A "Developing an EarthCache Augmented my ability to communicate Earth Science concepts to my students." and B- Developing an EarthCache Enhanced my ability to connect the scientific concepts I teach to places of geo-significance. (1= strongly disagree; 5= strongly agree).

	Augmented/Enhanced Ability	
Grade Level	**A Mean (StdDev)**	**B Mean (StdDev)**
Elementary (n=3)	4.0 (0.0)	4.3 (0.6)
Middle Grades (n=17)	4.3 (0.8)	4.2 (1.0)
High School (n=10)	(0.9)	1.7 (0.6)

1.6.4 2021 Follow up Survey

Table s1.10. Displays the results for participant background information from the 2021 survey.

2021 survey - response rates				
Responses rates				
Total MiTEP participants including cohort 2, 3 and 4	43			
Email contact information	29			
No email contact info	14			
Which MiTEP Cohort did you participate in?		% of responses		
C2	1	5%		
C3	14	70%		
C4	5	25%		
When you participated in MiTEP, which district did you work for?		% of responses		
Kalamazoo Public Schools	12	60%		
Jackson Public Schools	6	30%		
Grand Rapids	1	5%		
Other - see below	2	10%		
Forest Hills Public Schools (left GRPS during program)	1			
Jackson Intermediate School District	1			
In the years since participating with MiTEP, how many years have you:	None	1 -3 years	4-6 years	more than 6 years
worked directly with students?	2	3	1	13
taught courses that included earth science concepts?	3	6	3	8
taught courses that included other sciences?	3	7	2	8
taught elementary students?	14	5	1	0
taught middle school students?	10	3	3	4
taught high school students?	12	1	1	6
taught post-secondary students or adults?	19	0	0	1

Did you develop an EarthCache as part of your time at MiTEP? Please, choose the response that best fits your experience. Note: please choose 'yes' even if your EarthCache was published to the MTU website but not the official GSA website.				
	Yes, as part of the 2-week Earth Summer Institute.			16
	Yes, as part of my National Park Internship.			1
	Yes, as part of both the 2-week Earth Summer Institute and my National Park Internship.			3
Are you still in the same or similar teaching position as during your time with MiTEP?				
	Yes	10		
	No	10		
Which of the following best describes how your situation has changed?			some teaching since MiTEP	% of responses
	Working but no longer in the education field	1	0	
	Retired/No longer in the education field	1	1	
	Working in K-12 education as an administrator or support staff	5	5	
	Teaching K-12 students new a new district	2	2	
	Teaching K-12 students in subject area or grade band	1	1	

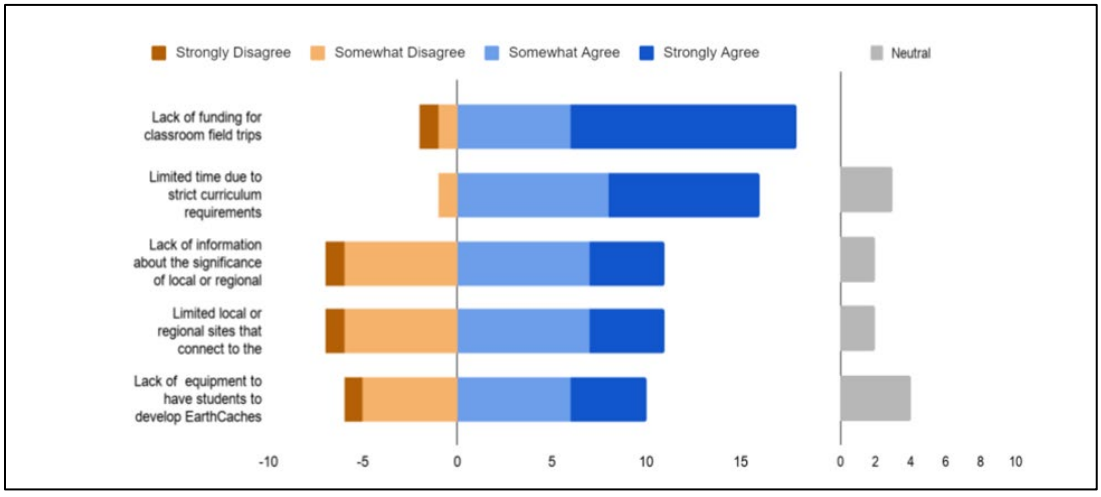


Figure s1.4. Displays the barriers to integration longitudinal results

1.7 Results: Interviews

Table s1.11. Displays the Interview Evidence Matrix, which provides details on the themes and co-occurring subthemes Evidence Matrix for 2012 group interviews & 2014 follow up Semi-structured Interviews Sample participant quotes are provided to highlight specific narrative that provides context for the identified subtheme. Further sub-themes appear; however, the results are limited. Future work should be informed by patterns appearing in results.

<table>
<tr><td colspan="2">Continued use of resources beyond the end of the programs (Cont.)</td></tr>
<tr><td rowspan="3">Teachers reported personally engaging personally with the geocaching website leading for continued learning and to visit new geosite sites beyond the end of the program, including:

Visiting EarthCaches with family or friends for recreational reasons, either on vacation or close to their home.
To learn more about geosites to use with students</td><td>Doing the process of it made a big difference in my understanding of it and knowing more about the website and understanding how many different places there are. If I go someplace now sometimes I'll check to see what might be in that area. FG2012 D2 GA C4</td></tr>
<tr><td>We took the kids down to um my sister's in Chattanooga. This, um, this summer and you know we did a couple, stopped on a couple [EarthCache] places along the way and…it has become a family hobby 2014 I4 P1 C3</td></tr>
<tr><td>First of all, I would have never experienced [EarthCache] otherwise. I had heard of stuff like then... probably more geocaching but I never... I never really look at it from an educational perspective I had always looked at it as it a fun perspective, ...so to get more knowledge about it was extremely valuable and then besides that to take a more educational perspective on it and think that it can be able to utilize with my students or that I can learn from them myself. 2014 I2 C4</td></tr>
<tr><td colspan="2">Geoscience Content Knowledge (CK)</td></tr>
<tr><td colspan="2">Increased awareness of significant geosites (e.g. urban examples such as building stone & eutrophic lake, find connections to other global examples)</td></tr>
<tr><td rowspan="3">Program Built knowledge of regional geosites including sites overlooked previously including in urban areas or sites close to their school.</td><td>"The most valuable thing I learned is that we have so many of these different geological features actually in our community that you may not be aware of so it makes people aware of these geological features that are close to them." FG2012D2GAC4</td></tr>
<tr><td>"I like the idea of just 'find something interesting' that's right in the middle of nowhere…. that [Mason Esker EarthCache site] is just a place that you drive on by and wouldn't even know the significance or importance". EC_FG11_C3_GC</td></tr>
<tr><td>"I liked EarthCache because they showed geo-significant places right in the city which I thought was really interesting". FG2012D2GbC4</td></tr>
</table>

For some developing the geosite lesson required research that lead to awareness of similar features outside of the region,	[When developing my EarthCache] I had to look at other [examples] in the world so I really learned a lot about a couple of different concepts and about the geologic history in a few different areas of the world and I felt that that was good. D1 GB C3
Developing geosite lessons lead to a deeper understanding of the geoscience content specific to the geosite	
Widespread perception that developing an EarthCache leads to in depth learning was widespread.	"I mean we acquired a lot of knowledge about a lot of things during the but [my geosite] is one that I can just sit and rattle off right now really easily without thinking much." 2014 I2 C4
	"I think it is [a valuable part of the summer program]. The EarthCache that I did, I felt really connected to my spot and I felt like I wanted to learn as much as I could about it and I still remember everything that I learned about that spot. It helped me to see how one place can help you understand the geology of an entire area a little bit better." FG2012D1GBC3
In addition to core geoscience content knowledge dialogue demonstrated participants' understanding of larger crosscutting concepts such as the Big Ideas and ways to connect material to other subject areas.	One thing that I was really aware of was the history of the place, the human history of the place and how it related to the geology…. Those things are linked together for me and I don't think we will be able to cover those resources and history without looking at the geology of Michigan. I think that that really underscored it for me that you can't teach social studies without teaching geology at least in Michigan." FG2012D1GBC3
Geoscience Practices & Technology Skills (Sk)	
Activities lead to successful use of GPSr technologies introduced during the course.	
Visiting EarthCaches provides a meaningful opportunity to navigate with GPS during the course.	"When we piled out of the van and [the instructor] was like, "Which direction are you going to go?" It was the first time I really understood how to use my GPS in a way. I mean I knew to make the marks and everything but it was the first time that you had done anything meaningful & purposeful."- FG2011GCC3.
	By the end of the week I could use that GPS ...I knew how to maneuver around it, I knew how to take way point, so by the end of that experience, just by doing that with EarthCaching gave me another tool that I knew how to use 2014I? C?
Novices able to achieve success with GPS through the program	"The skill was awesome. Being a tech-phobic teacher, this forced me to do some things I'm uncomfortable with, now I could show somebody how to use a GPS and develop [an EarthCache] on the computer." FG2012D1GBC3.

	I thought it was pretty valuable. I've never worked with a GPS unit before and so I thought that was cool to get to learn how to use that. D2 GB C4 x
Interest to engage with GPS beyond course	Working with the GPS and developing the skills, using that was of such great benefit that I want to ask for one for Christmas. D2 GA C4 x
Increase Ability to use Google Earth to explore geosites virtually.	
Teachers from both cohort 3 and 4 described the usefulness of learning how to explore geosites virtually through Google Earth and its zoom, time lapse, and recording functions.	"[I am now] able to get on Google Earth and say "see this is where it's happening" and actually be able to zoom in and see the area." FG2012D1GAC3x.
	"I gained computer skills including learning how to use the geocache site. That navigational thing and that was fairly simple for me but getting it into the Google earth site and everything was something that I've never done" FG2012D2GCC4.
	"I mean so many times we've had professional development that has just not been useful or significant to us. That you know EarthCaches and being able to implement Google Earth in the classroom and whatnot is one of those programs that enhances your instruction and it's immediately usable, it's not like you would have to have a lot of training." (2014 I3P2 C3)
Authentic interpretation experiences that increased success to identify significant geosites in region/community beyond those studied in the course.	
In depth interpretation needed to develop a geosite, beyond what is evident in the lessons.	I think you really had to look at the area you were in and pick out unique features and how this was before and how it's going to be later. Because you're trying to question [visitors], you're trying to get them to learn something. So, you are looking at every possible teaching element in that area because you don't know what you are going to use when you go back and write that.EC_FG11_C3_GB
Ability to identify significant geosites in region/community beyond those studied in the course.	"How can I take the idea of looking at this geological feature and seeing it, whether it's seeing it in a picture or Google Earth or whatever, 'what can I take away and know from the environment or the past or predicting what's going to happen in the future?', is what I've taken away from EarthCache." 2014 I4 C3.
	I would say yes [developing an EarthCache] was different [than other aspects of the field courses] ... It was, "Why is this place significant? What do you want people to learn from it?" and it makes you kind of change how you look at stuff and it's kind of has helped me, especially going to a new district to be like, "What is around here that I can pull to say hey! You know, this over here that you guys drive by every day? That's because of a

	glacier. Or because of this." You get what I mean? Like it helps you better pick things from your community out. I think that's what it did for me. 2014 I5P2 C3
	So, I mean at that point I didn't know anything about my EarthCache [site] and I think that was probably one of that was one of the most valuable parts of the EarthCache was trying together why something had occurred and just using the knowledge that I had ...let alone eventually researching and getting an understanding of the area in more detail but that [unable to hear] …. I had to do some observation look at the … the rock on either side of the canal, I had to think about what would allow them to do something here verses something else place… 2014 I2 C4
Evidence of ability gains related to other scientific practices	
Publication process led to an increase in communication skills and ability to publish online (which included limited HTML coding for GSA online submission process at the time).	Part of the skill though too was actually developing it and putting it online and getting it out there and published and seeing something new that I learned I was able to go public and other people can do it too and getting over this image of "I'm just a teacher" that I could maybe apply myself more worldly and other people can learn from what I've done too. FG2012D1GBC3
	It helps when we did the EarthCache that getting the format of things right on how to properly put things on the computer and things like that and references and things like that to communicate science on that geocache itself, make sure we're doing things correctly. FG2012D2GAC4
Process of learning through by asking clarifying questions.	When we got to our specific location. so, when we visited our spot [our geoscience expert] was great at saying ... Why here? … and then your brain starts to turn and you start trying to use those concepts that you have learned to try to answer that kind of question. 2014 I2 C4
Geoscience Pedagogical Knowledge (Ped) *Activities lead to gains in pedagogical abilities and confidence related to geoscience*	
Developed abilities to create meaningful learning experiences from geosite and other significant places	
A number of teachers perceived that developing a lesson tied to a geosite increased their ability to teach earth science through a particular place.	Geocaching was something that I had already been doing for two or three years at that point so I think it was valuable for me in that it gave me an opportunity to use it in more of an educational typesetting and the skills as far as how to use the GPS and find a place. The skills on how to take that spot and make it into a lesson that was valuable for students, I think was what I walked away with. FG2012 C4
	I think the whole process helped me look at [geosites] and realize that I could pull them into my classroom …. Now I have an idea of how to do that where before if you were to ask me how can

	you give the kids a real-world example of this I would have had no idea. FG2012D1GAC3.
	What is around here that I can pull to say hey! You know, this over here that you guys drive by every day? That's because of a glacier. Or because of this." You get what I mean? Like it helps you better pick things from your community out. I think that's what it did for me...the tools needed to be able to write sort of a lesson like that, or build a lesson in a different way other than the textbook...2014 I5 P2 C4
	I think [the MiTEP EarthCaching Program] helped us look more closely at different geological aspects of areas and how to draw some educational purpose out of those things and then combine it with what worked. FG2012D1GCC3
Some teachers perceived that the program-built confidence to apply with students.	I'm not even 100% sure that I brought them to an EarthCache page necessarily, but using the experience of going to that site and developing the EarthCache and asking myself those [interpretation] questions gave me more confidence and more reasoning behind why I would ask my students those questions. 2014 I3 P1 C2
Some teachers described how developing a geosite lesson built their awareness of the number of learning opportunities that can be made at each site.	I think for knowledge there's so much information that you got, you had to choose what were the most important things to put in EarthCache, why people would want to go there based on the information you put in (that type of thing). There is a lot and you have to narrow it down, what am I going to put in my EarthCache out of everything that I learned. FG2012D1GAC3.
	I think that's part of what EarthCaching does. It teaches you how to recognize or find things that you can bring into your classroom and it helps them learn how to guide that learning and what do you want somebody to learn from this? And, because I remember struggling with some of them there's so many different things that I could teach them about. You know, what do I really want them to, what's the biggest thing… I think to get rid of it would mean not as good of an experience. 2014 I5 P2 C3
Other pedagogical skills were developed by participating in the program activities	
Some participants perceived that developing EarthCaches enhanced their ability to ask effective and meaningful questions.	It also forced me to try to refine asking questions that were meaningful and that would be not only of importance and interest to young but also to old so it made me better construct a lesson that happens to be what I was hoping to accomplish with this project. D2 GA C4 or
	in the development of the EarthCache itself is when I started to realize I didn't know how to just ask a couple of things that are hugely important in order to gain a full understanding of what they've seen or what they've known. I've gotten to a point now

	in my everyday practice where I start to kind of try to boil it down to one important thing instead of you know these are the five content areas that we need to get through today and we're going to plug away and I'm going to ask you a million questions and you're going to have a quiz at the end and I see now that there's benefit in asking really specific and thoughtful questions much like the ones we put into the EarthCache to gain a better understanding and promote conversation and promote question asking and stuff like that. It's a lot of information to put into the EarthCache. You know, I mean, and then to boil it down to one or two questions at the end is hard to do but that way of thinking you know that way of thinking of just saying "How can I summarize all of this? And see if you understand or if you don't? "all the information I needed to be able to put this together and then ask three questions to make sure everybody understands it at the very end. When you boil it has changed a little bit of my everyday practice. 2014 I3P1 C3
A few participants perceived gains in their inquiry-based instruction skills.	To me it was more the process of taking something and finding a way to make it inquiry based. Which you did in other parts, but the EarthCache does it in a real way with a real place, that gets you away from the textbook and lets you kind of find a way to walk someone through learning something without even being there- 2014?
Some participants described how the process had improved their ability to facilitate learning experiences from a distance.	It's a lot of information to put into the EarthCache. You know, I mean, and then to boil it down to one or two questions at the end is hard to do but that way of thinking you know that way of thinking of just saying "How can I summarize all of this? And see if you understand or if you don't? "all the information I needed to be able to put this together and then ask three questions to make sure everybody understands it at the very end. When you boil it has changed a little bit of my everyday practice. 2014 I3P1 C3
Ability to use Google Earth & other media to explore geosites virtually in classroom learning experiences.	
Many participants perceived an increase in their ability to use Google Earth and its features as a classroom method vehicle for virtual exploration of significant geosites. Some described that virtual field explorations will continue to be relevant for classroom use.	Prior to this I would not have been comfortable modeling a Google earth [tour] in front of a class because I had never tried to use it on my own aside from a few specific places that we were looking at but knowing that I can find a specific EarthCache and look at the photographs and look at specific photographs that go along with that EarthCache, that somebody has thought through the scientific questions in the background and employing that already thought out work within my content is something that I can use to improve my classroom. FG2012D1GAC3
	I think just having an idea of how to use Google earth to pull different places in the world into your classroom is a huge skill because with funding and everything else most field trips are going to be limited so you have to find other ways to take kids to

	those places even if they are places in your own town but being able to take some pictures or a video of what you want the kids to see which is what we did in EarthCache and then being able to use Google earth to show them where it is and taking those virtual field trips, I think are going to become more and more important because the times of just taking the kids to this place is just not going to happen anymore.
	"That's one of the things that I've taken away from MiTEP so far was the use of Google Earth because my kids will bring something up or some conversation or we went there or oh my cousin lives in such & such. and I'll pull that thing up and we'll talk about the area. Someone didn't know what the Grand Canyon was, which I can't imagine in seventh grade, and so I got on Google earth and pulled it up. And they can see it. You know our kids don't have a lot of experiences. A lot of our kids have never been out of Jackson, the town proper, and so Google Earth allows them to not only see things that they have not seen but things they will never see".EC_FG11_C3_GB
Classroom Enactment - Perception of including EarthCaching & other program activities into the classroom (Class)	
Perceived benefits to integrating geosite lessons in K-12 classrooms	
In every interview in 2012 and 2014 teachers described a number of perceived benefits to integrating geosite lessons in K-12 classrooms including: increased student engagement, authentic technology integration, building student sense of place, opportunity for authentic assessment through project-based activities, extension for continued learning with after school programs or families beyond the classroom	I think it's an engaging way to teach. If you have the resources, kids get to hold onto a little electronic device and explore on their own and it's almost like a treasure hunt, it's a fun way to learn about earth science processes that they might be more open or willing to think about it because they get to do it in a more exciting way. 7d D2 GB C4
	To do EarthCaching with your students would be to get them better knowledge of something around your area or something that you're studying in earth science relating to your curriculum. I think that's important. And to be able to show them around an area that they live that there's other things than just Target and Meijer's … I feel like being able to show students that when they live in an inner-city all the houses surrounding them or maybe a park that there might be something around them that has to tie back into the earth that they live in. D2 GC C4
	I think the main reason to do EarthCaching is just so to make them aware that those places exist in their community and also that website will allow them to see places not in their community that would still be worth visiting even if they can physically go there. D1 GC C3 We all agree. Yes, we all agree D1 GC C3
	to connect them to what's actually around them and make their surroundings relative to their lives. D2 GB C4; 7d. I'd have to agree. I feel like it would allow students to connect the content to

	real-world applications, being able to see the things you're talking about in class in real life. 7d. D2 GB C4
	And I think just exposing your students to an EarthCache is good because they can do this with their families, brings them together, when you have schools where getting parents involved is a big issue, this is how kids can come back and maybe hopefully get their families their siblings their parents to go out and do something together and then bringing back to the community but also ties back to the classroom and you're getting them more involved because you exposed them to something new and something they might be potentially interested in. D2 GC C4 7a.
	It could give our kids pride too, to show their families if they walk down the street and say "hey look at the crack in this thing or look at this weird rock that's always been here it's huge and we all stand on it and we all mess with it but do you know where it came from?" And they could tell them, they love to be able to tell people what they know and if they could do that that would be great. They would go teach their grandfather and their grandmother about it and I think that specifically going in the neighborhoods and would say "see this gigantic boulder, see it's always been there, here's where it came from." D1 GB C3
	What I see as the main reason to do it is that it's of real valuable opportunity for our students to experience another way to demonstrate learning rather than the pencil and paper but this product is something that lives on after they're done it. It's something that people can continue to see and it goes beyond just the classroom or the school but it's like anyone that happens to be interested in something that they were interested in did the EarthCache.D2 GA C4
Perceived barriers to integrating official EarthCaches in traditional K-12 classrooms	
In all of the interviews participants identified and described challenges that make traditional EarthCache activities that they perceived as impractical to implement in most school settings including lack of administrative support, time or monetary difficulties to visit EarthCaches off-campus; lack of access to GPS or computers for students; limited number of published EarthCaches in the school community; difficult	How would I get a group of students out and back and 50 minutes even if I took half a group half the day now I'm dealing with 75 kids for half a day? We don't have the equipment. D2 GA C4
	Nowadays just getting the permission slips to take them anywhere is a problem. And we don't have a school nurse anymore, so now it's our responsibility to make sure that everyone's medication and allergies and bee stings and that all lies on us and you know it's just, and the financing, the busses. You know, "We're going to go look at this geologic feature. And by the way it's going to cost you 53 bucks for you to go." 2014 I41 C3

<table>
<tr><td rowspan="4">finding geosite that match their rigid curriculum requirements and limited time in single-subject courses for students to develop EarthCaches.

Teachers describe how they felt that even if they could take their students to a geo-significant site, being able to develop an EarthCache would be difficult because of the amount of time they perceive it would take to do in the class with student groups.

