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STUDENTS' UNDERSTANDING OF FINGER LAKES GEOLOGY USING A FIELD STUDY

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By

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Dedication: This work could not have been done without the help of all students/staff/administration of Penn Yan Academy. This of course includes the bus drivers that take us all over the Finger Lakes' back "roads." Thank you to all who tirelessly work at improving the science education of our students. Most of all, thank you to the students that come through my door every day and are willing to put themselves out there and try new things. It's your enthusiasm for learning that drives our instruction.

Abstract

The Finger Lakes area has some of the most unique geologic features in New York State including much evidence of the impact that glaciers have had on this environment. The area is rich in Devonian and Silurian era fossils, drumlins, U-shaped valleys, and glacial erratics. With all of this evidence it is easy to imagine a class of students outside in the environment examining these structures and developing conclusions about their origin. However, students in the Finger Lakes area are generally taught about the geology of the area using traditional techniques utilizing technology and diagrams in the classroom.

In this study, students were separated into a control group and an experimental group. The control group was exposed to traditional teaching methods including a PowerPoint presentation and a laboratory activity on the football field. The experimental group was exposed to a field study that included "EarthCache" type assignments where students are asked to use Global Positioning Systems to find evidence of past geologic events and use it to answer questions. Scores on a pre- and posttest using the "art of the sentence" techniques found in Doug Lemov's *Teach Like a Champion* were compared for overall growth of knowledge.

Students in both groups increased the scores, as expected. However, students in the experimental group increased their scores more than the control group in every concept that was focused on in this study, and increased 15% higher overall when compared to the growth of the control group students. The students who experienced the field study were more sophisticated with their usage of evidence to support their claims made in the posttest when compared to the control group's posttest usage of evidence, posting over a 35% score increase. Students that experienced the field study showed a higher understanding of the concepts focused on in this study. Therefore, this study provides evidence that a field study designed with a specific purpose, such as an EarthCache, can provide students with a deeper understanding of the geology of the Finger Lakes area. This deeper understanding can be attributed to the personal connection students had made with the environment while being driven by their natural curiosity of the natural world.

Introduction

The geology of New York is vast and interesting. The diversity of its history provides a challenge for those who wish to study the historical geology of the state. The Finger Lakes area of Upstate New York has some of the most stunning and beautiful geologic features such as Drumlins, waterfalls, fossilized reefs, glacial erratics and of course the 11 lakes themselves. The area is a wonderful place to learn about historical geology and the impact that glaciers can have on the landscape and biodiversity of an area. This study uses a field based education model around Canandaigua Lake and compares the results on open ended responses to traditional in-classroom methods of teaching geology.

This region was most recently dominated by the Pleistocene Glaciers, which are the major cause of the creation of Finger Lakes themselves. Before this era there was a shallow inland sea that covered the area during the late Silurian and Devonian time periods. There were great reef communities composed of corals and stromatoporoids; these fossils can be found around the Finger Lakes area in vast amounts (Miller, 2010). The inland sea was not connected to the oceans; therefore, evaporation formed salt and limestone deposits that can be found around the Finger Lakes area, most specifically in Syracuse and Watkins Glen. The Pleistocene Glaciers sculpted, carved, and gouged the landscape creating northward flowing streams. The glaciers deposited millions of tons of sediment and formed moraines that closed off the river valleys and allowed the lakes to form (Lawrence, 1970).

The process of how this area was carved by glaciers is taught in Earth Science courses across New York State, with specific attention paid to the concept of glaciers being an erosional process (NYS Physical Science Core Curriculum Performance Indicator 2.1u). However, the discussion of this region prior to the presence of glaciers, during the Silurian and Devonian time periods specifically, is generally lightly covered; a deeper treatment of the Finger Lakes area is absent in today's high school curriculum. In the Penn Yan Central School District, the Geologic Time unit consistently has the lowest test scores (A. Johnson personal communication, 2016). Geologic time is a widely

misunderstood concept in high school science (Trend, 2010). In particular, students struggle to understand landscapes and life forms that predate recorded history.