Interviews demonstrated that some participants EarthCaching with students would only be possible if they are tied to the classroom standards and could be developed in a way that would engage students to learn content in a way that would be worth the effort and resources expended to implement the activity.</td><td>The money to take the trip and the availability of EarthCaches in our area that actually lines up with the curriculum are the two major things that would prevent me from doing [EarthCaching with students]. D2 GC C4</td></tr>
<tr><td>Well yeah, we could create ones even in town. And there's just the logistics kind of thing of getting them there and taking time out of the classroom and priority in school and you're taking them away from English class and the English teachers have enough of that and you know that whole logistical kind of thing um is, is a challenge too. You know I can see us using EarthCaches and creating EarthCaches around town and using them in our summer program or Dawn using them in the after-school program. 2014 I41 C3</td></tr>
<tr><td>There are definite time constraints in our teaching field that have not been there in the past and unfortunately, they're becoming more and more stringent. If I can do an EarthCache of something that ...I can tie it to several different things it sure would make it a lot more beneficial to the students then if I was just surfing the net. Not doing EarthCache saves time to do things that I'm going to be evaluated on. Much of our education at this point has gone to more books and more thinking and more of creating that sort of thing then really exploring and trying to combine with other thoughts to form thought which takes time, time is the problem. D1 GB C3</td></tr>
<tr><td>To be perfectly honest with you if it doesn't meet a direct benchmark that I have to cover I don't have time...If I think it will help cover a benchmark and that it will get the idea across to my kids better then I will use it. If I can't I'm not going to use it. so that's the challenge to figure out ways to make it bring the curriculum more alive so that students will remember and get the point across better using this tool. D1 GB C3</td></tr>
<tr><td colspan="2">Intent to modify program activities to be included in the classroom (Int)</td></tr>
<tr><td>Results from 2011 and 2012 group interviews showed that several (?) teachers intended to visit significant places to learn classroom content as a class or having students go individually.</td><td>My biggest thing is to find the time. It's not like anything I do on a regular basis. Maybe I could do it once a year if I started doing it D2 GC C4</td></tr>
<tr><td></td><td>if you were studying volcanoes, then you have [students] explore on the internet different locations of volcanoes and they could create their own EarthCache- you could call it- of Mt. St. Helen's and they could take picture of it, what type of volcano is it, have them create logging questions about it. So, it's the same concept, but these are place that they can't explore but they could explore on the internet within their own classroom. 2011C</td></tr>
</table>

Many teachers describe how they could envision connecting virtually to get-significant places through the information provided on the EarthCaching website along with google earth and other online resources. Other examples included having students visit EarthCaches or geosites in a group or individually with families, or integrating EarthCaching into an informal/afterschool program. Some teachers described using the school grounds or similar local sites as the basis for integrating EarthCaches into the classroom. A few teachers described having students develop EarthCaches based on places in the community that they have/will visit individually in person or virtually.	I can envision an EarthCache club after school that they could either go check out once a month or develop some sites on their own from some local spots. D2 GA C4
	And I think just exposing your students to an EarthCache is good because they can do this with their families, brings them together, when you have schools where getting parents involved is a big issue, this is how kids can come back and maybe hopefully get their families their siblings their parents to go out and do something together and then bringing back to the community but also ties back to the classroom and you're getting them more involved because you exposed them to something new and something they might be potentially interested in. D2 GC C4 7a.
	It could give our kids pride too, to show their families if they walk down the street and say "hey look at the crack in this thing or look at this weird rock that's always been here it's huge and we all stand on it and we all mess with it but do you know where it came from?" And they could tell them, they love to be able to tell people what they know and if they could do that that would be great. They would go teach their grandfather and their grandmother about it and I think that specifically going in the neighborhoods and would say "see this gigantic bolder see it's always been there, here's where it came from." D1 GB C3
	I thought about doing an EarthCache for the high school because we've got lots of different kinds of stone in and around the high school. It would be cool to do something like that. It would make the kids much more aware. D1 GC C
	I think another way is that with EarthCache if you use them in your instruction you can cite some specific examples but, in a way, that's done where we can encourage outside learning. Learning beyond the school day or to have people check out the areas where they're going to create that new awareness. D1 GC C3\
	I like the idea to do it on the school grounds and then move out from there. I thought that would be really good way to even if they could just plot it with the one that they had just do one per class and I'm sure if used one GPS unit to plot it on the school website or something like that. D2 GA C4
	The kids could write up an EarthCache on a certain thing but not for publication just for the teacher and you be the publisher and get them used to the idea that this is something kids can do, this is something I would be wanting to do if our families going somewhere on vacation this summer let's look up where these are in that area, we want to build motivation D2 GC C4
Integration of program activities into classroom practice	

Inclusion of geosites in student learning experiences	
Some interviews demonstrated the perception that the program had led to the teachers including more geosites examples in student learning experiences. One teacher described how the field experiences supported increased engagement in the classroom.	[The program]] helped me with the geology of Michigan. Knowing more about the geology of Michigan, because it's not a class I ever took and it was something I never really had to apply to any of the teaching that I had, and now I find ways all the time to put that in with what the kids are doing. FG2012D1GBC3 After I developed [the EarthCache] I find myself looking for more of these [Geoheritage examples] when I'm out even on a family vacation and how can I bring that back to show my students or show other people and communicate that everywhere there's significant places that I wasn't aware of. FG2012D1GAC3
	[connecting that geologically significant place] just means so much more to students. It just, it just does. - I think um you know, especially our kids, the demographic subjects. Our kids haven't been to any of these places. You know, so you can talk to them about what a dam is or you can show a dam in a picture, but they have no life experience. If I can go there and bring the experience back to them with pictures and that kind of thing, then, in my experience, and then I get excited about it when I'm telling them about it. That transfers over, just much more than them reading out of a book. And so, you know, that's kind of been my goal for the last couple years ... I want to be able to give these kids experiences that they can't. it gives them a different level of background knowledge that they wouldn't have, that some of these kids would never experience on their own… there's something to be said by that person standing in front of you sharing the excitement of what they saw versus just reading it in a book. 2014 I4 P1 C4
However, it should be noted that two participants indicated during the group interview that EarthCaching did not change their use of geo-significant places in the classroom because they were already using these often or because they do not teach earth science	I don't know if it's changed a lot for me just because I was already using that in my classes on a consistent basis as far as the geo-significant place so developing the EarthCache really didn't change that a whole lot for me FG2012D2GAC4
Virtually visiting geosites in class with students is widespread	
Most frequently teachers reported an increase connecting their classroom content to geologically significant places virtually through Google Earth or photographs of geosites, or having students virtually visit the EarthCaches:	That's one of the things that I've taken away from MiTEP so far was the use of Google Earth because my kids will bring up a place .... and I'll pull that thing up and we'll talk about the area. Like, the other day, someone didn't know what the Grand Canyon was… so I got on Google earth and pulled it up. And they can see it. You know our kids don't have a lot of experiences. A lot of our kids have never been out of our town,

Whole class visits on google earth often paired with photos, field samples,	and so Google Earth allows them to not only see things that they have not seen but things they will never see. EC_FG11_C3_GB
	if I see a student who is interested in a particular rock, I can tell them about where that rock came from or where I got that rock and so they seem much more interested in the process that went into that rock when I can pull up an example from Google earth and say I got that right from there and this is what we learned about it then it seems to have so much more significance to them.FG2012D1GCC3
	Being able to go to the places through Google Earth the students are able to zoom in on places they may not be able to travel you know with their family or any other way um being able to zoom in on Google Earth and use the pictures that we've been there kind of gives them not necessarily a hands on, but it gives them a real sense of this is actually here it's not just presented to me out of a textbook and they're more engaged because it's not something in a textbook it's actually a place where something they can actually put their hands on especially if we brought back samples. They absolutely love the samples that we brought back from the U.P. and the meteorite I have to keep track of because they want to keep passing it around and I swear I'm going to find it in a pocket somewhere, but they just when they can see it for real life and not just a picture of something and when we can give them examples um, that's more engaging for them and I think they actually get more out of it. And it's more exciting for us to be able to do something outside of a textbook. 2014 I3 P2
	. I already have a core group of kids who are interested in doing geocaching and I've introduced EarthCache and they see examples just on the computer, we've looked at them, we've looked at a lot of ours on there so they have seen what we've done. There's people that you might be dealing with every day that might be making these types of things letting them know that they say "wow that's something we could do, you mean we could do that we could be famous for that" that's how kids think and so that's our goal but I think we need to think these are the kids who are going to be in our job someday so we have to give them a voice to be able to make that decision themselves should they be able to do it or not and I think developing an EarthCache hits on all of these different things that we're trying to do in our classrooms with the students and what we had to go through. D2 GC C4

Some teachers perceive that virtual options are cheaper and easier than outdoor field visits Examples include…. Students measuring using google earth imagery and features. Students engage in topics and with materials applied during professional learning including 'story of the stamp sands. Students engage in virtual field exploration through the use of driving questions. Students virtually explore a geo-significant site a pair of participants visited after the conclusion of the program. Students virtually engage with geoscience locations through multidisciplinary topics including scale and social sciences.	We do more virtual. Because it's easier, it's cheaper…It's just so much easier and you know you can take them some place on Google Earth in 10 minutes....When we do human effects on the environment, I show them the stamp sands on Google Earth...You know, so I wouldn't have done that, I wouldn't have known, I didn't know that existed, I didn't know that was a problem. Right, yeah. And so, you know, we and we've even gone back and now that we're starting to think about NGSS, one of the things we're doing differently this year is we are having them, I just show them the picture, we are having them look at it over time. And how that's changed over time, this year. Which is different than what we had done. And we are also going to have them um brainstorm ideas on how, on suggestions on cleaning up the area, "How would you clean this up?" Um so that, you know that's some stuff we're adding to that when we get to that part of the year that we haven't gotten there in the past. 2014 I4 C3
	[In the classroom I have done EarthCaches] Informally. You know, the idea of you know having this location and being able to go visit virtually on, on Google Earth and you know developing questions you know that the kids can answer based on you know what they see. But not, you know, in a lesson format and with a big idea and with all those components we had in the EarthCache. Just not packaged the same way and not actually going to visit some place. But that, that concept, taking that concept back to the classroom and using it in a way that I can use it with the kids, yes. 2014 I4 P1 C4
	My friend Dawn and I went out to Las Vegas two years ago... and we went to the Dam and Lake Mead. And the water level was way down. You could see it. We took tones of pictures. And then when we came back we showed them all that stuff and talked about the dam and all that kind of stuff and then Ray was showing pictures and then we were able to show it to them on Google Earth...there's this activity where you take a picture and you cut it into four pieces. You put it on the overhead or the document camera, one quadrant and then they make, they write down their observations on that, so they're basically like reading the picture, and make guesses to what they think it is. And then you lay down the second quadrant, and then the third, and then the fourth. And so, it was tying in the reading and the picture, and so we did lots of things with that. And then you know we took them there so they can see where it is and how the whole river system works, and that was all for human effects on the environment. 2014 I4 P1 C4
	Informally we have done [EarthCaching with students]. Well, I mean the Hoover Dam kind of thing, you know what I mean? You know, the idea of you know having this location and being able to go visit virtually on, on Google Earth and you know developing questions you know that the kids can answer based on you know what they see… that concept, taking that concept

	back to the classroom and using it in a way that I can use it with the kids, yes. 2014 I4 P1 C4
Some teachers describe virtually visiting official EarthCaches with students, examples of both their own EarthCaches and allowing students to self-select were provided.	We took a virtual tour. I showed them where [my EarthCache] was on Google Earth and I showed them photographs and you know we talked about how that huge structure came to be and we talked about how the rocks on the beach came to be. I didn't have them go through and have them submit answers to questions… For that last final step, they were asking me questions and I was asking them the same three logging questions…. I think it gave them a more well-rounded picture. Better than just saying this is a place that I went to or better than just looking at a textbook or telling them that you know these processes are occurring even though you don't see it every day it's happening over time. You know I think [the EarthCache] really was able to relay that information with a different perspective, a different angle of understanding. 2014 I3P1 C3
	yes, I am using EarthCaches in the classroom…. usually like virtual field trips. Take them to the computer lab. We have a lot of computers in my new school. The EarthCaches give you that technology the kids want. The kids want to use the computers, they want to see these places. You get more up to date photos instead of them looking at a photo out of textbook, so I think it's huge. I think it, it like I, I really do mean, the fun days in my class so far I've only been doing the geology for like a month, but it's like the fun days have been days where the kids can use a lot of this stuff and see it's more real to them than a day of a PowerPoint or a textbook that's not, it doesn't hook them like the EarthCaches and stuff do. Just doesn't. 2014 I5 P2 C3
	.. let them just go explore or just say like here's a real-world example of what we're talking about, go look at it! And I've only so far, because it just started, only started to show them this. But just being able to pull real places off of the, and talk to them about my experience and "You actually made this?!" "Yeah, I did." And you'd be surprised how much that gets kids' attention because it's me ... discussion right now, where I'm leading them through it…. I talked to them about the stamp sands, because we just did mining, so I talked about the Big Traverse Bay and I showed them some pictures I had. Of like the dark and the light sand and they were hooked. They were like "Wow!" and I showed them, they were like "Why isn't anything growing there?" Well because it can't! 2014 I5 P2 C3
	I did show the pictures show the pictures from my EarthCache in my class and pictures don't really do it justice but some of the questions in my EarthCache I asked of my students and let them start to form opinions about how it was related to what we were doing in class that day. And they were extremely interested just from seeing the pictures. They had more questions than I had for them, so that was cool. 2011C3 C6

Students visit significant places to learn content as a class or on their own - type of student engagement with geosites	
In some cases, participants report encouraging students to go EarthCaching on their own.	to get more knowledge about [the GSA EarthCache Program] was extremely valuable and then besides that to take a more educational perspective on it and think that it can be able to utilize with my students or that I can learn from myself even though I haven't had time to [EarthCache with students], I bring it up in my class, the EarthCaching and the website. hey there are places in this area that if you want to go they are right here, but here is an access point, her is a place where you kind find some of this stuff and hopefully you take the opportunity to do so and if you don't find here hopefully you will click on something off this website that you are interested in, that you can get involved in. so even though I have not had the opportunity to set one up with my students, I try and give them the information so that they can have the power to do something and check it out if they want. XX
In a 2014 interview, a participant described designing a student learning experience that mixed a in class Google Earth exploration with an outdoor field visit to the school-yard to explore scale, a crosscutting concept present in both national mathematical and science standards.	I can still use some of those tools like Google Earth to get a better sense of the sizes of different measurements that we were making and you know the closeness or the accuracy of the estimates that they made versus you know what it actually is in real life so we would go outside and we would have that you know quote unquote field experience, but then to summarize it or bring it back together we would use Google Earth to look at the place we had just gone to from above and see you know a more well-rounded picture of what I was trying to get them to learn and I think that made a big difference and a bigger impact that just saying you know here's how far 100 meters would be. So, some of those tools that we've gotten have been incredibly helpful in making a more well-rounded picture... 2014 I3 P1
Additional examples demonstrate how non-Earth Science teachers modified EarthCache lessons to enhance learning gains in geoscience and their core curriculum, including: 1) an informal educator developed a series of geocaches around the grounds of a nature center with EarthCache like lesson for groups of older students to explore earth systems and ecological concepts;	I work in a place where I can be outside with students all the time… so we did one lesson with a college group that came out to the farm where we set up EarthCaches … they were put into groups … it was like a scavenger hunt… so once they got to one EarthCache they did a little lesson at that EarthCache and then they went to find… that gave them clues to go find where the next EarthCache was… they did it all on… we don't have GPS units for everyone, they used their cell phones. which we had to do a lot of communications to make sure that everyone could do it, but it worked it happened and it was it a 4 hour long… lesson with five or six different geocache stops in our 250 acres all around us. I have something for them to read… one of them was an old tree and they had to go look at the stump and learn about the tree, the environment around the tree and whether or not the forest was still growing the same way it might have been when that tree that was cut down was still alive… that kind of thing… another...there is a lake on the property that is about the kettle lake and there is a few, we are at the end of the chain of a kettle lake and there are a few wetlands that are also little

	impressions that are also from little kettle lakes that are being filled in through succession. so, two of the others were about the kettle lake and they wetlands 2014 IX
Students participated in place-based research learning experience similar to developing an EarthCache The 2014 follow up survey results show that a few teachers reported that they intended to or had successfully facilitated place-based research learning experience for students, similar to developing an EarthCache where students visited sites as part of their class or individually on their own.	
In one example a middle school teacher described having individual students pick a meaningful outdoor location to research including describing the components of each of the earth systems and connecting back to content they learn throughout the year.	I had them choose a place, um, so it's kind of similar to and EarthCache. The idea I had was that I wanted them to pick somewhere they like, so I told them like we are more rural now. So, like is it your hunting, where you go to hunt? Your fishing, if you're into fishing. The beach. You know, wherever you like to go, I had them kind of pick that place and had them do a summary/intro of like what sort of things do you see there. Like when we were doing the earth system. They had to describe the components of the four spheres that were there. and then my goal is to have them go back and actually tie the things we're learning, so like we're doing rocks right now, and if the snow ever goes away, I'd tell them like one of your homework is now you have to go to the place you chose and now do a report of what type of rocks are there. Are they mostly metamorphic? Sedimentary? Igneous? How do you know? Maybe take a picture? Bring in a sample? You know, so it's kind of EarthCache-y. The thought process is, if it's somewhere that they're interested in and that eventually we can tie in human impact and what signs of human impact? Are there any other natural, you know glaciation when we get into that so kind of! 2014 I5P2 C3
In another example a cohort 2 teacher described how students developed a modified EarthCache, as part of a community-based research project. Over a semester, groups of 8th grade students identified a location at or near the school that provided an example of how water moves through their local watershed, such as vernal pools, rain gardens, or sites with intense runoff. Then, using the basic format and requirements of published EarthCaches, students developed a 'WaterCache' that would be explored by other students or community members. It should be noted that this teacher had unique structure and supports which may have helped them to overcome the barriers that others	It's a project-based class pretty much get to write my own curriculum and I just connect it to the different uh curriculum requirements and that kind of stuff. So, I get to pick and choose and it's a lot of research and it's a lot of language arts and science standards are covered in here, but in a project-based way. My textbook for the class, is that [Great Lakes Literacy Principles] pamphlet…[students] have some projects every quarter and for all their projects, they have to choose big ideas that fit what they're doing… they had to write the "Claim, Evidence, Reasoning" using the pamphlet, and they had to go out in that was their quarterly project. ...so, they had to do a different big idea each quarter. So, they got through four big ideas on their own. And so, each quarter they had to pick one and they had to take a photograph of something out somewhere that represented the big idea. Interviewer: How do you think that has helped your students? Oh! It opens their eyes to where they live. it just helps them to see the connection between the words they're reading and real life. You know? Because they're out there and they can find stuff. And they really have to explain the connection, like um, um well, okay. So that's what I do with the 7th and 8th grade CER, which really exciting this quarter's project um, let me think

perceived would make this type of project problematic in their own classrooms including: They had taught the class for 8 years at the time of the interview, this was the first year with implementing this EarthCache like project with the students. The classroom has a natural area adjacent to the school. The participant taught at an environmentally themed middle school in Grand Rapids Public Schools which she perceived to have more flexibility in curriculum than other 6th, 7th and 8th grade teachers in the same urban district.; and mini-grant and further project support through Groundswell, a hub of the Great Lakes Stewardship Initiative. They had taught the class for 8 years at the time of the interview, this was the first year with implementing this EarthCache like project with the students .	what the- I think last quarter the kids made um environmental water, environmental issue brochures. And so, they had to do a lot of research and these brochures had to find the connection with the big idea and these had to be Michigan. And so, it could be like invasive species. Some of them did fracking. Some of them did um, but they're all water based. Um and so but then this quarter we're doing WaterCaches. This teacher had just received a grant from Groundswell, a Great lake Stewardship Hub from Grand Valley State University, to conduct stewardship projects related to the watershed literacy. The teachers decided to use the funding to support implementing a modified EarthCache activity, they called a 'WaterCache'. the WaterCache, you know how [instructors] had that whole outline for developing an EarthCache? Where you had to have the waypoint, the final waypoint and you had to have your vocab and so what I basically did was I showed them my um ancient shoreline um EarthCache that I did in uh at Isle Royale. So, I showed them that and I had given them the same requirements pretty much and had them, they're doing that for their WaterCaches. So, the kids are loving it. First, they had to find something that's water related. And I'm pretty wide open. Some of them are doing a rain garden that's for runoff and some of them are doing vernal pools. And others are going to focus on amphibians or frogs. These are on the School campus and the adjacent nature center. my 8th graders a lot of them get to go to the nature center. We have walkie talkies…. They go out in pairs and they communicate with me where they're at and wherever and they've got a timeframe. And so just the real responsible ones go over to the nature center and they can um they're doing these Cache locations. And in the science …. they're taking technology in the field and I'm really hoping to do those [QR] barcode things…. so, we're going to eventually develop these Caches so people can look at them…. And so, before that I had them do a practice waypoint outside and we compared numbers you know and they had partners and so they realize that it's the hundred placements, and that it can only be a plus or minus one UTM accurate. And so, so that math part is there where they're looking at outliers. They got their five vocabs. And then the explanation piece they have to, I gave them the slow method, and they're doing three paragraphs and so they might be doing "What is a pond?" and so the first paragraph will explain what a Michigan pond is, and then. what kind of waterfowl you might find in the Michigan pond. And then the third one they're going to ask "How do you explain, identify a wood duck?" A so that they're going to write that up and either use some photographs they've taken or they can pull something off [the internet], to show somebody something described in their paragraph. …. it's definitely a research project because to do that explanation piece of the WaterCache, or you know, the pseudo EarthCache...In order for them to write that, I'm saying a minimum of three paragraphs, they have to research… And then they have to find something on the [ESLP Big Ideas] pamphlet. I

	even told them for one of their citations they could cite the brochures. They all have to have their own stuff typed up and stuff. They have to write their own rough drafts and then from the rough drafts, you know the explanation and images section and then they're going to peer edit that writing...so they're helping each other with the research and gathering information, but they are individual in the writing. And it has to be their own words and so I have this flow map where the kids are like taking notes while they're reading stuff. They can do the same location, but it has to have a slightly different twist to it, ... You know that for me the one hardest thing is the technology and um and being able to- I mean it's working, it's working great right now because I've got kids coming up here right now they can figure out a lot of the- I don't have a web design, which I want the ability to do a video. I'm lacking I don't know how to do that, but we'll get there. Students are asked to develop a logging question for the water cache that allows visitors to prove that they were there. Students work to be sure that the answer to the questions could not be something that they can look up without physically being there. one of the groups that is focusing on erosion control and (???) they got some cool pictures of the bars they put in and so um their log in (or logging?) question is um you know, "Walking from the top, you know, down to the creek uh bridge, how many water bars are there?" And so, the person would have to you know, count (???) they would have to count how many bars are on that trail…. And so first they're bringing them to the water bars that they put in and explaining what the function is and all that. And so, to prove they're there, they're going to have to tell me, "Well, there's five," because they put them in, you know. And then um they also have to citation; MLA um citation is part of it. And then at the bottom of it they have to have two big ideas that it connects with and explain why. [The Project] is an easy motivator, you know, they just want to go out and do their thing. The other motivator I think is the choice. Is that they are picking it, they're telling me. I mean that's where the whole "project-based" thing comes in. The technology use, the GPS, using the cameras, you know? …. They're just out there giggling when they come in. You know, it's just being out and having a purpose I think. You know, they just get excited about it….
Community Benefits	
Most commonly it was mentioned that their EarthCaches were acting as an educational tool where people could continue to grow their geoscience literacy. Some mentioned that they perceived the	it's setting up learning about features from a tourist perspective in a way that's inquiry-based where if you go to pictured rocks or something and you read the signs that are there that tell you about how pictured rocks was formed you might read it and remember it for a couple days and then you forget it but if you decide to do the actual EarthCache and log in to it you have to