New York State has adopted the New York State Science Learning Standards, which will go into effect on July 1, 2017. The NYSSLS are based on the foundation of the National Research Council's A Framework for K-12 Science Education; Practices, Cross Cutting Concepts and Core Ideas; and the Next Generation Science Standards. Because the NYSSLS are based upon the Next Generation Science Standards, they are very closely aligned with the Next Generation Science Standards, and in most cases the exact same. These standards are built upon a three-dimensional learning framework including "Practices, Cross-Cutting Concepts and Disciplinary Core Ideas," (nextgenscience.org) The standards set expectations for what students should be able to achieve by the end of instruction for certain grade levels; these are called "performance expectations." Teachers in New York State and other states that have either adopted or adapted the Next Generation Science Standards are going to be expected to prepare students for these standards, which rely heavily on problem-based learning. Field based studies fit the Next Generation Science Standards by providing students with field practices in geology.

Two performance expectations addressed in this study are:

1. Performance Expectation MS-ESS2-2: Construct an explanation based on evidence for how geoscience processes have changed Earth's surface at varying time and spatial scales.

2. Performance Expectation HS-LS4-5: Evaluate the evidence supporting claims that changes in environmental conditions may result in: (1) increases in the number of individuals of some species, (2) the emergence of new species over time, and (3) the extinction of other species

In today's classrooms, information about geologic history is often presented to students in the form of printed diagrams and representations that demonstrate how glaciers carved the valleys and deposited sediment forming moraines. Students may see pictures of U-Shaped valleys and glacial erratics that provide visuals of the glacial erosion process. Lectures on geologic time cover millions of years in as short as a 60-minute period. Students learn how to interpret diagrams that show the process of a changing landscape and are aware that change has occurred; however, ultimately understanding the landscape of the Finger Lakes at any time before the lakes existed is difficult and not easily conceived.

A more engaging and personal experience with the landscape is needed. The outdoor environment provides students with opportunities that resemble how scientists work in the natural sciences, (Esteves 2015). However, the novelty of traditional field trips tends to overrule the educational value of being outside, unless they are designed with a specific purpose, (Behrendt & Franklin, 2014). To that end, this study aimed to immerse students into the geology of a glacially formed lake very close to their home and expose them to the evidence supporting an environment in Western New York that does not consist of long and slender lakes. Using GPS technology, EarthCaches, and the environment around us, students explored, observed, handled, found and visualized evidences from the geologic past and formed conclusions about the geologic past, present and future of the Finger Lakes area.

The research is guided by the following questions:

- To what extent does field-based learning using EarthCaches help students learn about the geologic processes that led to the formation of the Finger Lakes?
- How does this type of instruction compare to typical in-class instructional approaches in terms of student learning outcomes and interest?

Specifically, to what extent does field-based learning using EarthCaches help students:

- Develop explanations of how the Finger Lakes were formed?
- Develop explanations of how the landscape of New York State looked 400-500 million years ago?
- Interpret relationships between environmental changes and species extinctions?

Literature Review

Geologic time is a difficult concept not only for students to understand, but also for many adults. The idea of a world before humans is hard to comprehend without direct observations and personal experience. As humans, many struggle to imagine a world outside of their own existence because we cannot see how it directly influences our daily lives and our personal experiences. The world before and after our own lives does not exist in our consciousness and therefore is hard to imagine. There has been much research on this topic with elementary (Ault, 1982; Schoon, 1992), high school (Marques & Thompson, 1997; Oversby, 1996; Schoon, 1992), and college aged students (DeLaughter et al., 1998; Libarkin et al., 2005; Schoon, 1992). Overall, research has shown that students at different grade levels are familiar with the order of biological events in Earth's history, but are unfamiliar with geological events such as formation of mountain ranges (Trend, 2001). In general, most students have the misconception that both the Earth and life originated at the same time (Marques and Thompson, 1997).

The struggle students experience in understanding geologic time is due to a lack of motivation, interest, and personal connection to the concept of geologic history, which directly influences student learning. It is well documented that student interest and motivation is related to student learning (Ainley, 2002). Increasing access to technology for students increases student engagement, responsibility for learning, time on task, and student interest (Taylor, 2011). Using field-based methods for teaching and providing students with opportunities to use technology are needed to increase motivation to learn about this interesting area by offering a more personal connection to the concept of deep time.