EarthCaches they developed as experience educators were higher-quality than some of the published examples. Many groups perceived that visiting their EarthCaches supported local community members to discover new concepts and/or build value for the site that they were not aware of previously. Additionally, some mentioned that communities may have increased tourism with the large addition of EarthCaches that they developed	answer questions about it you have to think about it more instead of just reading something so maybe it's helping people learn about their world also in a way that sticks better. D2 GB C4
It's a fun activity that builds awareness of the regional Geoheritage sites and deeper learning gains than most traditional modes of information for tourists	I feel that personal responsibility to make them aware of the beauty and the awe of this planet and what this planet has been through and how it continues to change and I think EarthCache is a way for us to not only pass it on to our students and to our community at large. I mean, that stuff's there for anyone to use, and I know from the people, its, people are going and they're looking at Woods Lake and they're looking at that little area where the water's stagnant and they're stopping to think about it. And um if we can get them to do that about more and more and more areas, then people, especially since Geocache has become popular, we're doing our little part. 2014 I4 C3
It's important that the general public is Earth Science Literate so that they can be productive citizens and the EarthCaches provide access to that information. This appears to important in cases of both beautiful, pristine sites as well as examples of human destructive forces	…… They could really understand more about the history, the human history of Michigan] and understand why it's formed the way it is. Why the copper is there adds a whole another dimension to the experience of being there and it's one of the reasons that I fell in love with the U.P. after learning about this because it helped me see the whole picture and how things came to be the way they are, the way things are shaped the way they are, why people were able to make their lives the way they were there. I think it paints a really rich picture of the state so if people will use it, if people became aware of it and use it I think that it's something that would really help them appreciation the place that they live in and understand it a little better. From an educational point of view, it's a huge resource for people that may not be in a classroom for educational purposes. D1 GB C3
	In the written responses for the people who had visited my EarthCache I've read a lot of people saying thank you for bringing me here I never knew this much beauty existed etc. It seems to be a popular location once people have seen it. Most people have said I really want to come back here at a different time of year and see what it looks like or I want to bring someone else here. I feel like the value is high in terms of their appreciation for a hidden piece of beauty. D1 GA C3

	*The exact opposite, I had the stamp sands so the people were going down there and saying wow, we've destroyed a piece of our environment. D1 GA C3
	"I think another value too is that when we have significant places that illustrate geology or illustrate some type of natural phenomena that visitors in the community are aware of that they're much more careful to preserve those for other generations and my particular one is being exploited all the time in very unsavory ways and I think this is a way that we can at least preserve sections of it to show people what is actually there. Another factor that my student recently just said "we have that in our town? nothing ever happens in our town". D1 GC C3
	I think it's neat that tourists can learn a little bit more about why or how things are forming when they go to Houghton or the surrounding areas I know I've never heard of EarthCache before and I think that it's really cool for that particular community that they can bring in people that are interested in doing something like this or are interested in learning about the earth and not necessarily visiting the typical tourist sites, you're able to see more of the community and what the people that live there go see and drive-by on a regular basis and so I think that that's something cool that they have going on for them up there it's not like you go there to check out some earth science stuff it's just an added benefit of touring that area. D2 GB C4
It is beneficial for the community where these are places because it is a fun activity that might bring tourists in or further enrich their experiences in the area	You sit in a hotel room for a day or two and say let's get out and do something and you have this challenge. Because if you had just driven around and saw a rock it wouldn't mean anything to most people but to find out that it is something we can look up on the internet and find out about, that's cool. D2 GC C4
Builds awareness for local community as well	It was based on some of the responses I've gotten back from my EarthCache being what I would consider could potentially be a fairly popular place but has caused some people to pause and look differently at a place that maybe they walked by all the time without thinking about what they were seeing, I think that's good building awareness within your community. D1 GC C3
	My area too was one that was relatively undisturbed in a neighborhood and bringing the attention to something that people probably drive-by every day and one of the people that did mine replied to that "though I go by that spot every single day and I've never really even noticed it. Next time I go by I'm going to look at your questions and try to answer them." Bringing that attention to something that is so familiar yet so unknown at the same time I think is really valuable. D2 GB C4

Teacher made EarthCaches	they were very educational they were much more worthwhile, they were much more worth visiting and I do think it's a good idea to have teachers develop things like this for people who do this. Now a lot of people who aren't teachers can have the knowledge but they don't know how to communicate to just everyday people in a way that they can understand but teachers do know how so it is very beneficial to have teachers doing this kind of thing, if this kind of thing is going to be out there they all need to be high quality. I have been told over and over again that we have been doing very high quality EarthCache as we develop them very well and I don't think if you're not a teacher you understand the difference between a well done one and not well done one because the key is to make it that anyone can understand it. If you're a waitress you still need to be able to get something out of it, that it will make sense to anybody. That's why we develop it with vocabulary terms and history and we do it in layman's terms. We're not using necessarily big words if we do we explain what the words mean and we explain how to do it. I think that was one of the things that was most important about the EarthCache, that they were done by teachers. D1 GB C3

2 Case Study 2. Integrating Michigan Geologically Significant Sites into K-12 learning experiences through Virtual Geosite Investigations: *Results from Western U.P. Initiatives*

2.1 Setting

The project leadership team included:

- Lloyd Tucker Wescoat (Center for Science and Environmental Outreach at Michigan Technological University/ Lake Superior Stewardship Initiative) coordinated the overall project, co-develop the virtual field experience for teachers, co-conducted the one-day workshops, supported the teachers in planning and implementing their own virtual field experience for students and coordinated overall communication.
- Emily Gochis (Western Upper Peninsula MiSTEM Network/Lake Superior Stewardship Initiative/Copper Country ISD) served as the Co-Principal Investigator for this project with responsibilities including: recruitment of educators and experts, co-facilitation of the virtual field experiences and PLC sessions, management of the grant budget and reporting, and coordination of evaluation and dissemination of teacher-developed virtual field experiences.
- Steve Kass (REMC1/CCISD) was responsible for leading the technology professional development component for workshops, providing ongoing technical support to schools as they developed, and management/maintenance of equipment.
- Dr. Erika Vye (Great Lakes Research Center at Michigan Technological University; Keweenaw Geoheritage) acted as a geoscience content expert for the project, connecting with schools to support and coordinate the development of the Virtual Experiences.

Other contributing partners on the project included:

- Dr. Alex Mayer (Department of Civil and Environmental Engineering at Michigan Technological University) and Dr. Jeremy Shannon (Department of Geologic and Mining Engineering and Sciences at Michigan Technological University) provided expertise for the development of exemplar Virtual experience.
- Copper Country ISD provided conference coordination and business office services free of charge.
- Center for Science and Environmental Outreach at Michigan Technological University provided organization and other support.
- Regional Schools administrators supported the marketing and coordination with their teachers and students. Teachers participated in professional development activities and development of the Virtual Geoheritage Investigations (see Figure s2.1).

- The following Partners organizations supported schools with the development of the Virtual Geo Investigations:
  - Houghton County @ Calumet Waterworks Park
  - Keweenaw County @ Gratiot River Park
  - L'Anse Township
  - Keweenaw Geoheritage

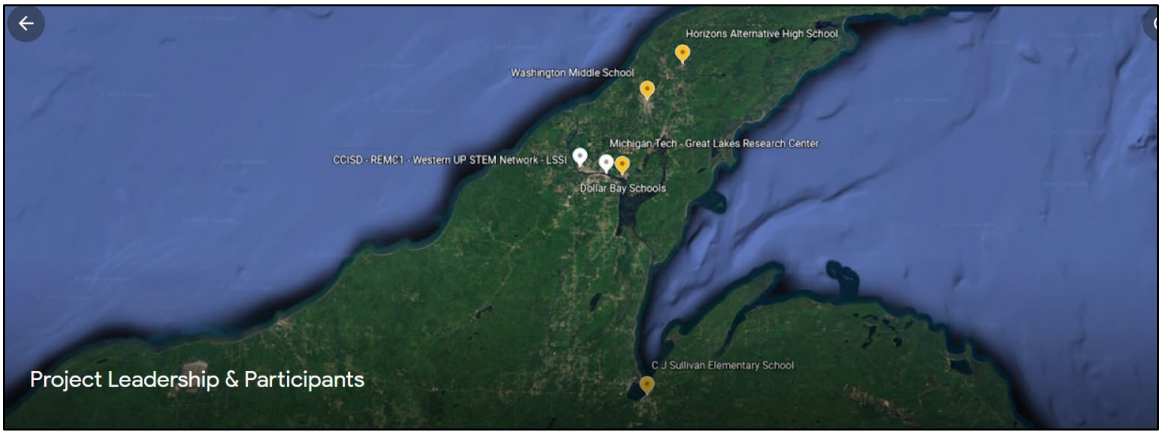


Figure s2. 1 Google Earth image which displays the locations of the participating school districts and lead organizations that participated. Note the Ewen Trout Creek, located south of this image, is missing.

Table s2.1. Displays the information on the participants prior technology experiences that were collected prior to the project through the Pre-workshop survey.

Please rate the amount of experience that you have with the following on a scale from 1 to 5, with 1 being NONE and 5 being Expert.			
	Using Google Expedition	**Using a 360-degree camera**	**Identifying the earth science processes that shape a feature/site**
1	7	11	3
2	4	1	3
3	1	0	6
4	0	1	1
5	2	1	1

Table s2.2. Displays the information on the participants prior virtual reality experiences that were collected prior to the project through the Pre-workshop survey.

How many Virtual Reality Experiences have you:	
experienced personally?	
none	5
1-2	4
3-5	4
more than 5	2
implemented in the classroom?	
none	11
1-2	2
3-5	0
more than 5	2
developed?	
none	12
1-2	1
3-5	0
more than 5	2

2.2 Participant Resources

The project website was provided to participants to support them through the summer workshop and lesson design. The example virtual geosite investigation and other classroom VR examples are included. The website can be viewed at: https://sites.google.com/remc1.org/geo-investigations/home.

Figure s2. 2. Image of the flier used to recruit participants to join the summer workshop

Geo-investigations through Virtual Field Experiences

Up to 15 teachers are invited to collaborate in the next phase of this professional learning opportunity by joining the Virtual Field Experience PLC. Outcomes will be to build your own VR experience using important geosites in the Western Upper Peninsula to highlight local history and science topics such as natural hazards.

Benefits:

- $250/teacher as a stipend to plan a VR field experience
- Learn how to facilitate student experiences using technology in a meaningful way
- Identify geo-significant sites and phenomena in the community that connect to the classroom
- Exclusive access to VR equipment and 360° camera
- Mentorship and support throughout the school year from provided experts

To qualify for this stipend, you must agree to:

- Engage in PLC sessions to develop and implement virtual field experiences and assess student learning experiences (15 hours throughout July 2019- May 2020 school year; team fieldwork, online & face-to-face meetings; dates TBD)
    - Attend (or view recording) of the kick-off meeting on October 1, 2019, from 4-5 p.m. ET
    - Attend a brief virtual check-in session later in the year
    - Attend a REMC1 virtual reality kit training (if not already trained)
- Select and tour a geosite of your choice with a provided expert
- Implement a virtual field experience with students (either student or teacher-developed field experience is welcome)
- Participate in an evaluation plan (teacher pre/post-test and focus group)
- Showcase the experience at Lake Superior Celebration at the Great Lakes Research Center at Michigan Tech University in April 2020 or an alternative showcase event.

Components of Virtual Field Experience:

- Teachers and their mentor will identify one geo-significant site and phenomena in their community that connects to their standards-based classroom.
- Lesson plan integrating MiTEC and ESLP with standards-based curriculum and includes a student assessment.
- Virtual Field Experience
    - Google Expeditions Virtual Experience
    - Teacher Narrative
    - Google Map with Pins

Funding for this is provided by the Great Lakes Fisheries Trust, Lake Superior Stewardship Initiative, Michigan Space Grant Consortium, REMC1, and the Western UP MiSTEM Network.

Figure s2. 3. Image of the document provided to participants with the expectation and benefits of deigning the student experience outlined

2.3 Instruments

2.3.1 Pre-workshop Survey (Google Form)

This questionnaire is part of a pre/post survey that will be used to investigate the experiences that rural educators have through integration of technology and science standards through geo-significant places. All information will be used for this purpose alone and is completely anonymous.

Directions: *Please use the space provided to answers to the following questions:*

- What is the name of the district you teach in?
- What is your position?
- What grade level(s)?
- What is the main subject area(s) that you teach?
- How many Virtual Reality Experience have you: experienced personally? implemented in the classroom? developed? ____
- How many college level Earth Science courses have you had?
    - None 1-5 6-10 11-15 > 15
- How often do you teach students Earth Science concepts currently?
    - In every lesson most lessons some lessons rarely never
- How often do you connect to geologically-significant places when teaching?
    - In every lesson most lessons some lessons rarely never

Directions: Please rate the amount of experience that you have with the following on a scale from 1 to 5, with 1 being NONE and 5 being Expert.

- Using Google Tour Creator
- Using Google Expeditions
- Using a 360-degree camera
- Identifying the earth science processes that shape a feature/site
- Using examples of geo-significant places when teaching students

Directions: Please select one of the following confidence levels that best fits each statement below: Not confident, Slightly confident, Somewhat confident, Confident, Very Confident

- How confident are you in your understanding of the Michigan Integrated Technology Competencies for Students (MITECS)?
- How confident are you in your knowledge of the Michigan Science Standards/NGSS for the grade level you teach?
- How confident are you in your understanding of the Earth Science?
- How confident are you in your ability to implement curriculum focused on improving student knowledge about Michigan Integrated Technology Competencies for Students (MITECS)?
- How confident are you in your ability to implement curriculum focused on improving student knowledge about earth science literacy?
- How confident are you in your ability to implement curriculum that integrates science and technology?

- How confident are you in your ability to design learning opportunities that integrate technology across content areas?
- How confident are you in your ability to conduct a Virtual Field experience with your students?
- How confident are you in your ability to develop your own Virtual Field experience?
- How confident are you in your ability to develop learning experiences that integrate earth science literacy?
-

2.3.2 Post workshop Survey (Google Form)

This questionnaire is part of a pre/post survey that will be used to investigate the experiences that rural educators have through integration of technology and science standards through geo-significant places. All information will be used for this purpose alone and are completely anonymous.

- What is the name of the district?
- What grade level(s) do you work with?

Select the agreement level that best fits your feelings for each of the following statements: Strongly disagree Disagree, Slightly Agree, Agree, Strongly Agree

- The workshop was useful and provide relevant information.
- The workshop help developed my ability to recognize geo-significant features.
- The workshop help developed my confidence to connect geo-significant places to the lessons I teach.
- The workshop helped to develop my ability to recognize geologic processes that shape the landscape.
- This workshop has improved my knowledge of Earth Science processes and concepts.
- The workshop help developed my ability to use Virtual Reality Field Experiences in the classroom.
- The workshop helped develop my ability to develop a Virtual Reality Field Experiences that could be used in the classroom.
- The workshop helped develop my confidence to implement curriculum that integrated science and technology.
- The workshop helped develop my confidence to design learning opportunities that integrate technology across content areas
- I have new tools in my toolbox that I will be able to implement immediately in my classroom.
- Overall this workshop was beneficial and increased my ability to deliver quality instruction/curricula to my students.

Directions: *Please rate the amount of experience that you have with the following on a scale from 1 to 5, with 1 being NONE and 5 being Expert.*

- Using Google Tour Creator
- Using Google Expeditions
- Using a 360-degree camera
- Identifying the earth science processes that shape a feature/site
- Using examples of geo-significant places when teaching students

Please answer the following open-ended questions:

- How could this workshop have been improved?
- What are the most helpful topics/strategies that you will take home from this workshop?
- What sort of technical, content or other support would you need to develop your own geo-investigation Virtual Field experience?

2.3.3 Participant Post Program Survey (Google Form)

This questionnaire was part of a pre/post/post survey that was used to investigate the experiences that rural educators have through integration of technology and science standards through geo-significant places. All information will be used for this purpose alone and are completely anonymous.

- Please rate the amount of experience that you have with the following on a scale from 1 to 5, with 1 being NONE and 5 being Expert. *
- To what degree do you agree or disagree with the following statements about this experience of developing a Virtual Field Exploration. Strongly Disagree, Disagree, Somewhat Agree, Agree, Strongly Agree
    - Using Google Expedition
    - Using a 360-degree camera
    - Identifying the earth science processes that shape a feature/site
    - Using examples of geo-significant places when teaching students
- How interested are you in developing another geo-investigation through virtual field experience? * Not Likely - 1 - 2 - 3 - 4 - 5 Very likely
- What sort of technical, content or other support would you need to continue developing and/or using geo-investigation Virtual Field experiences with your students?
- What are the most helpful topics/strategies that you gained from this experience? *
- How could this experience have been improved?
- Do you have any other questions or comments?

2.4 Results

2.4.1 Artifact Analysis

A rubric was used to review the published VGIs and associated evidence collected from observations, direct communications and field notes. The rubric was created based on and research based educational and pedagogical frameworks (K12 Science education, MITECs, ESLP, PBLP, SEPs) that were associated with the target performance outcomes of the program. The rubric was designed with 4 rating levels to measure performance. Other published virtual field experiences were used to prepare the rubric - Team members individually scored the items - We sought at least 80% agreement; if we did not achieve that level, we further clarified the rubric descriptions. Issues of validity were discussed to ensure that the scores were representative. There was Written feedback and overall ratings provided for each of the published VGIs.

The following are the measures and ratings for each of the criterion:

- Science and Engineering Practices
    - 4- students demonstrate proficiency of 3+ SEP at or above grade level, with at least one indicator in each
    - 3- students demonstrate proficiency of 2 SEP at or above grade level, with at least one indicator in each
    - 2- students demonstrate proficiency of 1 SEP at grade level at multiple indicators at or below grade level
    - 1- students demonstrate proficiency of 1 SEP below grade level
    - 0 - students demonstrate proficiency of no SEPs
- Geoscience Content -
    - ESS
        - 4- contains 2+ target ESS at or above grade level
        - 3- contains 1 target ESS at or above grade level
        - 2- contains 2+ target ESS below grade level
        - 1- contains 1 ESS below grade level
        - 0 - contains no target ESS
    - ESLPs
        - address 2 ESLP & multiple indicators
        - address 2 ESLP with at least one indicator each
        - address 1 ESLP with more than one indicator
        - address 1 ESLP with one indicator
        - contains no target ESLP
- MITECs
    - 4- address 2 MITEC & multiple indicators
    - 3- address 2 MITEC with at least one indicator each
    - 2- address 1 MITEC with more than one indicator
    - 1- address 1 MITEC with one indicator
    - 0 - contains no evidence of student MITEC achievements

- Geoheritage
    - 4 - highlights more than one geo significant places - including the cultural or phenomena that makes a place special
    - 3 - highlights one geo-significant places - including the cultural or phenomena that makes a place special
    - 2- situated in a geo-significant place but does not necessarily demonstrate awareness
    - 1- situated in a community place but does not necessarily demonstrate geosite awareness
    - 0- is not situated in a community place
- PBSE - Place Based Principles (see https://greatlakesstewardship.org/wp-content/uploads/2017/07/PBSE-Rubric-1.pdf)
    - Researchers used the Place Base Stewardship Education Principle rubric to score each of the five VGIs, providing a rating for every element of the 10 principles. Because the principles and elements are not evenly distributed a rating guide was developed to guide researcher in their review of the published artifacts. It was determined that researcher would provide a score for each of the four parts of the PBSE principles, including:
        - "Part I Set the Focus: examines the connection of PBSE to the local context and to some core environmental concepts (Principles 1 and 2).
        - Part II Develop the Foundation for Place-based Teaching and Learning: focused on experiential teaching and learning strategies (Principles 3a–3e).
        - Part III Deepen Impact: is focused on strategies to intensify and deepen the impacts of PBSE efforts, including school community partnerships, multiple learning experiences of meaningful duration, and generating real benefits for the community and environment (Principles 4–6).
        - Part IV (Develop Skills for Participation in Democratic Practices) is focused on the strategies that help students develop as active participants in community life, including fostering student voice, modeling democratic practices, exploring various perspectives, clarifying personal values, and engaging in public discourse (Principles 7–10).
    - Then a score was determined for part based on a two criteria system. First, by determining by the total # of elements present at each rating level compared to the total elements that exist at that PBSE part. Second, by calculating the number of principles present compared to the total number of principles listed in that PBSE part.

2.4.2 Summer Workshop Survey Results

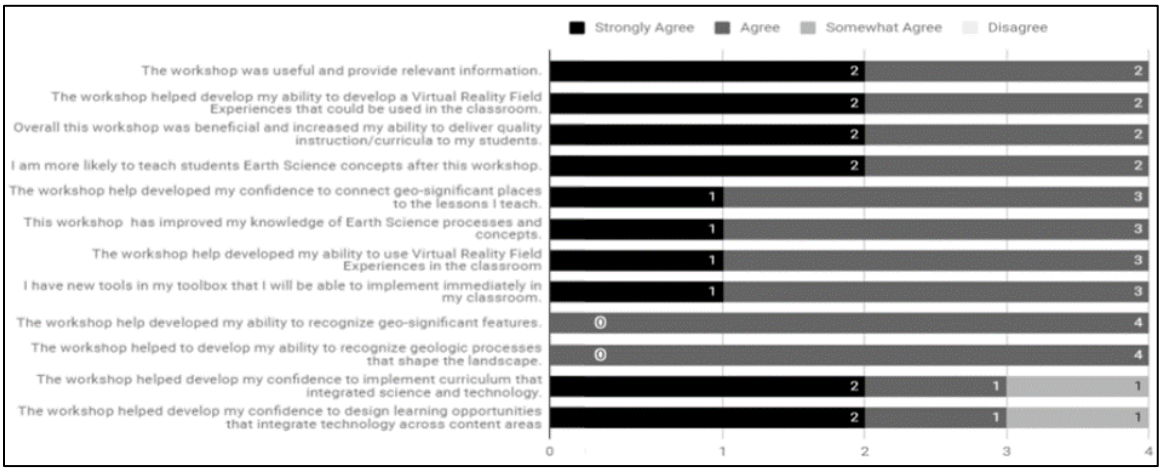


Figure s2. 4. Displays the results of the post-workshop survey (n=4, 27% response rate)

Table s2.3. Coded responses from open-ended questions on the Post Workshop Survey

Post Workshop Survey: What are the most helpful topics/strategies that you will take home from this workshop? (PWQ1)	
Improve Pedagogy Pedagogical understanding of doing VR with geoscience; Pedagogical ability to engages students through EC	Looking at VR development from a geoscience perspective. (PWQ1) Creating Hands on spaces or simulations to teach (PWQ1) Using geocaches to engage students. (PWQ1)
Increase Skills - Skill to use Google Expedition Time to practice the skills so we could learn them before returning to the classroom	I learned to use Google Expedition &look forward to using that, along with the necessary hardware. (PWQ1) Thanks for giving us time to practice with the material. So often lots of information is thrown at us and then we go home, remembering little of what we learned. Thanks for giving us time to process its use. (PWQ1)
Post Workshop Survey: How could this workshop have been improved? (PWQ2)	
Need more time to discuss integration into individual settings	Maybe even more emphasis on and time to plan how to take this knowledge to our individual settings. (PWQ2)
Post Workshop Survey: What sort of technical, content or other support would you need to develop your own geo-investigation Virtual Field experience? (PWQ3)	
Continued Access to Systems of Support including Connections to 'the right' community partners & further content support	Probably the science content support/ability to reach out to the right contacts for information on each site. (PWQ3) Some expert knowledge on the geology and science at different sites. (PWQ3)
Access to the equipment	Time available to rent the equipment. (PWQ3)

2.4.3 Post Program Survey Results

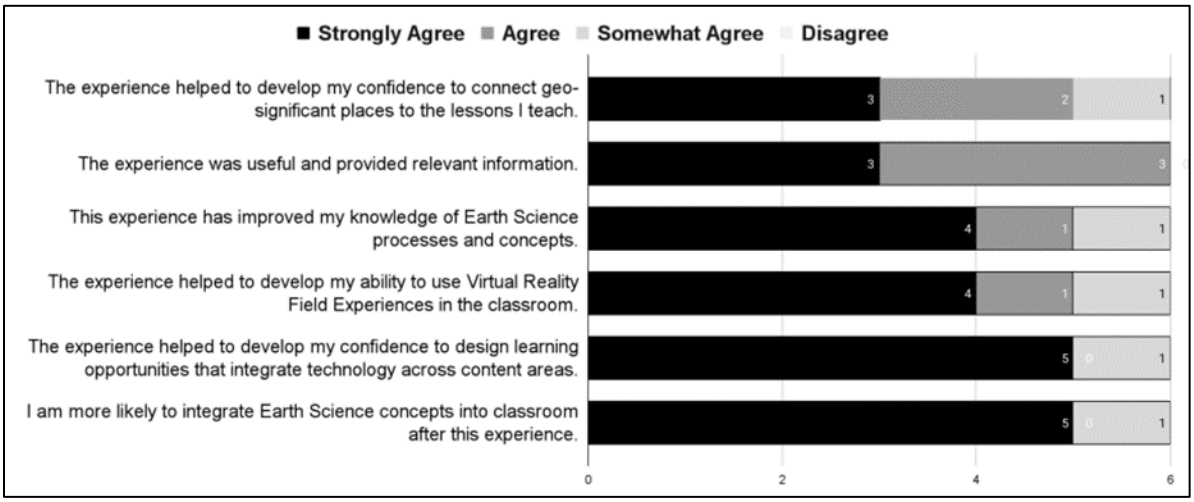


Figure s2. 5. Displays the result to the post-program workshop survey question related to the program's ability to achieve its intended outcomes

Table s2.4. Coded responses from open-ended questions on the Post Program Survey

Q1: What sort of technical, content or other support would you need to continue developing and/or using geo-investigation Virtual Field experiences with your students?	
Continued Access to content and technical experts	I would need access to experts like [the geoscientist] to help with our knowledge and learning. Continued access to technical support through REMC1
Access to the 360- degree camera, equipment	I would need access to tools like 360 cameras Continued access to equipment
Further practices with the software and incorporating it into classroom	Practice using the different platforms incorporating into classroom I still need to take the time to learn how to use RoundMe It's been a year since we did the project so I would just need to reacquaint myself with the program.
Q2: What are the most helpful topics/strategies that you gained from this experience?	
Knowledge/Skill Gains: Learning content from experts Technological skills	using 360 cameras Our expert partner was also essential support. She was able to connect with students with both knowledge and passion. Her collaboration also motivated and informed me as a teacher.
Pedagogy Gains: Student Choice in activities Meaningful shift to virtual platform during covid-19 Relating content to local places	I have a plan for how I want each student to take his/her own pictures to provide more ownership to the students for the entire tour. How to tie the 360 images to the related scientific concepts. The timing of creating the project with students occurred as schools were shut down due to the pandemic. We were thrown into teaching and learning in virtual spaces. This experience provided a bridge from our shared physical space into a collaborative virtual space. Our project was also grounded in outdoor local spaces encouraging students to visit and experience sites with their families. Our expert partner was also essential support. She was able to connect with students with both knowledge and passion. Her collaboration also motivated and informed me as a teacher. It was an excellent experience for both my students and myself. [Students] really enjoyed researching a near-by falls. I gained more expertise in doing Project Based Learning with my students.
Q3: How could this experience have been improved?	
Adjustment for technological challenges, especially related to the software	I think that once the issues with the camera needing to be upgraded were resolved, it took little time to learn to use it. When creating the tour on Tour Creator, it could not be shared. That made collaboration more difficult. The owner had to be logged onto Tour Creator, which made it more difficult for students and myself to work on the tour. If we were able to share the project on google expedition, that would have been beneficial.
Providing further examples and applications	more examples of applications

3 Case Study 3. Integrating Michigan Geosites into K-12 learning through Professional Development & Mentorship Program: *Results from Nah Tah Wahshl*

3.1 Summer Youth KidZone: May - August 2013

3.1.1 Participants

The 14 Youth Employees involved in this study were tribal members and descendants, aged 14-18, employed through the Summer Youth Employment program. Six were employed as KidZone Youth Assistance and Eight were involved in the Hannahville Day Care program. Table X shows the breakdown of participant gender and grade level. The tables below outline the background experience, Gender and Grade- level as collected through the pre-project survey.

Table s3.1. Displays the data collected from the Summer Youth Assistants about their science background prior to the intervention

Experience	none/never	1 or 2 times/classes	3 or 4 times/classes	5 or 6 times/classes	More than 6 times/Classes
Courses in School	0	8	5	2	0
Research Project in School	1	7	3	2	2
Science Fair	10	5	0	0	0
Independent Science Exploration	10	4	0	1	0
After-school or summer programs	7	2	4	1	1
Through television or internet	1	6	4	2	2

3.1.2 Study Design

This project allowed for a Quasi Experimental design, with a control group formed from Summer Youth Employees participating in the Daycare Program. Summer Youth Employees participating as KidZone Youth Assistant formed the experimental group. The participants had a similar schedule & compensation as the participating KidZone students, however worked with younger children and did not participate in the project.

The groups were not randomly selected. Youth employees complete an application for employment with Hannahville Youth Services, and self-select from a wide variety of employment options. The Daycare group was selected because of the likelihood of shared

interest to engage with younger children. Interviews were conducted. Youth could choose not to participate in the project and still serve as KidZone Youth Assistant. This is a Non-equivalent control group design whose control group is not equivalent to the experimental group because it could not be randomly assigned.

To be sure there was no spillover of intervention, a pretest & survey were given to both groups to determine if they are equivalent or not prior to the project. Other data collections included a post-project Motivation Survey, a group interviews with the participants and collaboration adults, and archival analysis of facilitator and student products and other artifacts. All data collection was conducted as part of the regularly scheduled activities with Hannahville Youth Service at the Nah Tah Wahsh School building in Hannahville, Michigan.

3.1.2.1 Summer Youth Pre/Post Survey & Content Test

In June 2013, prior to the project implementation, students from the control (n= 8, 100% participation rate) and test groups (n= 6, 100% participation rate) completed a self-administered, pre-content test & pre- survey. A similar post-content test & pre-survey (test n= 6, 100% participation rate, control n=8, 89% completion rate) was administered to the same groups in August 2013, after the completion of the project. The content test and survey are located Instruments section of the supplemental resources

The pre/post survey was designed to measure any effect on participants' attitudes towards science, research and community educational outreach; confidence in use of technology; and background information about the participants and the control group. The survey was reviewed by graduate students with geoscience educational experience. The results of the survey were entered into excel. Tables and figures were developed from Likert-type questions to analyze any changes in response frequencies.

The content test was designed to measure participants' understanding of water-related Earth Science content knowledge including knowledge of watersheds, hydrological processes in man-made and natural settings. The test was modified from the Environmental Literacy Water Assessment (2011-12) The original version can be accessed at: http://envlit.educ.msu.edu/publicsite/html/wc_assess.html. This was part of the School Water Pathways Activity (Caplan, B., 2012), which includes a rubric developed based on a learning progression for water in socio-ecological systems (Gunckel, K., 2012). The tests and scoring rubric were reviewed by graduate students with geoscience educational experience for validity. The pre and post-tests were graded by both the researcher and a hired geoscience PhD with experience in geoscience teacher education. Discussion around the rubric, goals were conducted before and during grading. Each answer was recorded in excel and transferred to SPSS. Various descriptive statistical tests for each answer set were performed and labeled according to the scorer's name. The effect size for the experiential group to Control group was calculated with a pooled StdDev (Coe, 2002). Additionally, the effect size on experimental participants' post scores to pre-scores was calculated for each content grouping. These groupings included: Water Pathways, Watersheds, Substances & Water, Engineered Systems, and Water Movement within Trees. Tables and figures were developed to display the results.

3.1.2.2 Post Motivation Survey

In the field of educational science, the ARCS Model of Motivational Design (Keller, 1983, 1987, b, c, 1999, 2010; Keller & Kopp, 1987) has been used myriad times to apply motivational strategies to instructional materials, and to test their effects. A Post-course Motivation survey (n= 6, 100% participation rate) was developed based on a Keller-like Instructional Materials Motivation Survey. The survey (located Instruments section) was administered at the end of the project to assess the motivational characteristics of the project. The survey used a 5-point Likert-like scale with 29 questions to measure the Attention, Relevance, Confidence, and Satisfaction (ARCS) model of motivation. Likert-like scale responses were converted into numerical codes (-2,-1,0,1,2) and were reported as mean scores with standard deviations by grouping. Each answer was recorded in excel. Tables and figures were developed from responses to the Likert-type questions in order to analyze any changes in response frequencies.

3.1.2.3 Summer Youth Post Interviews

A post-program group interview was conducted in July 2013 with KidZone Youth Assistants (n= 4, 67% participation rate). The purpose was to understand participants' perspective of the effect of the intervention on their geoscience content knowledge, skills, and attitudes towards geosciences and careers. A separate group interview was conducted with the adults that were part of the educational community to gain their perspective of the project's success at achieving its goals. The interview protocol for student and adult interviews is located in the Instruments section of the supplemental resources. These types of interviews are useful for getting high-quality data in a social context where people can consider their own views in the context of the views of others (Patton, 2002, p386). Group interviews have limitations, though, including the possibility that a participant with a minority viewpoint may not speak up against a dominant viewpoint or personality and therefore may not be useful for "the micro-analysis of subtle differences" (Krueger, 2009).

3.1.2.4 Artifact Analysis:

The following is a list of the artifacts that were analyzed:

- Field Notes - Recorded Field Notes
- Hannahville Summer Youth Employment Webpage
  - 2013 Kidzone Student/Parent Handout with teachers, schedules, larger theme
- Hydrological Field-Based Investigation Materials
  - Project Goals
  - Project Agenda
  - Hannahville Water Budget Investigation - Intro Presentation
  - GIS Map: Hannahville Land Use
  - GIS Map: Depas Tributary Land Use
  - GIS Map: Study Area & Stream Sampling Sites
  - Research Based Curriculum and Learning Progressions & supplemental curricular items - hardcopies

- Student Products

- Hannahville Water Budget - final group product - hard copy + final calculations
- Students Individual Field Notebooks & Compilation of Products from each experience
- KidZone Summer Program Youth Developed Lesson Plans*
- Youth Developed Hydrological Videos for community showcase

- Hydrological data sets that were collected in collaboration with Hannahville Youth through the 2013-2015 period. The data collection was designed & initiated in 2013 with Summer Youth Employees. The samples include: Snow Samples, Isotope Samples, Level Logger in Depas Tributary, Seismic Refraction and Weather Data

3.1.3 Results

3.1.3.1 Pre/Post Survey

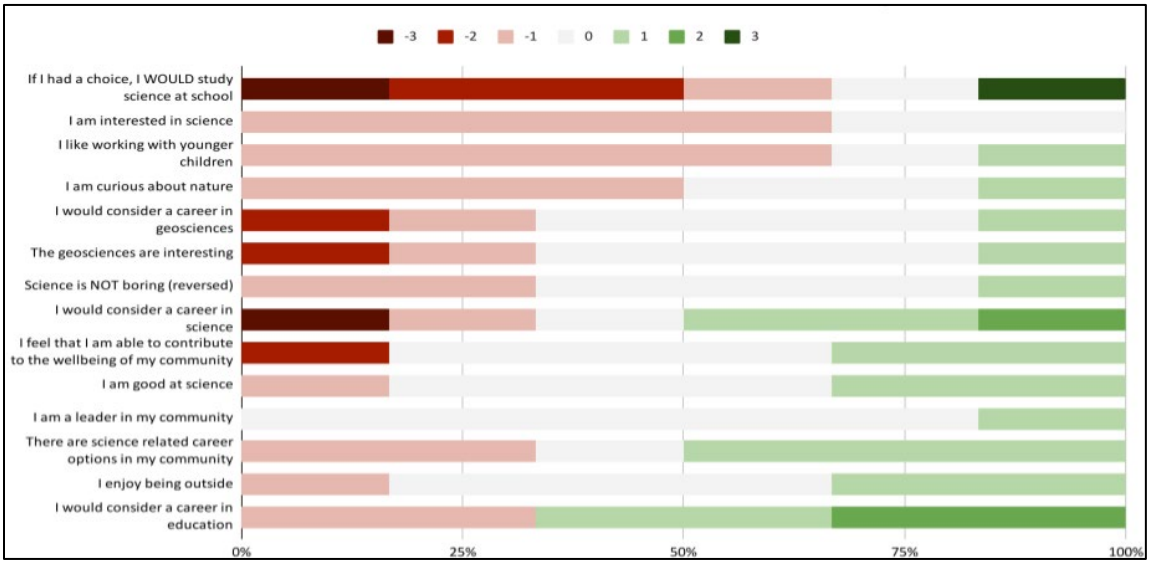


Figure s3.1. Displays the change in response frequency related to science & career measures on the Hannahville Summer Youth Pre/Post Interest Survey

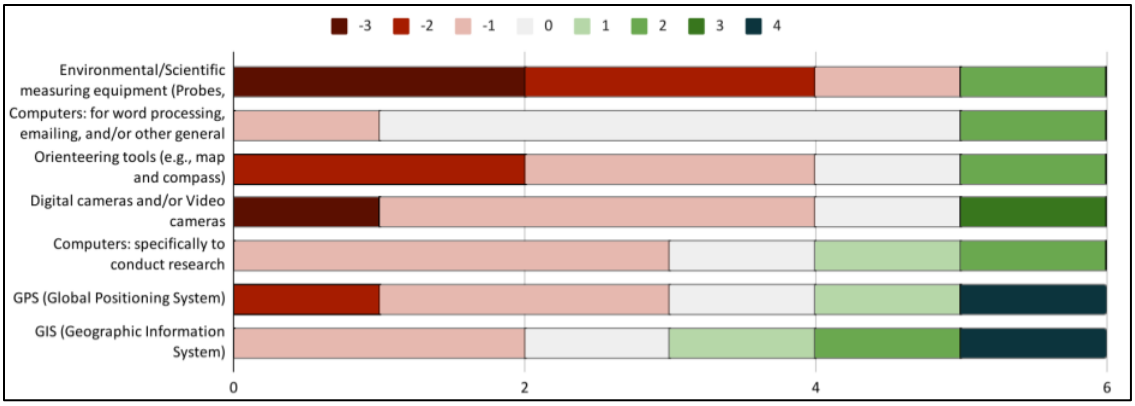


Figure s3.2. Displays the change in response frequency on test participants' confidence with technology skills that were collected as part of the Hannahville Summer Youth Pre/Post Interest Survey

Table s3.2. Displays the test group's effect size for each question that was part of the Pre/Post Content Test Results

Grouping	Question	Q#	Effect Size
Tree Question	A large tree can use 200 gallons of water a day. What happens to those 200 gallons? Please fill in the table below.	12-total	-0.72
Water Pathways	Your soccer game gets canceled at half time due to a massive downpour of rain. As you run for cover, you notice that there are large puddles forming on the grass covered playing field, but no puddles are forming in the sand covered playground just a few steps away. How does the water on the sandy playground get to where it's going?	5	-0.43
Tree Question	Tree Question. Like many rivers, the Ford River in northern Michigan has lots of large trees growing along its banks. What would happen to the amount of water in the river if all of the trees died or were cut down? Be sure to give reasons for your answer.	11	-0.3
Engineered Systems	Where does the water that is used in your school come from? Please explain how it gets to your school. Starting at the drinking fountain Trace back as many steps as you can.	13	-0.22
Watersheds	Which watershed is your community located in? Circle any that apply: Ford, Lake Superior, Great Lakes, Cedar, Lake Michigan, Mississippi, Menominee, Delta	17	0
Water Pathways	Please explain what happened to the amounts of evaporation and transpiration. Include the reasons why.	3	0.24
Water Pathways	Your school is considering replacing part of the school parking lot with an open space of grass and trees. Before the decision is made to do this, however, the potential impacts of this change on the water budget have to be considered. Which of the pie charts below best fits the change that would be most likely? (circle the best answer)	1	0.32
Water Pathways	Your soccer game gets canceled at half time due to a massive downpour of rain. As you run for cover, you notice that there are large puddles forming on the grass covered playing field, but no puddles are forming in the sand covered playground just a few steps away. 4. Why are there no puddles in the sandy playground? Where could the water landing on the sand be going?	4	0.34
Water Pathways	River Map. Can pollution in the river water at point B get to point C? (circle one) Yes No	7A	0.37
Substances & Water	A. If the playing fields were treated with fertilizer, do you think that some of the fertilizer could get into the river? If you think yes, describe how fertilizer could get into the river. If you think no, describe why fertilizer would not get into the river.	9B	0.48
Water Pathways	River Map. Can pollution in the river water at point B get to point C? Explain why or why not.	7B	0.53
Water Pathways	Please explain what happened to the amounts of infiltration and runoff. Include the reasons why.	2	0.55
Watersheds	Below are graphs of the annual streamflow data for the Manistique River (a) & the River Raisin (f). The image below shows their location in Michigan. Use the graphs to answer the question. What might cause these differences?	18B	0.58
Watersheds	Below are graphs of the annual streamflow data for the Manistique River (a) & the River Raisin (f). The image below shows their location in Michigan. Use the graphs to answer the question. How can these rivers continue to flow even if there has not been rain for several days?	18D	0.59
Substances & Water	If some of the fertilizer got into the river, how might the fertilizer affect the river water and living things in the river?	10	0.6

Water Pathways	The next week you come back to the soccer field and you notice there is no water on the grassy field. What happened to that water? Your soccer game gets canceled at half time due to a massive downpour of rain. As you run for cover, you notice that there are large puddles forming on the grass covered playing field, but no puddles are forming in the sand covered playground just a few steps away.	6	0.66
Engineered Systems	Where does the waste water from your school go? Please explain how it gets to where it is going. Starting at the drain, trace forward as many steps as you can.	14	0.73
Substances & Water	A. If the playing fields were treated with fertilizer, do you think that some of the fertilizer could get into the river? Circle Yes or No	9A	0.86
Watersheds	Below are graphs of the annual streamflow data for the Manistique River (a) & the River Raisin (f). The image below shows their location in Michigan. Use the graphs to answer the question. What differences in streamflow do you notice?	18A	0.89
Water Pathways	River Map. Draw an arrow showing the direction water is flowing away from point F. How do you know the water flows in this direction?	8	0.90
Watersheds	How would you describe what a watershed is to someone who has never heard of such a thing?	16	1.18
Engineered Systems	How does understanding the hydrology (movement of water through the landscape) allow a community to use their water resources sustainably?	15	1.21
Watersheds	Below are graphs of the annual streamflow data for the Manistique River (a) & the River Raisin (f). The image below shows their location in Michigan. Use the graphs to answer the question. Which graph is most like the Cedar River streamflow? Why?	18C	1.45

Table s3.3. Displays the test participants pre-post test scores by content grouping. These groupings included: Water Pathways, Watersheds, Substances & Water, Engineered Systems, and Water Movement within Trees.

Groupings	Total # Questions	% Within Each Effect Size Range			
		> 0	0.24-.48	0.5 - 0.8	> 0.8
Water Pathways	9	11%	44%	33%	11%
Watersheds	6	17%	0%	33%	50%
Substances & Water	3	0%	33%	33%	33%
Engineered Systems	3	33%	0%	33%	33%
Water Movement Through Trees	2	100%	0%	0%	0%
Total	23	22%	22%	30%	26%

Results demonstrate that there was no effect on 22% of the questions, which were most prominently connected to water movement through tree grouping. Results show that there was a medium to large effect on more than half of the measures, with the highest effect in watersheds and engineered systems

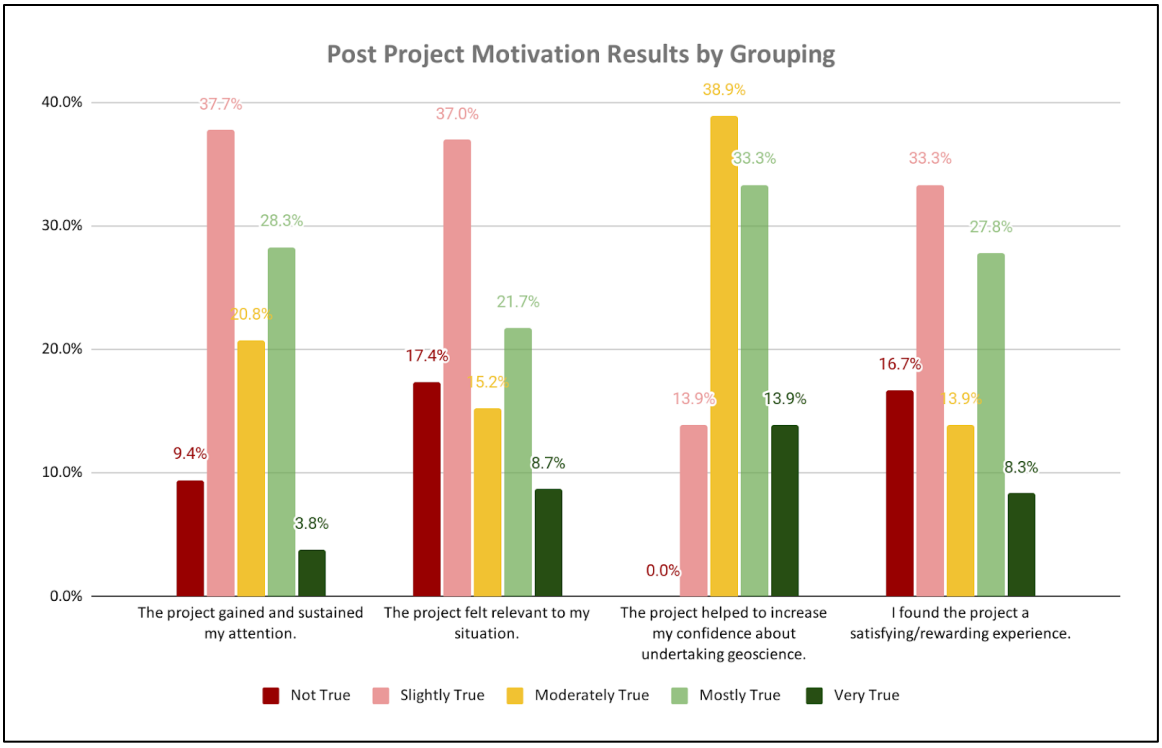


Figure s3.3. Post Motivation Survey (n=8, 100% completion) results by grouping (i.e., Attention, Relevance, Confidence, and Satisfaction)

The figure above shows that participants perceived that the project had the most positive effect on their confidence about undertaking geosciences (mean= 3.47, StDev=.91). With more mixed results in students' responses regarding attention, confidence and satisfaction.

Table s3.4. Displays the results to the Summer Youth Post- Project Motivational Survey

Grouping	**Attention**	**Relevant**	**Confidence**	**Satisfying**
Count	53	46	36	36
Mean Score	2.79	2.67	3.47	2.78
Std Dev	1.08	1.25	0.91	1.27
Not True	9%	17%	0%	17%
Slightly True	38%	37%	14%	33%
Moderately Ture	21%	15%	39%	14%
Mostly True	28%	22%	33%	28%
Very True	4%	9%	14%	8%

3.2 Fayette Historical State Park Interdisciplinary Lessons

Figure s3.4. Displays a Google Earth image of Fayette Historical State Park with the geosite locations that were part of the teacher workshop highlighted in red. Educators used this map, a compass and GPS unit to locate & complete each of the EarthCache-like lesson.

Table s3.4. Displays the title and guiding question for each of the geosites that the teachers visited during the teacher field-based workshop. The locations correspond to the red pins in Figure s3.4.

Geosite	Guiding Question
Big Bay de Noc	How have the differences in rock types along the shore of Big Bay De Noc lead to its formation?
The Backbone of the Great Lakes	How is the landscape here similar to Niagara Falls & Door County Wisconsin?
Life on the edge	How do living organisms interact with the geologic landscape?
Spider Cave	How were the many resources of the Garden Peninsula used to make iron?
Fayette's Natural Resources	How were the many resources of the Garden Peninsula used to make iron?
A Tropical Vacation	What evidence that these rocks were formed at the bottom of a tropical sea can do you observe?

3.2.1 Teacher Developed field day

3.2.1.1 Schedule of the students' Fayette field day

- 8:30 Depart Nah Tah Wahsh
- 10:00 Buses arrive
- 10:00- 10:25 bathrooms & break into groups
- 10:25- 10:30 walk to first stations
- 10:30- 1:30 30-minute sessions
- 5 Stations: small groups of students rotate through stations each session is 25 minutes each w 5 minute 'passing time' (see student groups and schedule below)
- Lunch (all group 30 minutes)
- 1:30 Depart Fayette
- 3:00 Arrive at Nah Tah Wahsh

Table s3.5. Displays the subject matter and topic for each of the five interdisciplinary lessons that the teacher-designed for their high school curriculum

	Content Connections	**Topics**
1	Culture/Language	Fayette, an Indigenous Perspective
2	Social Studies/ Music	The importance of music within present & past cultures
3	Health/Science	How are scientific practices and procedures determined to be either approved or unapproved?
4	Art/ELA	Photography and Descriptive Writing
5	Math/Building Trades	What is the importance of a slope on a roof system?

Figure s3.5. Google Earth image with locations of geosite lessons that students explored during the teacher-designed field-day.

3.2.2 Study Design

Non-experimental design. A case study research design was employed using methods similar to those described by Fraenkel, Wallen et al. 2012. A suite of instruments to measure each program goal. The instruments included surveys, semi-formal individual and group interviews, and archival content. The survey and interview data are based on teacher perception. All aspects of the project research were conducted in accordance with

protocols approved by the Michigan Tech Human Subjects Review Committee. All data collection was conducted as part of the regularly scheduled activities at Fayette Historical State park near Garden, Michigan or at the Nah Tah Wahsh School building in Hannahville, Michigan.

3.2.2.1 Survey

Fayette Survey Data was collected through a series of participant surveys, occurring at the beginning and end of the one-day field workshop, and after implementing the field experience with students. Surveys were designed to measure geoscience pedagogical and content knowledge, as well as participants' interest related to the program goals.

The surveys included a demographic questionnaire, Likert-like questions and open-ended questions. Likert-item questions were a series of four or more questions measuring the same single variable (i.e. skill, knowledge, etc.). Each Likert- type scale question asked teacher participants to indicate their agreement with items on a 5-point scale ranging from 1 (strongly disagree) to 5 (strongly agree).

The results of the survey were entered into excel. Tables and figures were developed from Likert-type questions to analyze any changes in response frequencies. Open-ended questions were coded and themes displayed in tables.

3.2.2.2 Artifact Analysis

The following documents were included as part of the

- PD day overview
- Workshop Experiences
    - Pre-Field Trip Slides
    - Field day Detailed Agenda Friday, October 11th – Rain or Shine!
    - Fayette EarthCaches
    - Teacher answers to logging questions - hard copy
- School-year Session agendas
    - GK12 PL Summary - needs light clean up
    - Session 1- Lesson 1: Place-Based Educational Adventures
    - Session 2- Field Explorations
    - Session 3- Selecting your collaborative interdisciplinary field exploration topic
    - Session 4- Develop Lesson Goals
    - Session 5- Develop the lesson plan
    - Session 6- Reflection
- Resources
    - Developing a Fayette Investigations Step-by-Step Guide
    - Developing Learning Objectives
    - Lesson Plan Development Guide
- Student Field Day Implementation
    - Fayette Field Day Schedule - draft

    - Fayette State Park Lesson Schedule and Student Schedules - May 14, 15, 16
- Teacher Lesson Plans
    - Fayette, an Indigenous Perspective
    - Photography and Descriptive Writing & Rubric
    - What is the importance of a slope on a roof system?
    - How are scientific practices and procedures determined to be either approved or unapproved?
    - Role of Music in today's society and at Fayette historical town
- Fayette Post Lesson Reflection
    - Fayette Post Lesson Reflection matrix
- Research Field Notes during visits to Nah Tah Wahsh
    - 2013: Nov 13, Nov 14
    - 2014: March 18, April 1, April 10

3.2.3 Results

Data from the Fayette State Park Project was collected through a series of participant surveys, occurring before and after the workshop, and after the field lesson implementation.

3.2.3.1 Fayette State Park Pre-Project Survey

The pre-workshop survey *(n=9, 100% completion)* was designed to collect demographic and background information and establish a baseline of participants' self-reported experience level with the workshop activities. The survey included both Likert-type Scale Questions and Open-ended questions. The results are displayed in the figures below.

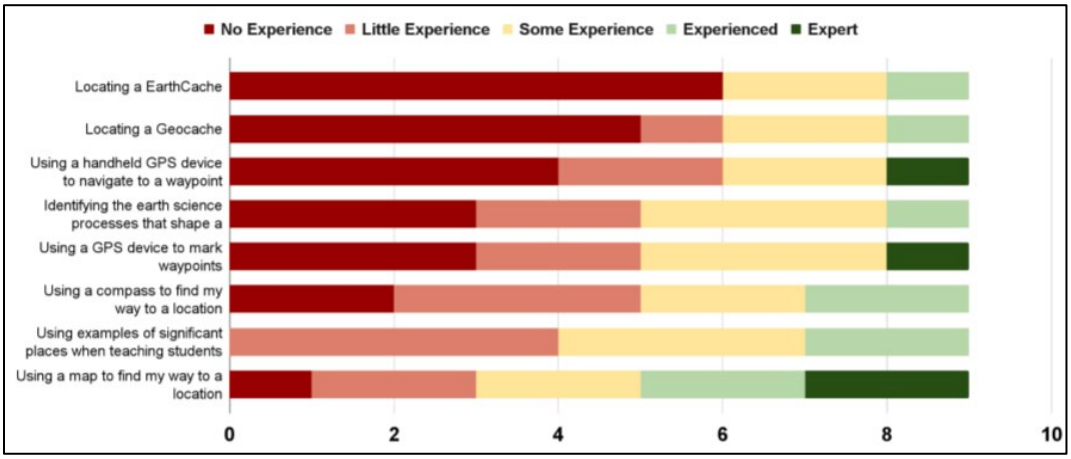


Figure s3.6 Displays the results from the Fayette State Park pre-workshop survey. result from Likert-type questions. ***Participants were asked to select the rating that best described how each statement related to them on a Likert-type scale from 1 to 5, with 1 being strongly disagreeing and 5 being strongly agreeing***

3.2.3.2 Fayette Post- Workshop Survey

The post workshop survey *(n=9, 100% completion) was* designed to measure participants' perceived PCK gains, as well as their feelings towards the strengths and weaknesses of the workshop to achieve its intended goals. The survey included both Likert-type scale questions and open-ended questions. The results are displayed in Figure s3.7 below.

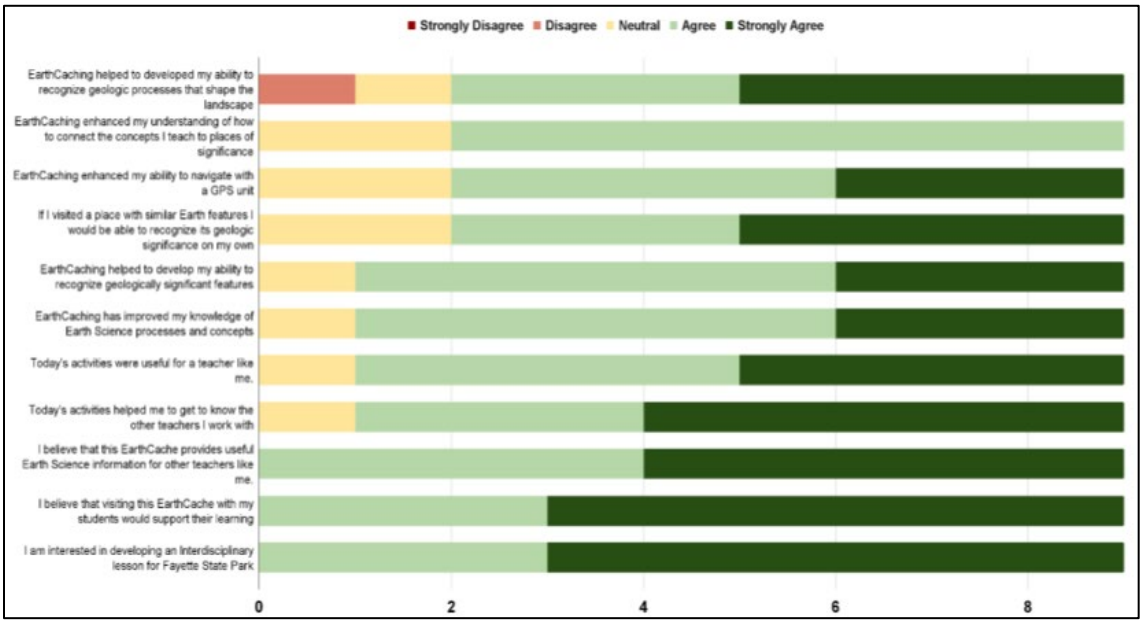


Figure s3.7. Displays the results to the Fayette Post-Workshop Survey Likert-type items. Workshop participants were asked to select the rating that best described how each statement related to them on a Likert-type scale from 1 to 5, with 1 being strongly disagree and 5 being strongly agreeing.

Figure s3.7 demonstrates that all of the Fayette Teacher Field Day field trips (100% agreed/strongly agreed) that they: Were Interested in developing an interdisciplinary lesson based on the Geoheritage site; Believed that the visiting the same sites would support student learning; Felt that the workshop activities provided useful Earth Science information for a teacher like themselves. There was strong agreement (89% agreed/strongly agreed, 11% neutral) that the field workshop activities: Supported them to get to know the other teachers they work with; Improved their knowledge of Earth Systems processes and concepts; Were useful for a teacher like themselves; Helped to develop their ability to recognized geologically significant features. There was relatively strong agreement (77% agreed/strongly agreed, 22% neutral) that the field workshop activities: If I visited a place with similar Earth features I would be able to recognize its geologic significance on my own; EarthCaching enhanced my ability to navigate with a GPS unit; EarthCaching enhanced my understanding of how to connect the concepts I teach to places of significance. The majority of participants agreed, there was a difference among some participants (77% agree/strongly agreed, 11% neutral, 11%disagree) that the

field workshop: helped to develop their ability to recognize geologic processes that shape the landscape.

Table s3.5. Displays the results from the open-ended questions on the Fayette Post Survey ***(n=9, 100% completion)***

What was the best thing(s) about todays' activities?			
Being outdoors or in the place (5)	Being with others/ Team Problem Solving (4)	Learning to use the GPS (2)	Being Active/ Moving (2)
What changes or suggestions do you have to make today's activities more useful for you?			
Pre-teaching how to use the GPS (4)		Question at students' level (2)	Less Reading (1)
Would you consider visiting an EarthCache site again? Yes (9) No (0) Why?			
To learn about the places around me (3)	To gain more knowledge (3)	It is fun/enjoyable (3)	Would like to do with students (2)
Would you consider doing an activity like EarthCaching with your students? Yes (8) No (1) Why or Why not?			
Good to connect students to nature/ feature/ real life (3)		Goof to get students moving (3)	New way to teach (1)
What other local places could you connect your curriculum to support student learning?			
Kitch-iti-kipi/Big Spring (4), Sugarloaf (2), Any outdoor/natural site (2), School Nature Trail (1), Lake Superior (1), Lac Flambeau (1)			
Other Comments			
Larger time block would be nice (1)	good team building (1)	enjoyable experience (3)	

Table s3.5 shows that teachers would repeat the learning activity again for several reasons including: To learn about the places around me (3), To gain more knowledge (3), It is fun/enjoyable (3) and they would like to do it with students (2). They also provided thoughts about other local places they could connect to their curriculum to support student learning including: Kitch-iti-kipi/Big Spring (4), Sugarloaf (2), Any outdoor/natural site (2), School Nature Trail (1), Lake Superior (1), Lac Flambeau (1). Responses provided a catalogue of their views of the best aspects of the field PD. These included: Being outdoors or in the place (5), Being with others/ Team Problem Solving (4), Learning to use the GPS (2), Being Active/ Moving (2).

3.2.4 Fayette Post- Project Survey

The post- project survey *(n=10, 100% completion) was* designed to measure participants' perceived PCK gains, as well as their feelings towards the strengths and weaknesses of support activities provided throughout the year at their ability to achieve their intended goals. The survey included both Likert-type scale questions and open-ended questions. The results are displayed in the figures below.

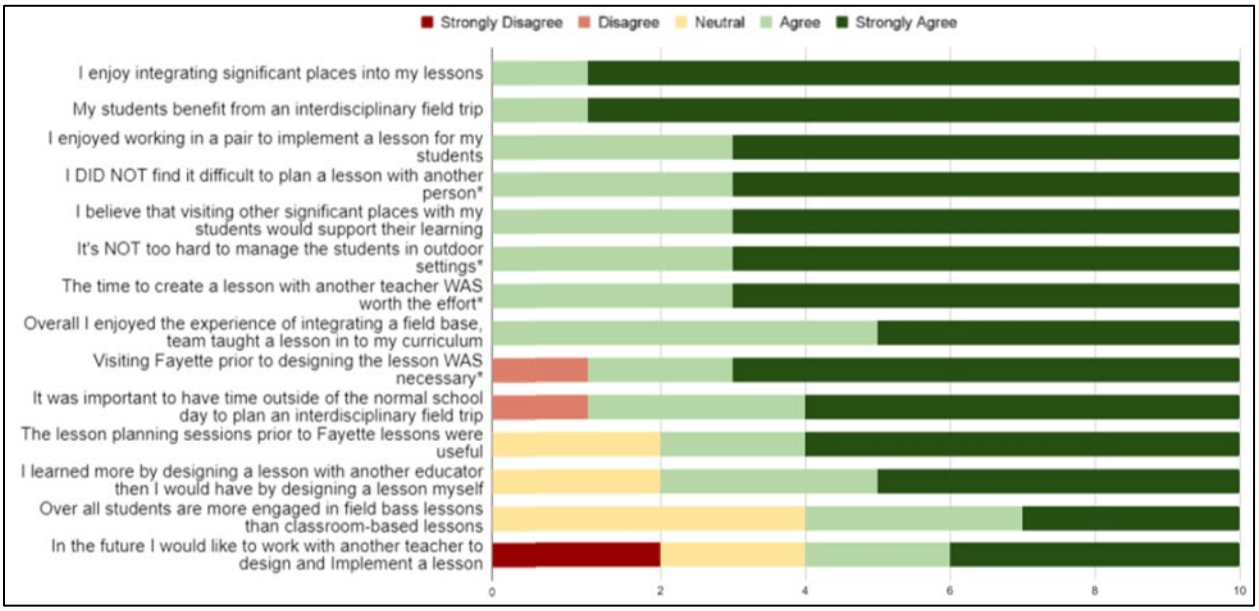


Figure s3.8. Displays the results from the Likert-type question results from the Fayette Post-Program Survey (N=10, 100%). Workshop participants were asked to select the rating that best described how each statement related to them on a Likert-type scale from 1 to 5, with 1 being strongly disagree and 5 being strongly agreeing.

Figure s3.8 demonstrate that all of the participants perceived (100% agreed/strongly agreed) that they: They enjoyed integrating significant places into my lessons; It's NOT too hard to manage the students in outdoor settings*; and that they believed that visiting other significant places with my students would support their learning. Figure s3.8: also shows that the P2 teachers' perception of the value of various program design elements: 100% agreement - The time to create a lesson with another teacher WAS worth the effort*; 90% agreement/10% disagreed that Visiting Fayette prior to designing the lesson WAS necessary*and It was important to have time outside of the normal school day to plan an interdisciplinary field trip. Figure s3.8 also demonstrates that all of the participants perceived (100% agreed/strongly agreed) that they: Overall, I enjoyed the experience of integrating a field base, team taught a lesson in to my curriculum and they enjoyed working in a pair to implement a lesson for my students; and that they DID NOT find it difficult to plan a lesson with another person*. There was a more varied response (60% agree,20% neutral, 20%strongly disagreed) that in the future I would like to work with another teacher to design and Implement a lesson. Lastly, Figure s3.8 also demonstrated that all of the participants perceived (100% agreed/strongly agreed) that they believed their students benefited from an interdisciplinary field trip. There was a

more neutral response (60% agree, 40% neutral) to whether "Over all students are more engaged in field bass lessons than classroom-based lessons". Perhaps this demonstrates that students were engaged in the associated classroom- based activities as well.

Table s3.6. Coded responses to each of the open-ended questions on the post-project survey are displayed on the table below (n=10, 100% completion rate).

What were the most beneficial aspects of the pre-field trip lesson planning sessions?		
Time to focus/ prepare was beneficial (7)	Working with fellow educators (3)	Visiting the significant place/ field location ahead of time (2)
How could the pre-field trip lesson planning sessions be improved?		
More one-on-one with partner teacher (3)	Provide food (1)	Visit field after some initial lesson planning (1)
More planning time / sessions (2) More time in the field (1)	Whole day vs. series of sessions (1)	Google Docs / share space (1)
In the future would you want to repeat the experience of planning and implementing a place paste, interdisciplinary lesson? Yes (10) No (0) Why?		
Great experience for students/ benefit/effective/fun/ greater learning learning/ teamwork (6)	Facilitator support / planning session lead to success (2)	Getting to know the staff as a new teacher (1)
Approach important - whole school/interdisciplinary/out of box (3)	Gain new understanding of students' capabilities (1)	

3.3 U.P. Geoheritage Field Investigations Summer 2014 - Spring 2015

During the first phase of the program, participants will engage in a summer field Institute where teachers spend 1-5 days in the field investigating earth science literacy principles NGSS scientific practices through the lens of Geoheritage sites including those which highlight past and present Earth System Interactions, such as: Kitch-iti-kipi Spring at Palms Brook State Park, the Niagara Escarpment at Fayette State Park, the Cedar River Watershed, glacial features within the Menominee Drumlin Field, Precambrian geology and historical mining activities in Marquette and Iron Mountain. These same places have been spiritually linked to Native Americans for thousands of years and now hold important educational examples for us today. Lessons will be co-facilitated by geoscience experts and Hannahville Indian community members. During the second phase teachers chose one of the Geoheritage examples visited during the field institute to integrate into their classroom curriculum. To support successful integration of place-based Geoheritage field investigations teachers engaged in several PD mini-workshops to develop an extended BSCS 5E lesson plan (Bybee, 2014). Additionally, one-on-one support was provided during the development and implementation of the Geoheritage field investigation into their classroom curriculum. After implementation teachers engaged in facilitated group discussions centered on perceived successes and challenges including field-based learning and relevant places into their classroom. “Geoheritage” is a generic but descriptive term applied to places or areas of geologic features with significant scientific, educational, cultural, or aesthetic value (Geological Society of America 2012).

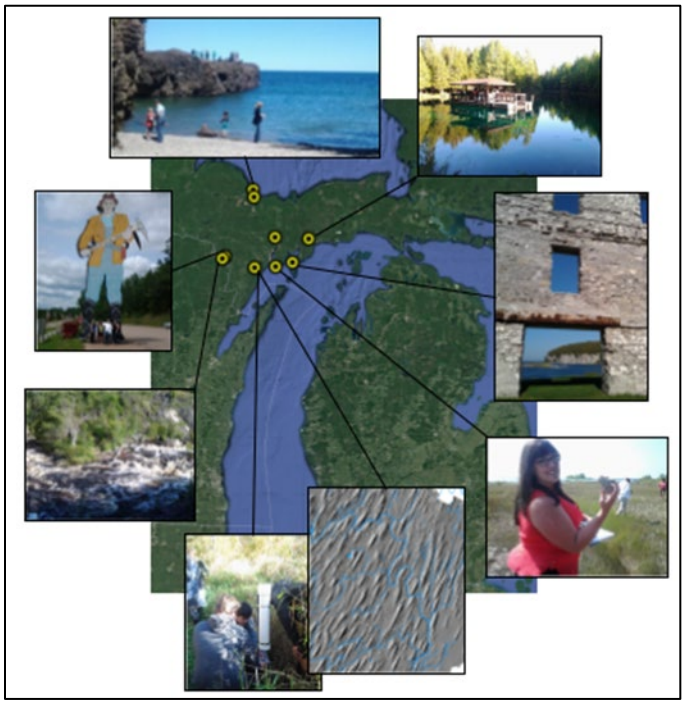


Figure s3.9. shows the locations of the geosites visited during the U.P. Geoheritage Field Investigations Summer Teach Course. The selected images were taking by E. Gochis in 2014 during field visits.

Workshop Agenda

- Day 1: Iron Mountain
  - Sturgeon River Dam
  - Vulcan iron mine
  - Piers Gorge
- Day 2: Hannahville- Earth Systems
  - Drumlin Field
  - Hannahville Trails - Micro-habitats; Invasive Species
  - Watershed - Depas vs Ford; Measure Discharge & Water Quality with Environmental Department
- Day 3: Marquette
  - Harvey: stromatolites, Kona Dolomite, Fault and Schist
  - Presque Isle: Jacobsville Sandstone, Unconformity, black rocks
- Day 4: Hannahville - Water Pathways
  - Water cycle activities
  - Visit the Water & Waste Water Treatment
  - Collect and Analysis data from the Depas Water Budget Study
- Big Bay De Noc
  - Kitch-iti-kipi Big Spring
  - Stonington Peninsula; Fossils

Table s3.3

Grade Level	Topics	Site(s)	Guiding Question(s)	N
4th	Earth Science	Peninsula Point, Stonington, MI	What can we learn about Delta County's past by looking at rocks and land formations? What evidence can we find to support the claim that once Michigan was covered by a sea?	13
6th	Life Sciences	Kitch-iti-kipi Spring/ Indian Lake	How can change in one part of the ecosystem affect change in other parts of the ecosystem?	10
7th	Physical Science	Kitch-iti-kipi Spring	Why does water at Kitch-iti-kipi Spring behave the way it does? Could the Source of the water at the Spring be from Lake Superior?	12
8th	Earth Science	Hannahville, Rapid River, Harvey & Marquette	How can rocks & earth materials provide evidence of Earth's history? Michigan's history?	13
11th	Chemistry	Depas Watershed; Hannahville, MI	How does scientist use stable isotope data in real-world situations?	8

3.3.1 Study Design

This project had a Non-experimental, Case Study design with the researcher acting as a research participant. The summer teacher workshop data was collected through participant response to a Sense of place survey and geoscience content test that was given at the beginning and end of the summer field workshop. Additional data was collected immediately following the summer course through a Post-Summer Course Motivation survey. Other data collections included group interviews with the select participant groups and participating teachers, and archival analysis of facilitator and student products and other artifacts. All data collection was conducted as part of the regularly scheduled activities with Hannahville Youth Service at the Nah Tah Wahsh School building in Hannahville, Michigan.

3.3.1.1 Pre/Post Sense of Place Survey

A pre-post survey was designed to measure changes in participants' place attached survey h Likert- type scale question asked teacher participants to indicate their agreement with various descriptions of the Upper Peninsula region. Each item was rated on a 5-point scale ranging from 1 (strongly disagree) to 5 (strongly agree). The results of the survey

were entered into excel. Tables and figures were developed from Likert-type questions to analyze any changes in response frequencies.

3.3.1.2 Post Motivation Survey

Additional data was collected immediately following the summer course through a Post-Summer Course Motivation survey. In the field of educational science, the ARCS Model of Motivational Design (Keller, 1983, 1987, b, c, 1999, 2010; Keller & Kopp, 1987) has been used myriad times to apply motivational strategies to instructional materials, and to test their effects. A Post-course Motivation survey (n= 6, 100% participation rate) was developed based on a Keller-like Instructional Materials Motivation Survey. The survey (located Instruments section) was administered at the end of the project to assess the motivational characteristics of the project. The survey used a 5-point Likert-like scale with 29 questions to measure the Attention, Relevance, Confidence, and Satisfaction (ARCS) model of motivation. Likert-like scale responses were converted into numerical codes (-2,-1,0,1,2) and were reported as mean scores with standard deviations by grouping. Each answer was recorded in excel. Tables and figures were developed from responses to the Likert-type questions in order to analyze any changes in response frequencies.

3.3.2 Pre/Post Content Test

A pre-post content test was designed to measure participants' understanding of general and regional specific geoscience content knowledge covering a wide-variety of topics including: knowledge of watersheds, hydrological processes in man-made and natural settings, earth systems interactions, geologic time, rock cycle & classification, plate tectonics, topographic and geologic maps, earth resources, and geologic cross sections as they relate to Upper Peninsula and Michigan geologic history. The test included both multiple choice and open-ended questions. Questions on the test were modified from an introductory level Michigan Technological University Geoscience course. Tables and figures were developed to display the results.

3.3.2.1 Group Interviews

Group interviews were conducted with all participants. Interviews were conducted by the researcher. The interview schedules were prepared as a result of the analysis of pre/post workshop surveys, student feedback and field observations. The interview was voluntary, lasting between 30-60 minutes. The dialogue was recorded then transcribed later for analysis. Analysis of the interview was conducted to better understand which teachers are more likely to benefit from this kind of program and any influence on teacher use of place-based pedagogy or earth science integration. The interview questions include:

- Describe your lesson objective and lesson plan for the other teachers
- Reflect on what went well and what modification you would make if you were to repeat this in the future
- How does this experience benefit your students?

- What would you change about the overall experience?
- Do you think this experience changed your motivation to teach Earth Science? Field Experiences?

3.3.2.2 Artifact Analysis

The following is the list of items that were included in the artifact analysis:

- Teacher Lesson Reflections
  - Conference Presentation
  - Analysis Process & Rubric Scores
- Teacher Summer Course
  - Course Flyer
  - MTU Course Topic Proposal
  - Agenda and Participants per day
- School-year Educator Support (Resources/Agendas)
  - Workshop Slides Aug 1, 2014
  - Lesson Portfolio Overview Instructions
  - Lesson Reflection Questionnaire
- Teacher Developed Student Field Experience - Implementation of Lessons in Geo-significant locations
  - 4th Grade: What can we learn about Delta County's past by looking at rocks and land formations? What evidence can we find to support the claim that once Michigan was covered by a sea? Peninsula Point, Stonington, MI
  - 6th grade: How can change in one part of the ecosystem affect change in other parts of the ecosystem? Kitch-iti-kipi Spring/Indian Lake
  - 7th grade: Why does water at Kitch-iti-kipi Spring behave the way it does? Could the Source of the water at the Spring be from Lake Superior? Kitch-iti-kipi Spring/Indian Lake (student worksheet)
  - 8th grade: How can rocks & earth materials provide evidence of Earth's history? Michigan's history? Hannahville, Rapid River, Harvey & Marquette
  - 11th grade: How do scientists use stable isotope data in real-world situations? Depas Watershed; Hannahville, MI
- Other
  - *Teacher Presentations at MSTA*
    - MSTA Geo Rocks - MSTA 2015
    - Spring into Hands on Learning - MSTA 2015
  - Professional Conference Presentations
    - EXPLORING GEOHERITAGE SITES INTERDISCIPLINARY INVESTIGATIONSs - 2015 GSA NC Regional
    - MSGC Conference 2016 Increasing K12 Student Engagement in Earth System Science through Collaboratively Developed Interdisciplinary Investigations of Geoheritage and Community
- Authentic Research Projects

- Kitch-iti-kipi Spring
- Depas Creek Tributary
- Stable Isotopes
- Shallow Geophysics Techniques

- Researcher Field Notes
  - 2014: Oct 6, Oct 7, Oct 09, Oct 13, Nov 19, Nov 20, Dec 3

3.3.3 Results

3.3.3.1 Pre - Post Summer Workshop Content Test

Participants who complete the full five-day portion of the summer workshop completed a pre and post content test.

Table s3.10. Displays the result Pre and Post Content Test UP Geoheritage Field Course. Only teachers participating in the five-day course participated.

Participant	Pre-Test % correct	Post-Test % correct	Difference
1	66%	76%	+10.3%
2	72%	93%	+20.7%
3	27%	47%	+20.0%

Table s3.11. Displays the participants' change in response rate from the U.P. Geoheritage Summer Field Course Pre-Post Test.

What type of plate boundary has Michigan experienced in the past? Convergent; Divergent; Transform; Convergent & Divergent Only; All of the above; None of the above	+2
Which of the following sources of energy is the most important for driving earth's weather systems? Wind; The sun; Biomass; Radioactive decay	+1
The natural release of carbon from limestone reservoirs into the atmosphere is most often accomplished by the: Abrasion by wind-blown sands; Destruction by lichens & microorganisms; Formation of stalagmites and stalactites; Chemical reaction between limestone and rainwater	+1
The diagram below explains how photosynthetic cyanobacteria could have produced O2 as a waste product of photosynthesis and then the free oxygen would combine with the iron ions to form magnetite (Fe3)4). Which of the following Proterozoic rocks in the UP does this theory explain? Jacobsville Sandstone; Banded Iron Formation; Fossiliferous Limestone; Kona Dolomite	+1
An igneous rock with a coarse-grained (phaneritic) texture cooled: very fast; fast; slowly	+1
An unconformity is: a sedimentary layer; a crack in the rock; a time gap in the geologic sequence of events; a radiometric anomaly	+1
The Principle of ____allows one to determine the relative age of a: original horizontality; superposition; lateral continuity; fossil succession	+1
An ore deposit is: a large deposit of any mineral; a mineral deposit that can be mined at a profit; a rock with any concentration of normally valuable minerals	+1
A city located on the coast of Michigan has warmer winters and cooler summers than a city at the same elevation and latitude located near the center of Michigan. Which statement best explains the difference between the cities' climates?	+1

The block diagram below represents the drainage basins of some river systems separated by highland divides, shown with dashed lines. The arrows show the directions of surface-water flow. The three areas separated by highland divides are called: Meanders; watersheds; floodplains; tributaries	+1
Igneous rocks form by: lithification of sediment; solidification of magma; solid state textural or mineralogical alteration of existing rocks; precipitation of seawater	-1
The topographic map below shows the largest island of the Hawaiian Islands. Which map below best shows the most likely stream drainage pattern of this island? a, b, c, d	-1

Results of the pre-posttest show that all participants who participated in the full workshop scored at least 10% higher on the post-course test than on the pre-course test. There were two questions in which a participant scored higher on the pre-test than on the post-test. The questions in which participants improved were directly related to Michigan's geologic history and the content covered in the course related to the geo-significant locations that were visited. The participants who participated in 1 or 2 days of the course did not take the pre/ post-test so there is no way to measure what effect the course had on their content knowledge.

3.3.3.2 Pre– Post Summer Workshop Sense of Place Survey

Immediately before and after the summer field course, participants were asked to rate their agreement with a series of Sense of Place statements based on the following Likert-type scale: 1=strongly disagree, 2=disagree, 3= no opinion, 4= agree, 5=strongly agree.

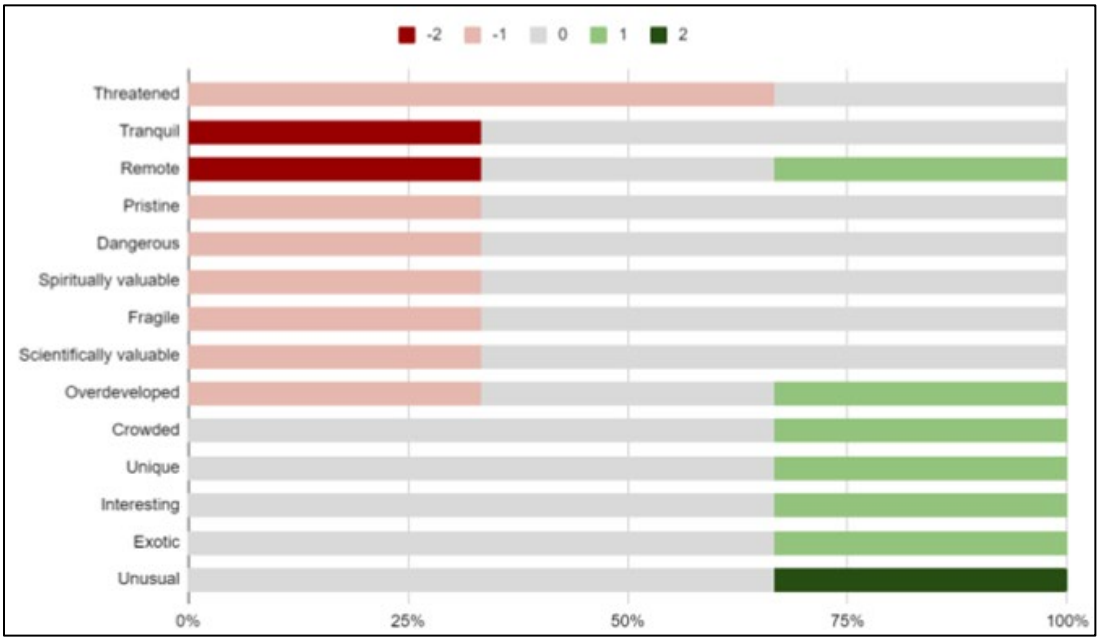


Figure s3.10. Display the magnitude and direction of changes in participant answers between the pre-& post- Place Attachment survey. Results with no change between pre and post surveys were: ancient, ecologically important, fun, scenic, beautiful, important for Native American culture, and wilderness.

3.3.3.3 Post Summer Course Motivation Survey

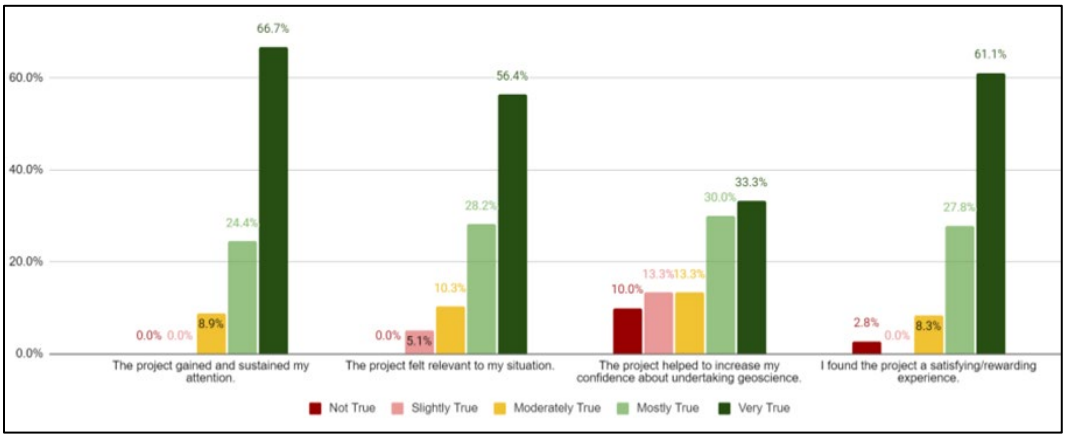


Figure s3.11. Displays the results from the Post Summer Course Motivation Survey. This instrument was given to all participants, including those that did not attend all five days of the workshop.

All summer field course participants completed the post project motivation survey (n=6, 100% completion). Results, shown in Figure s3.11 demonstrated that the majority of participants perceived that the field course gained and sustained their attention, that they found the course to be a satisfying or rewarding experience and the course was relevant to their situation. Results were much more mixed in their perceptions that the course helped to increase their confidence in geosciences. In figures s3.12 and s3.13, the results have been separated into two distinct sets, those participating in only 2 days (n=3) versus participants that participated in the full 5-day course (n=3). While confidence ratings are still lower in the 5day group than in the attention, relevance, confidence or satisfaction groupings, the results are much stronger than in the 2-day group. The results from the 2-day group demonstrate more limited confidence ratings and somewhat lower satisfaction experiences.

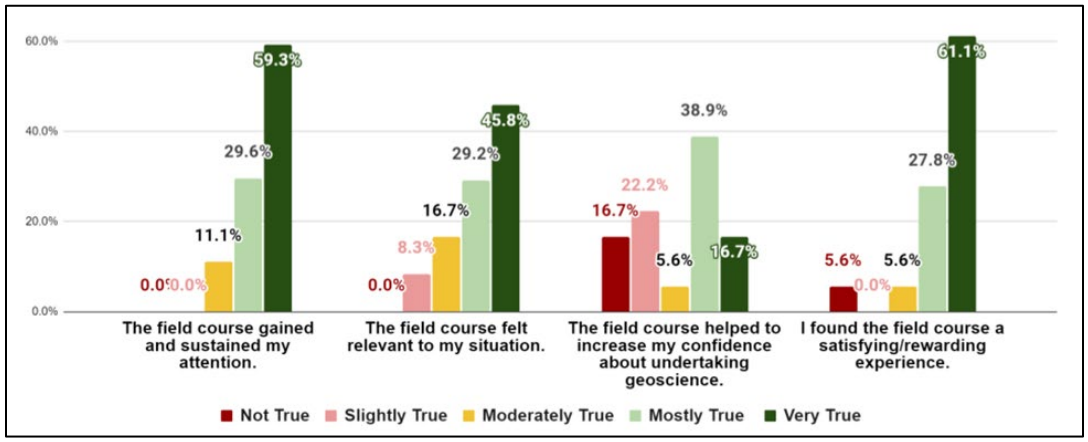


Figure s3.12. Displays the results from the Post Summer Course Motivation Survey for the participants that participated in only two of the five days of the summer workshop.

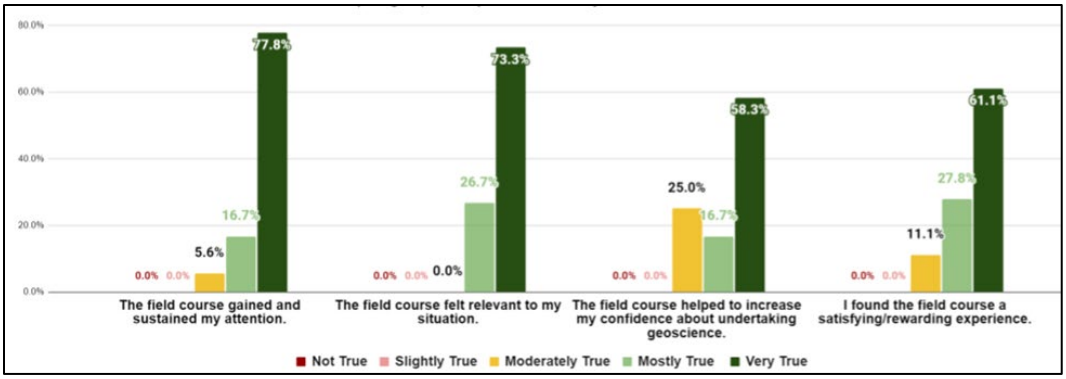


Figure s3.13. Displays the results from the Post Summer Course Motivation Survey for the participants that participated in all five days of the summer workshop.

Table s3.12. Results from the Post Summer Field Course Motivation Survey: Frequency distribution of each individual survey item.

Post Motivation Survey Item	Not True	Slightly True	Mod. True	Mostly True	Very True
I enjoyed this field workshop enough to do something similar next summer.	0%	0%	0%	33%	67%
This field workshop gained & sustained my attention.	0%	0%	0%	50%	50%
The quality of this field workshop helped to hold my attention.	0%	0%	0%	50%	50%
The way the field workshop was designed helped to keep my attention.	0%	0%	17%	50%	33%
I learned something surprising or unexpected working on this field workshop	0%	0%	0%	33%	67%
The variety of activities during the field workshop helped to keep my attention.	0%	0%	33%	17%	50%
The field workshop was NOT dry and unappealing.	0%	0%	0%	0%	100%
The amount of repetition for this workshop DID NOT cause me to get bored sometimes.	0%	0%	0%	50%	50%
This field workshop was NOT boring	0%	0%	0%	0%	100%
The technology used during this field workshop was frustrating/irritating.	0%	0%	50%	0%	50%
When I first heard about this field workshop, I had the impression that it would be easy.	50%	17%	33%	0%	0%
As I progressed through the workshop, I felt more confident that I could learn the content.	0%	0%	17%	50%	33%
I feel confident that I did well in this field workshop.	0%	17%	0%	50%	33%
I understand the material that was covered during the field workshop	17%	0%	33%	33%	17%
The field workshop was NOT too difficult	0%	17%	0%	0%	83%
There was so much information that it was hard for me to pick out the important points.	0%	17%	17%	50%	17%
It is clear to me how this field workshop is related to things I already know.	0%	33%	17%	17%	33%
Successfully completing this field workshop was important to me.	0%	0%	17%	33%	50%
The field workshop was relevant to my needs and interests.	0%	0%	17%	33%	50%
It is already apparent to me how people use the knowledge in this field workshop.	0%	0%	0%	83%	0%
The contents of this field workshop are worth knowing.	0%	0%	0%	17%	83%
I am able to relate the contents to things I have seen, done or thought about in my own life	0%	0%	17%	33%	50%
The assignments during this field workshop are useful to me and are worth completing.	0%	17%	0%	50%	33%
This workshop IS relevant to my needs because I DID NOT already know most of it.	0%	0%	0%	17%	83%
Completing this field workshop will give me a satisfying feeling of accomplishment.	0%	0%	33%	17%	50%
I enjoyed this field workshop so much that I would like to know more about the topic.	0%	0%	0%	33%	67%
I enjoyed working on this field workshop.	0%	0%	0%	50%	50%
I feel that I got recognition of my work by the means of comments and other feedback.	17%	0%	17%	33%	33%
The gains from this workshop are worth the effort that I am putting into the field workshop.	0%	0%	0%	33%	67%
There were NOT too many activities during that I felt weren't worth completing.	0%	0%	0%	0%	100%

Table s3.13. Displays the coded results from the open-ended questions on the U.P. Geoheritage Post Survey (n=9, 100% completion)

What was the most beneficial aspect(s) of this course for you?		
participating in hands on/discussion/field (2)	Being in the field (3)	Being with Peers (2)
familiar with regional geologically significant places (3)	Learning to 'read the landscape' (1)	Experience in Place-Based Inquiry (1)
What suggestion would you make to improve this course?		
Build on prior knowledge of the participants (1)	more time /longer day (2)	move technical session earlier in the day (2)
overwhelming because of lack of background (2)	continue it! (1)	provide more detailed class syllabus (1)
Not as many days (1)		Gear towards elementary (1)
Would you be interested in participating in something like this again? Yes (6) **Why or why not?**		
To visit more regional places & learn the geology (1)		To do field work (1)
To learn new ways to teach students outdoors (1)		To gain knowledge (2)

3.4 Artifact Analysis Summary

Data collection: Throughout the project field observations and unstructured interviews were conducted. In 2012 the PI began the study by spending time observing what was occurring in the school, mainly the high school science classroom. Unstructured interviews were conducted with students and staff, to confirm the interpretation of needs and cultural context. Written notes were documented during or immediately after the observation and interview as written notes, with interpretation notes occurring later. From 2013- 2015, further observations and informal interviews were conducted throughout the 4th-12th grade community with a wide range of participants. Samples of the participants and wider school community were involved in discussion of findings to verify initial and ongoing analyses.

Analysis of Documents, Artifacts and Field Notes: Documents developed by the participants, such as instructional plans, field-based learning artifacts and their students' work, were collected and analyzed (see each project within this supplemental document for complete information). Additionally, field notes from classroom observations and open-ended unstructured interviews with students, staff and community partners were collected throughout the project. Content analysis was conducted on the collected materials and field notes.

The Geosites Integration Matrix was designed to systematically identify, analyze and rate the strength of the project at meeting its goals, as observed within the collected materials. The rubric as developed based on existing rubrics or reference materials wherever possible. The NGSS Disciplinary Core Ideas (DCIs) for Earth and Space Science (NGSS, 2013) and the Earth Science Literacy Principles (ELSP, 2009) were consulted to inform elements relevant to the geoscience content. Additionally, the NGSS (NGSS, 2013) were consulted to incorporate elements necessary for evaluating how science and engineering practices (SEPs) scientific crosscutting concepts, including nature of science, were integrated into learning experiences. Geoheritage research informed the elements of the similarly named category, to consider the mode in which the geosites were connected to educational and cultural aspects of learning that lead to increased knowledge and sense of place (Groat, 1995; Casey, 2001; Semken, 2008). The Guiding principles for exemplary place-based stewardship education (Great Lakes Stewardship Initiative, 2016) informed elements of the pedagogies of place-based education.

Each project was scored separately. The resources were reviewed, focusing on one criterion at a time. The results were based on only observable data demonstrated within the products or other artifacts. Evidence and criterion were noted a spreadsheet, along with a written statement describing the reasoning for the rating. The Geosites Integration Matrix (see main dissertation section X) was created to display the rating for each project's professional development (PD) experiences separately from the student experiences. Project 1, summer youth, classroom experiences are not provided because there were not enough artifacts collected during the youth assistance classroom lesson plan implementation to provide adequate detail for analysis. Project 2, Fayette, student experiences were rated as a single experience because all students from multiple grade

levels participated in all of the teacher-developed experiences. Whereas in project 3, U.P. Geoheritage, each of the 5 student experiences was scored separately because students only participated in a single teacher-designed lesson. When the lesson's rating for a criterion varied in project 3, the range is demonstrated with two circles connected by a line with two **. Whereas when the classroom lessons were similar in rating, however there were significant differences within the criteria, the range is demonstrated with two circles connected by a line with a single *. ** indicates differences between projects * indicates differences between indicators that are consistent between projects

3.5 Instruments: Summer Youth KidZone

3.5.1 Background & Interest Pre- Survey

- Name: _____
- Birth Year: _____
- Expected Grade Level next year: _____
- Number of Years working with Kid Zone:
- youth employment:
- How would you describe your overall interests in science, the environment and outreach activities? Select Not True, Slightly True, Moderately True, Mostly True, Very True for each of the following statements:
    - I am interested in science
    - I am good at science
    - Science is boring
    - If I had a choice, I would not study science at school.
    - I would consider a career in science
    - The geosciences are interesting
    - I would consider a career in geosciences
    - There are science related career options in my community
    - I am a leader in my community
    - I feel that I am able to contribute to the wellbeing of my community
    - I enjoy being outside
    - I am curious about nature
    - I would consider a career in education
    - I like working with younger children

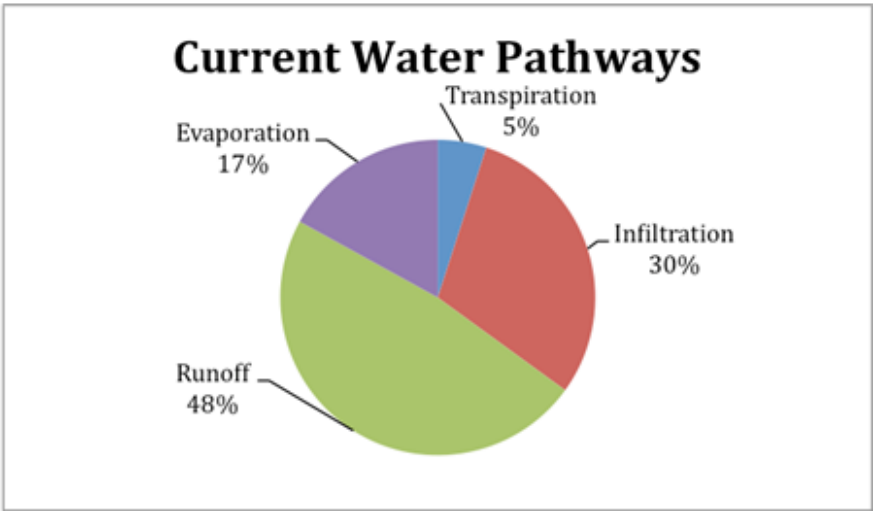
- How would you describe your exposure to science? How much science have you done through the following situations? Select None/Never 1 or 2, times/classes or 4, times/classes 5 or 6, times/classes as often as, possible for each of the following activities
    - Courses in School
    - Research Project in School
    - Science Fair
    - Independent Exploration
    - After-school or summer programs
    - Through television or internet

- How confident do you feel with using the following specific technologies? Not Confident, Slightly Confident, Moderately Confident, Mostly Confident, Very Confident, I have never used this
    - Computers: for word processing, emailing, and/or other general functions
    - Computers: specifically, to conduct research
    - GPS (Global Positioning System)
    - GIS (Geographic Information System)
    - Digital cameras and/or Video cameras
    - Environmental/Scientific measuring equipment (Probes, Weather Stations, laboratory, etc.)
    - Orienteering tools (e.g., map and compass)
- Briefly describe your educational plans. How far do you plan to go through school?
- What are your career goals and plans?
- How would you describe your research experience and skills?
- Have you ever conducted field research? If so, what did you do with the results of your research?
- Internet or library research? If so, what did you do with the results of your research?
- What is your experience with presenting research findings?
- Have you worked with others in a teaching or mentoring setting (for example, through kid zone, 4-H or scouting) where you served as a teacher or leader?
- Is teaching or mentoring something you would like to pursue?

3.5.2 Pre/Post Knowledge Test: Hannahville KidZone Water Investigations & Outreach

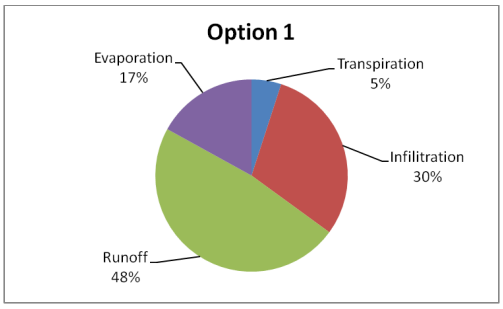
Water Pathways

The pie chart below describes where water goes on your school grounds when it rains.

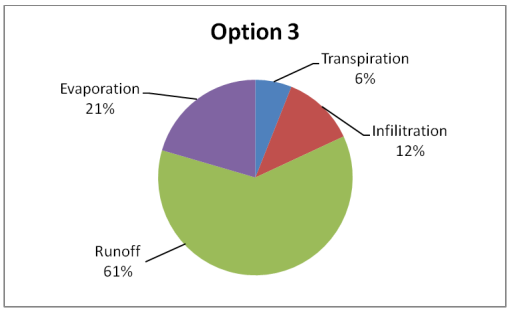


1. Your school is considering replacing part of the school parking lot with an open space of grass and trees. Before the decision is made to do this, however, the potential impacts of this change on the water budget have to be considered. Which of the pie charts below best fits the change that would be most likely? (circle the best answer)

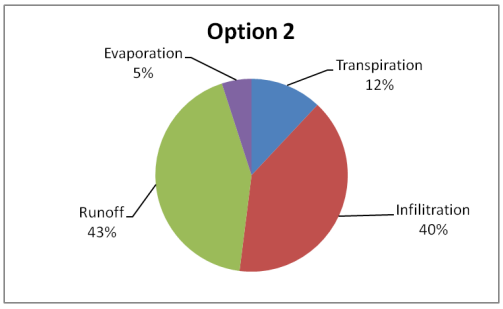
A



C



B



2. Please explain what happened to the amounts of infiltration and runoff. Include the reasons why.

3. Please explain what happened to the amounts of evaporation and transpiration. Include the reasons why.

Soccer Game Questions

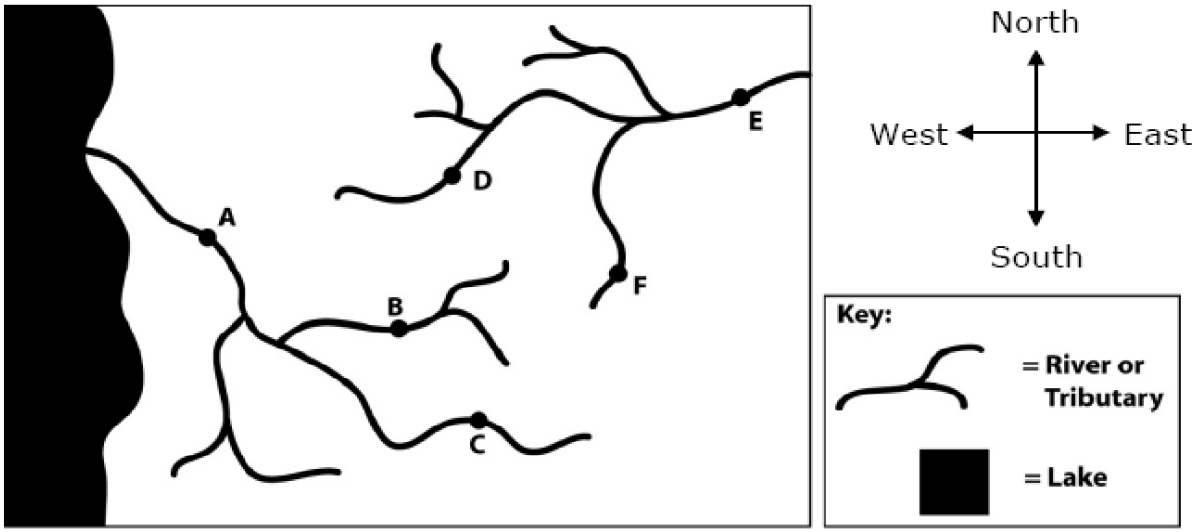
Your soccer game gets canceled at half time due to a massive downpour of rain. As you run for cover, you notice that there are large puddles forming on the grass covered playing field, but no puddles are forming in the sand covered playground just a few steps away.

4. Why are there no puddles in the sandy playground? Where could the water landing on the sand be going?

5. How does the water on the sandy playground get to where it's going?
6. The next week you come back to the soccer field and you notice there is no water on the grassy field. What happened to that water?

River Map

Use the map below to answer questions 7 and 8.



7. Can pollution in the river water at point B get to point C? (circle one): **Yes, No**
Explain why or why not.
8. Draw an arrow showing the direction water is flowing away from point **F**. How do you know the water flows in this direction?

Substances & Water

The picture below shows part of a school campus with several grassy playing fields near a river. Use the picture to answer questions 9, 10 and 11.

9. A. If the playing fields were treated with fertilizer, do you think that some of the fertilizer could get into the river?

(Circle one) YES NO

If you think yes, describe how fertilizer could get into the river. If you think no, describe why fertilizer would not get into the river.

10. If some of the fertilizer got into the river, how might the fertilizer affect the river water and living things in the river?

Tree Questions

Like many rivers, the Ford River in northern Michigan has lots of large trees growing along its banks.

11. What would happen to the amount of water in the river if all of the trees died or were cut down? Be sure to give reasons for your answer.

12. A large tree can use 200 gallons of water a day. What happens to those 200 gallons? Please fill in the table below.

List one place the water could go and explain how it gets there.	How much of the water that the tree uses would go there? All Most Half A little
List a second place the water could go and explain how it gets there.	How much of the water that the tree uses would go there? All Most Half A little
List a third place the water could go and explain how it gets there.	How much of the water that the tree uses would go there? All Most Half A little

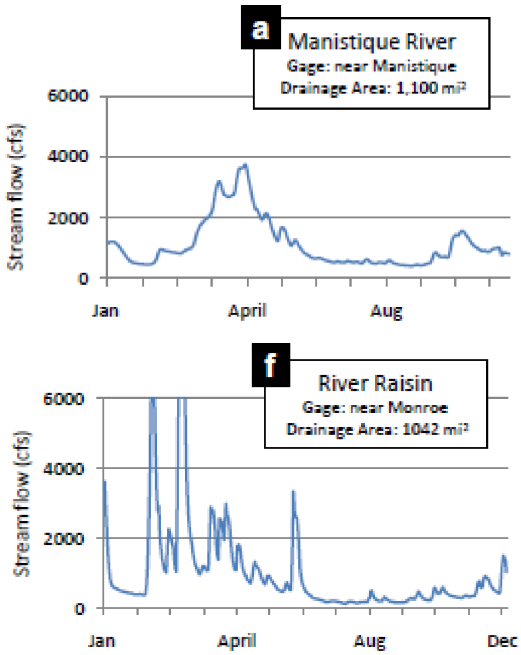
Engineered Systems

14. Where does the water that is used in your school come from? Please explain how it gets to your school. Starting at the drinking fountain Trace back as many steps as you can.
15. Where does the waste water from your school go? Please explain how it gets to where it is going. Starting at the drain, trace forward as many steps as you can.
16. How does understanding the hydrology (movement of water through the landscape) allow a community to use their water resources sustainably?

Watersheds

17.How would you describe what a watershed is to someone who has never heard of such a thing?
18. Which watershed is your community located in? Circle any that apply: Ford, Lake Superior, Great Lakes, Cedar, Lake Michigan, Mississippi, Menominee, Delta

19. Below are graphs of the annual streamflow data for the Manistique River (a) & the River Raisin (f). The image below shows their location in Michigan. Use the graphs to answer the question.



a. What differences in streamflow do you notice?
b. What might cause these differences?
c. Which graph is most like the Cedar River streamflow? Why?
d. How can these rivers continue to flow even if there has not been rain for several days?

3.5.3 Background & Interest Post- Survey

- How would you describe your overall interests in science, the environment and outreach activities? Select Not True, Slightly True, Moderately True, Mostly True, Very True for each of the following statements:
    - I am interested in science
    - I am good at science
    - Science is boring
    - If I had a choice, I would not study science at school.
    - I would consider a career in science
    - The geosciences are interesting
    - I would consider a career in geosciences
    - There are science related career options in my community
    - I am a leader in my community
    - I feel that I am able to contribute to the wellbeing of my community
    - I enjoy being outside
    - I am curious about nature
    - I would consider a career in education
    - I like working with younger children
- Briefly describe your educational plans. How far do you plan to go through school?
- What are your career goals and plans?
- Is teaching or mentoring something you would like to pursue? Why or Why not?
- How would you describe your research experience and skills?
- How confident do you feel with using the following specific technologies? Not Confident, Slightly Confident, Moderately Confident, Mostly Confident, Very Confident, I have never used this

    - Computers: for word processing, emailing, and/or other general functions
    - Computers: specifically, to conduct research
    - GPS (Global Positioning System)
    - GIS (Geographic Information System)
    - Digital cameras and/or Video cameras
    - Environmental/Scientific measuring equipment (Probes, Weather Stations, laboratory, etc.)
    - Orienteering tools (e.g., map and compass)

3.5.4 Student Focus Group Protocol Questions

1. What did you enjoy about this project? Why?
2. What was the most challenging about this project? Why?
3. What did you learn about the environment by participating in this project?
4. What did you learn about your community by participating in this project? (specifically related to resource management & science careers)
5. What skills (leadership, communication, research, technology, etc.) did you gain or improve by participating in this project?

6. How did working on this project change your idea about what it means to "do science"? Why?
7. How, if at all, did your work with Kid Zone and this project influence your future educational or career plans? Why?
8. What value does your work this summer provide for the community? Why?
9. How would you change this project so that it is more valuable to you? To the community?

3.5.5 Adult Interview Protocol Questions:

- What value, if any, did the students' work have to the understanding of
    1. the community's hydrology (movement of water through the landscape)?
    2. Sustainable resource management?
- Do you think that partnerships between the school and your department are mutually beneficial? Why or Why not?
- What types of scientific or educational investigations do you feel are of the greatest priority to the community?
- How would you describe the community's general level of understanding of natural resource management?

3.5.6 Post Course Interest Survey

Directions: There are 31 statements in this questionnaire. Please think about each statement in relation to the instructional materials you have just studied, and indicate how true it is. Give the answer that truly applies to you, and not what you would like to be true, or what you think others want to hear.

Think about each statement by itself and indicate how true it is (Not True, Slightly True, Moderately True, Mostly True, Very True). Do not be influenced by your answers to other statements. Check the box under the appropriate column.

- The instructor knows how to make us feel enthusiastic about the subject matter of this project.
- The things I am learning in this project will be useful to me.
- I feel confident that I will do well in this project.
- This project has very little that captures my attention.
- The instructor makes the subject matter of this project seem important.
- I have to work too hard to succeed in this project.
- I do NOT see how the content of this project relates to anything I already know.
- Whether or not I succeed in this project was up to me
- The subject matter of this project is just too difficult for me.
- I feel that this project gives me a lot of satisfaction.
- In this project, I try to set and achieve high standards of excellence.
- The students in this project seem curious about the subject matter.
- I enjoy working for this project.
- I feel satisfied with what I am getting from this project.

- The content of this project relates to my expectation and goals.
- The instructor uses an interesting variety of teaching techniques
- The students actively participate in this class.
- To accomplish my goals, it is important that I do well in this project.
- I do NOT think I will benefit much from this course
- Throughout the project, I have believed that I can succeed if I try hard enough
- The personal benefits to me are clear.
- My curiosity is often stimulated by the questions asked or the investigations given on the subject matter in this class
- I find the challenge level of this project to be about right: not too easy and not too hard
- I feel rather disappointed with this project.
- The amount of work I have to do for the project is appropriate.
- I get enough feedback to know how well I am doing.
- I am able to relate the contents of this project to things I have seen, done or thought about in my own life.
- By participating in this project, I feel more likely to consider college than before
- The benefits of this project to my community are clear.
- I would participate in a project like this again
- I would continue with this water investigation now that summer Kid Zone is over

Briefly describe your educational and career plans. How far do you plan to go through school? What are your career goals and plans?

3.6 Instruments: Fayette Historical State Park

3.6.1 Pre- Fayette Workshop Survey

Survey Purpose: This questionnaire is part of a pre/post survey will be used to investigate the experiences that educators have through EarthCaching. All information will be used for this purpose alone and are completely anonymous.

Directions: Please rate the amount of experience that you have with the following on a scale from 1 to 5, with 1 being NONE and 5 being Expert.

- Using a compass to find my way to a location
- Using a map to find my way to a location
- Using a handheld GPS device to navigate to a waypoint
- Using a GPS device to mark waypoints
- Locating a Geocache
- Locating an EarthCache
- Identifying the earth science processes that shape a feature/site
- Using examples of significant places when teaching students

Directions: *Please use the space provided to answers to the following:*

- What do you expect to get out of today's professional development session?
- What subjects do you teach?
- What grade level(s) do you teach?
- How long have you been teaching in your current position?
- How many years have you been teaching?
- Does your current curriculum include Earth Science curriculum? Yes No
- How many college level Science courses have you had?
    - None 1-5 6-10 11-15 > 15
- How many college level Earth Science courses have you had?
    - None 1-5 6-10 11-15 > 15

3.6.2 Post- Fayette Workshop Survey

Survey Purpose: This questionnaire is part of a pre/post survey will be used to investigate the experiences of science educators EarthCaching. All information will be used for this purpose alone and are completely anonymous.

Read each of the statements below & circle the rating that best describes how the *statement relates to you: Strongly Disagree, Somewhat Disagree, Neutral, Somewhat Agree, Strongly Agree*

- EarthCaching improved my ability to navigate using a compass
- EarthCaching improved my ability to navigate with a map
- EarthCaching enhanced my ability to navigate with a GPS unit
- EarthCaching helped to develop my ability to recognize geologically significant features
- EarthCaching helped to developed my ability to recognize geologic processes that shape the landscape
- EarthCaching enhanced my understanding of how to connect the concepts I teach to places of significance
- I have little experience visiting a place with this type of Earth feature
- If I visited a place with similar Earth features I would be able to recognize its geologic significance on my own
- EarthCaching has improved my knowledge of Earth Science processes and concepts
- I did NOT know that geologically significant places like this EarthCache existed in the state
- I believe that visiting this EarthCache with my students would support their learning
- I believe that this EarthCache provides useful Earth Science information for other teachers like me.
- Today's activities helped me to get to know the other teachers I work with
- Today's activities were useful for a teacher like me.
- I am interested in developing an Interdisciplinary lesson for Fayette State Park

- What was the best thing(s) about todays' activities?
- What changes or suggestions do you have to make today's activities more useful for you?
- Would you consider visiting an EarthCache site again? Why or Why not?
- Would you consider doing an activity like EarthCaching with your students? Why or Why not?
- What other local places could you connect your curriculum to local places to support student learning?
- Do you have any other comments?

3.6.3 Post- Fayette Lesson Survey

Survey Purpose: This questionnaire will be used to investigate the experiences that educators and students have by integrating a field-based, interdisciplinary lesson into their standards-based curriculum. All information will be used for this purpose alone and are completely anonymous.

Directions: Read each of the statements below & circle the rating that best describes how the statement relates to you. *Strongly Disagree, Somewhat Disagree, Neutral, Somewhat Agree, Strongly Agree*

- In the future I would like to work with another teacher to design and Implement a lesson
- I learned more by designing a lesson with another educator then I would have by designing a lesson myself
- I enjoy integrating significant places into my lessons
- The time to create a lesson with another teacher was NOT worth the effort
- I believe that my students are more motivated to learn when lessons include a field-based activity
- Over all students are more engaged in field bass lessons than classroom-based lessons
- It's too hard to manage the students in outdoor settings
- My students benefit from an interdisciplinary field trip
- The lesson planning sessions prior to Fayette lessons were useful
- Visiting fight Fayette prior to designing the lesson was not necessary
- It was important to have time outside of the normal school day to plan an interdisciplinary field trip
- I enjoyed working in a pair to implement a lesson for my students
- I found it difficult to plan a lesson with another person
- I believe that visiting other significant places with my students would support their learning
- Overall, I enjoyed the experience of integrating a field base, team taught a lesson in to my curriculum

Directions: Read the following questions carefully and write your answers in the spaces provided

- What were the most beneficial aspects of the pre-field trip lesson planning sessions?
- How could the pre-field trip lesson planning sessions be improved?
- In the future would you want to repeat the experience of planning and implementing a place paste, interdisciplinary lesson? Why or why not?

3.6.4 Post- Fayette Lesson Reflection

Fayette Observation

- Lesson Title:
- Day #:
- What evidence do you have of student understanding of the learning objectives?
- What type of student-student interactions did you observe?
- What type of student- teacher interactions did you observe?
- What misunderstandings or misconceptions did you observe?
- How did the students construct their understanding through the lesson activities?
- Additional thoughts or observations?
- What worked well? How? Why?
- What could be improved? How?

3.7 U.P. Geoheritage Field Investigations Pre/Post Course Survey:

3.7.1 Pre/post summer workshop: Part 1 Place Attachment Survey

*Directions: Please rate the statements below with the following scale:*1=strongly disagree, 2=disagree, 3= no opinion, 4= agree, 5=strongly agree.
The Upper Peninsula is:

- Ancient
- Ecologically important
- Pristine
- Fun
- Scenic
- Threatened
- Beautiful
- Crowded
- Remote
- Dangerous
- Unique
- Interesting
- Important to preserve
- Educational
- Authentic
- Tranquil

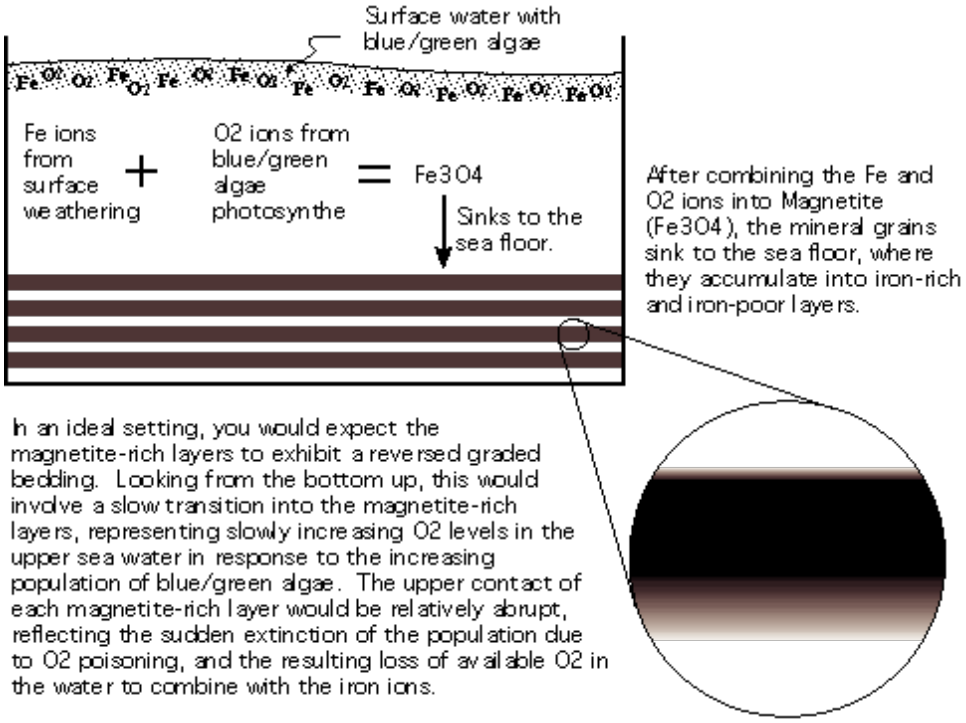
- Privilege to visit
- Spiritually valuable
- Relaxing
- Fragile
- Important for Native American culture
- Wilderness
- Overdeveloped
- Historical
- Exotic
- Unusual
- Adventurous
- Scientifically valuable
- Comfortable

3.7.2 Pre/post summer workshop Part 2: Content Test

Directions: For each of the following question, circle the best choice.

1) When limestone is slowly dissolved by groundwater flow creating conduits and caves, it is an interaction between which two spheres?
   - Geosphere and hydrosphere; Hydrosphere and atmosphere; Atmosphere and biosphere; Biosphere and geosphere
2) Which of the following sources of energy is the most important for driving earth's weather systems?
   - Wind; The sun; Biomass; Radioactive decay
3) A stream's discharge is _____.
   - The terminus where it enters another body of water; The source of the stream or the head waters; The process of returning water to its original source; The product of a stream's velocity and channel cross-sectional area
4) The natural release of carbon from limestone reservoirs into the atmosphere is **most** often accomplished by the _____.
   - Abrasion of the limestone by wind-blown sands; Destruction of limestone by lichens & microorganisms; Formation of stalagmites and stalactites in limestone caves; Chemical reaction between limestone and rainwater
5) Which of the following is the result of a continental collision orogeny?
   - Mt. St. Helens Volcano; Lake Superior; The Rocky Mountains; Iron Ore
6) What type of plate boundary has Michigan experienced in the past?
   - Convergent; Divergent; Transform; Convergent & Divergent Only; All of the above; None of the above;

7) What happens when groundwater, over a long period, is removed faster than the rate of natural recharge?
   - The water table drops; The streams flow year-round to make up for decreasing groundwater; The deepest wells go dry first and then the shallow wells go dry due to the lack of water; The land slightly rises; it rebounds without the weight of the water
8) Glacial rebound has shaped the Great Lakes primarily by:
   - Raising outlet elevations, thereby raising lake levels; Causing the whitefish river outlet to become abandoned in favor of the Mississippi river; Raising land near shorelines, thereby narrowing and Deeping the lake; All of the above
9) Which of the following radioactive dating techniques can be used to date the age of the earth itself?
   - Carbon-14; Uranium-235; Potassium-40; Radon-193
10) Which of the following can affect Earth's climate EXCEPT?
   - Volcanic eruptions, Living organism, Impact of extraterrestrial objects, All of the above

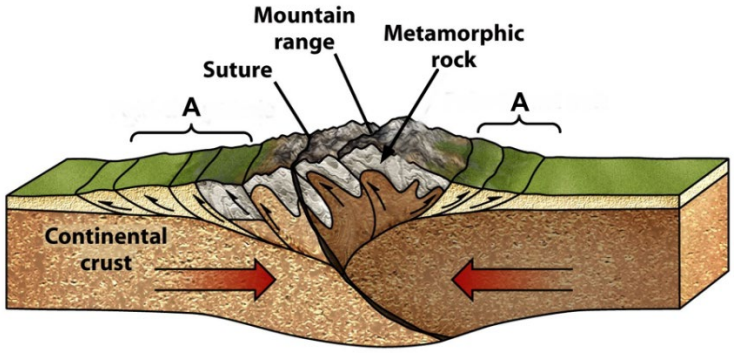


11) The diagram above explains how photosynthetic cyanobacteria could have produced O2 as a waste product of photosynthesis and then the free oxygen would combine with the iron ions to form magnetite (Fe3)4). Which of the following Proterozoic rocks in the UP does this theory explain?
   - Jacobsville Sandstone; Banded Iron Formation; Fossiliferous Limestone; Kona Dolomite
12) When water goes straight from snow or ice to water vapor it is called sublimation. Which two Earth spheres are involved in this type of movement?

- Geosphere and hydrosphere, Hydrosphere and atmosphere, Atmosphere and biosphere, Biosphere and geosphere

13) Igneous rocks form by:
- lithification of sediment; solidification of magma; solid state textural or mineralogical alteration of existing rocks; precipitation of seawater

14) An igneous rock with a coarse-grained (phaneritic) texture cooled
- very fast, fast, slowly



15) In the figure above, the plate tectonic setting is:
- convergent margin involving subduction; transform margin; convergent margin involving collision; divergent margin; hot spot

16) The _____ is the rigid, outermost plate of the Earth.
- Mantle, lithosphere, asthenosphere , core, Moho

17) Uniformitarianism states that:
- the Earth is uniform throughout its interior; all geologic events occur at roughly the same rate; physical processes operating today have occurred in a similar manner throughout geologic time; catastrophic events such as volcanic eruptions alter the Earth's surface

18) The rock formation in the figure below represent a(n)
- fold; basin; fault; orogeny

19) Relative age measurement refers to:
- age measured in years; the order in which events occur; age measured by Carbon 14 dating only; age measured by Potassium-Argon dating only

20) An unconformity is:

- a sedimentary layer; a crack in the rock; a time gap in the geologic sequence of events; a radiometric anomaly

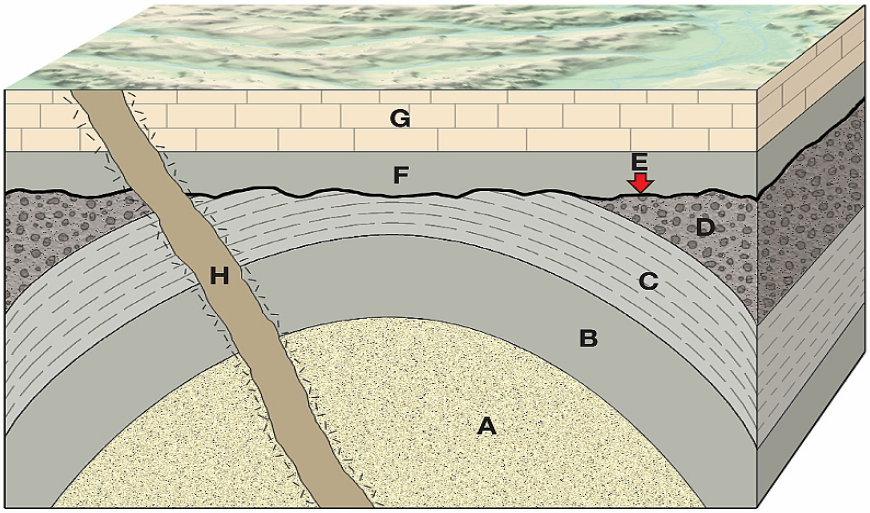
21) Fossils of which type of animal would most likely be found in the surface bedrock of Hannahville?
- Reptile; brachiopods; birds; mammals

22) Divisions in the geologic time scale are based on:
- extinction events observed in the geologic record; major orogeny observed in the geologic record; the appearance of certain animals or plants in the fossil record; all of the above; none of the above

23) The Principle of _____ allows one to determine the relative age of a right-side-up rock unit because it is above another rock unit.
- original horizontality; superposition; lateral continuity; fossil succession

24) An ore deposit is:
- a large deposit of any mineral; a mineral deposit that can be mined at a profit; a rock with any concentration of normally valuable minerals

25) True or False- Michigan was once covered by shallow, tropical seas.



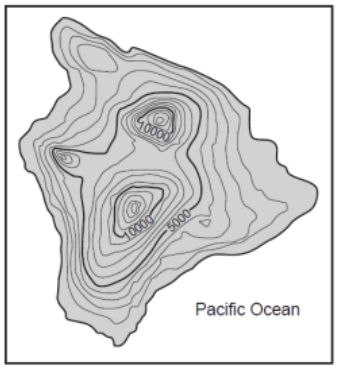
26) Which rock type in the figure above is the youngest? A b. B c. C d. D e. E f. F g. G h. H

27) A city located on the coast of Michigan has warmer winters and cooler summers than a city at the same elevation and latitude located near the center of Michigan. Which statement best explains the difference between the cities' climates?
- water change temperature more slowly than land surfaces; Warm, moist air rises when it meets cool, dry air.; Wind speeds are usually greater over land surfaces than over lake surfaces.; lake surfaces have a lower specific heat than land surfaces.

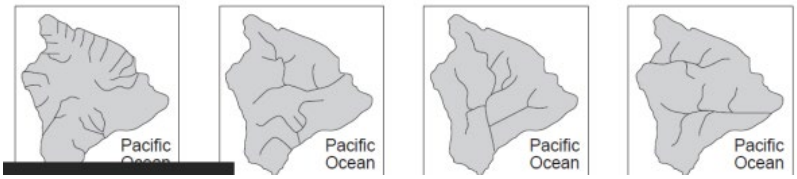
28) The block diagram below represents the drainage basins of some river systems separated by highland divides, shown with dashed lines. The arrows show the directions of surface-water flow. The three areas separated by highland divides are called

- Meanders; watersheds; floodplains; tributaries

29) The topographic map below shows the largest island of the Hawaiian Islands.



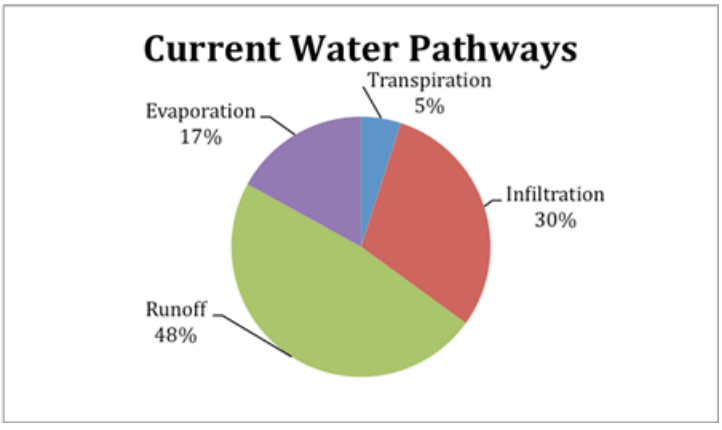
Which map below best shows the most likely stream drainage pattern of this island?



3.7.3 Pre/post summer workshop Part 3: Content Short Answer

Directions: Read the questions below and write a response to each in the space provided.

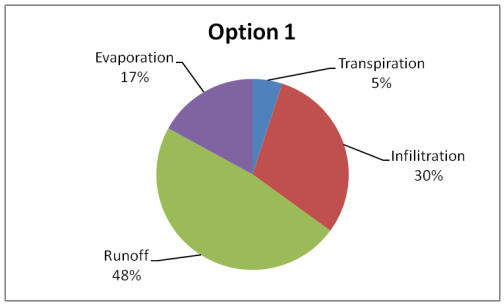
Water Pathways- The pie chart below describes where water goes on your school grounds when it rains. Use the chart below to answer the following two questions.



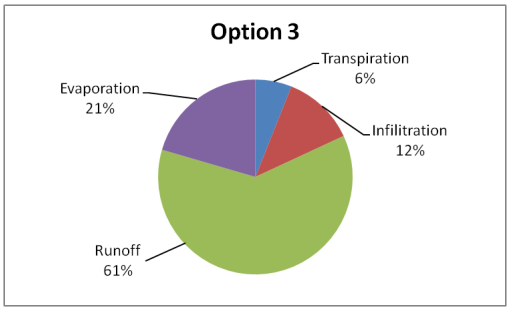
1. Your school is considering replacing part of the school parking lot with an open space of grass and trees. Before the decision is made to do this, however, the potential

impacts of this change on the water budget have to be considered. Which of the pie charts below best fits the change that would be most likely? (circle the best answer)

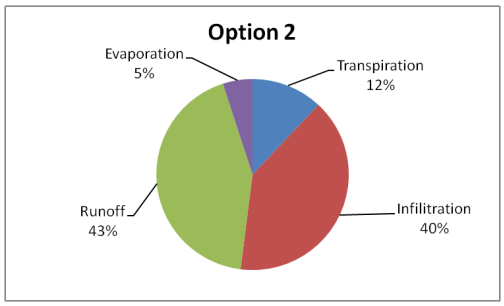
A



C



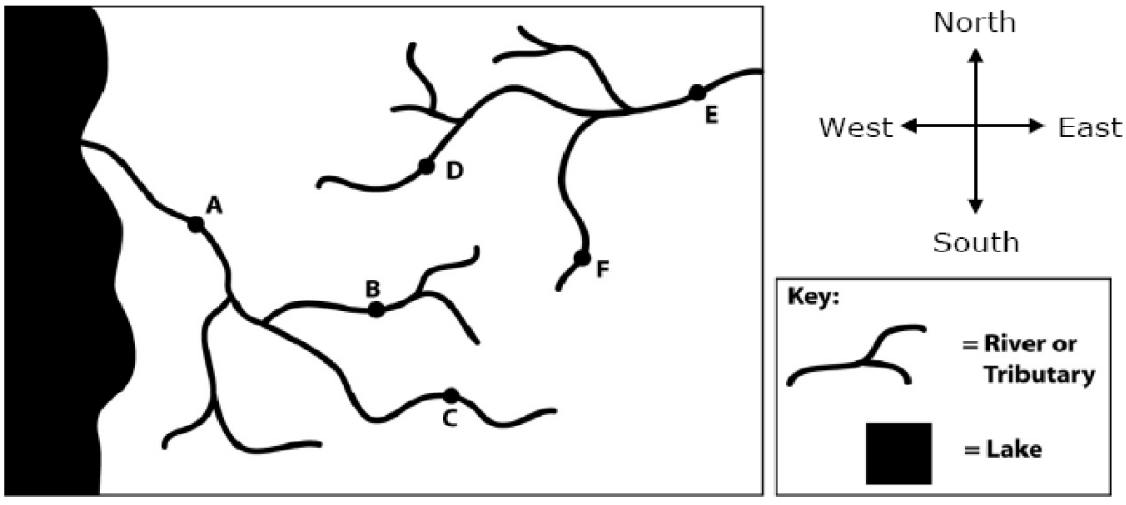
B



2. Please explain what happened to the amounts of <u>infiltration</u> and <u>runoff</u>. Include the reasons why.

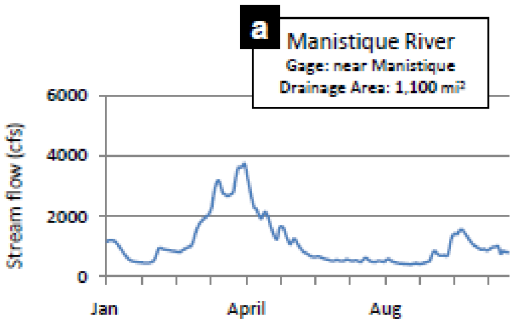
3. Please explain what happened to the amounts of <u>evaporation</u> and <u>transpiration</u>. Include the reasons why.

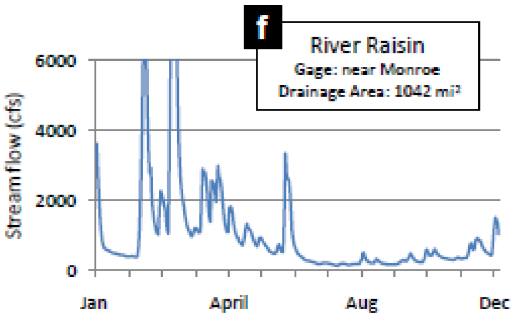
Use the map below to answer question 4



4. Draw an arrow showing the direction water is flowing away from point **F**. How do you know the water flows in this direction?
5. Picture yourself driving in the area near Hannahville. Describe the general shape of land forms you encounter. What patterns do you observe?

6. Below are graphs of the annual stream flow data for the Manistique River (a) & the River Raisin (f). The image below shows their location in Michigan. Use the graphs to answer the question.





a. What might cause the differences in stream flow observed in these two graphs?
b. How can these rivers continue to flow even if there has not been rain for several days?
c. Describe a water quality monitoring plan that scientists might use to evaluate the health & water quality of these rivers?

7. List examples of past events which have shaped the Upper Peninsula to become what we are familiar with today?
8. The rocks that formed near Marquette Iron Range were formed during the Precambrian. How was earth different at this time?
9. How is groundwater flow in karst-prone rocks, such as limestone & dolomite, different than groundwater flow in other types of soil and rocks?
10. If you were designing a lesson on the geology of the Upper Peninsula what would be the most important themes you would want to communicate to your students?

3.7.4 Post Workshop Motivation Survey

There are 30 statements in this questionnaire. Please think about each statement in relation to the instructional materials you have just studied, and indicate how true it is. Give the answer that truly applies to you, and not what you would like to be true, or what you think others want to hear.

Part A: Think about each statement by itself and indicate how true it is. Do not be influenced by your answers to other statements. Check the box under the appropriate column. (Not True, Slightly True, Moderately True, Mostly True, Very True)

1) When I first heard about this field workshop, I had the impression that it would be easy for me.
2) Completing this field workshop will give me a satisfying feeling of accomplishment.
3) It is clear to me how this field workshop is related to things I already know.
4) There was so much information in this field workshop that it is hard for me to pick out and remember the important points.
5) This field workshop gained & sustained my attention.
6) Successfully completing this field workshop was important to me.
7) The quality of this field workshop helped to hold my attention.
8) As I progressed through the field workshop, I felt more confident that I could learn the content.
9) I enjoyed this field workshop so much that I would like to know more about the topic.
10) The field workshop was dry and unappealing.
11) The field workshop was relevant to me needs and interests
12) The way the field workshop was designed helped to keep my attention.
13) It is already apparent to me how people use the knowledge in this field workshop.
14) The field workshop was too difficult
15) I enjoyed working on this field workshop.
16) The amount of repetition for this workshop caused me to get bored sometimes.
17) The contents of this field workshop are worth knowing.
18) I learned something surprising or unexpected working on this field workshop
19) I feel confident that I did well on this field workshop.
20) This workshop is not relevant to my needs because I already knew most of it.
21) I feel that I got enough recognition of my work on this field workshop by the means of comments and other feedback.
22) The variety of activities during the field workshop helped to keep my attention.
23) This field workshop was boring
24) I am able to relate the contents of this field workshop to things I have seen, done or thought about in my own life
25) The technology (GPS, Google Earth, etc.) used during this field workshop was frustrating/irritating
26) There were too many activities during the field workshop that I felt are not worth completing.
27) The assignments during this field workshop are useful to me and are worth completing

28) I understand the material that was covered during the field workshop
29) The skills and knowledge that I'm gaining from this field workshop are worth the time and effort that I am putting into the field workshop.
30) I enjoyed this field workshop enough to do something similar next summer.

Part B:

1) How many days did you participate in field workshop activities?
2) What was the most beneficial aspect(s) of this workshop for you?
3) What suggestions would you make to improve this workshop?
4) Would you be interested in participating in something like this again? Why or Why not?

3.7.5 Post Lesson Reflection Questionnaire

1) What evidence do you have of student understanding of the learning objectives?
2) What type of student interactions Did You observe?
3) What type of teacher-student interactions Did You observe?
4) What misunderstandings or misconceptions Did You observe?
5) How did the students construct their understanding through the lesson activities?
6) Additional thoughts or observations?
7) Consider the overall field trip & lesson planning.
8) What worked well? How? Why?
9) What could be improved upon? How?