A study conducted in Portugal showed that field-based education in the geological sciences helped to develop scientific reasoning and inquiry based skills in students ranging in age from 15 to 19 years, (Esteves, 2015). The results from this study also showed increased understanding of geological concepts and increased interest in and motivation to study geology. In a review of literature on field trips, DeWitt (2008) suggests that these experiences may not be best for teaching isolated facts, but are most effective as an opportunity for students to explore first-hand the natural world around them and to develop cognitive skills and long term learning. The author also suggests that school field trips help students develop new interests in science, which may develop into science careers in the future. Field-based education has also been shown to have long term impacts on retention of knowledge. Eighteen months after a field trip, students in this study recorded positive responses toward learning, including increased interest in returning to the field site in the future, (Knapp, 2000).

While there is clear evidence from several studies indicating an increase in student interest in field trips as well as evidence of both short and long term learning subsequent to the field trip, research on field trips suggest that these experiences need to be intentionally planned and purposefully executed (Orion & Hofstein, 1994). Field trips can sometimes be more of a novelty to students and can inhibit learning; therefore, it is necessary to determine a specific purpose for the trip prior to travelling to establish a clear educational outcome for students (Behrendt & Franklin, 2014). Orion and Hofstein (1994) concluded that field trips must be situated appropriately in the curriculum and used as part of the unit plan rather than as an isolated activity. Field trips that occur early in the curriculum that are used as a 'concrete bridge' with in-class lessons should reduce the 'novelty factor' and make the field trip a strong learning tool and not just a fun day out of school (Orion & Hofstein, 1994). The field-based approach is an excellent method to teach geologic concepts when strategically planned to take advantage of all the environment has to offer.

In addition to field-based experiences, greater student interest and a more thorough understanding of geologic concepts in the Finger Lakes may be achieved by using current technology, including cell phones, Global Positioning Systems, and Google

Earth. The Geological Society of America recognizes the importance of cell phones, iPods, and other portable electronic devices in maintaining students' interest, and advocates for a blending of virtual and physical worlds (Lewis & McLelland, 2007). Implementing technology as a teaching and learning tool is likely to increase motivation due to current student interest in technology (Ainley, 2001).

An example of a technology that may be effective for teaching geologic concepts in the field is EarthCaching. EarthCaching blends the use of Global Positional Systems and the natural curiosity of students to explore geologic features in the environment and to solve problems using evidence collected in the field. While EarthCaching, students use a GPS device to follow coordinates to a geologically interesting area pre-identified by educators, geologists, or the public and use the environment to answer geologic questions pertaining to that environment. For example, a fossil rich environment located at the bottom of a U-shaped valley in the Finger Lakes can provide clues or evidence to such assessment items as:

1. What process created this valley?
2. Describe the environment when the fossils found at this location were alive.
3. Find evidence that this location was once not what it is at present time (besides fossils).

In a study by Gochis (2011), in-service science teachers participated in a two-week field course that targeted the usage of EarthCaches to make observations about geologic features in order to interpret the area's geologic history. The purpose of this study was to promote Earth Science in public school classrooms by using EarthCaches to help teachers understand how scientists identify a geologic feature within the landscape.

The EarthCache model of teaching geologic history can connect classroom geologic concepts with geologic fieldwork. This allows students to see geologic features that can be interpreted and understood as evidence of the geologic past while appealing to student's natural curiosity. Using multiple strategies to teach geologic time, including field based education and EarthCaches, may improve overall understanding of geologic

time. It may also increase student interest in learning geologic features found in abundance in the Finger Lakes.

Methodology

Study Aims and Research Questions:

The aim of this study was to determine whether engaging students in a field study around the Finger Lakes area utilizing Global Positioning Systems and EarthCaches helps students develop a deeper understanding of geologic processes and interest in the topic. Students were provided with opportunities to observe evidence of glaciation such as drumlins, erratics, northward flowing rivers, along with fossilized remains of organisms from pre-glacial landscapes. This experience also aimed to provide students with a personal connection to the Finger Lakes landscape, and how it is a great example of local glacial activity in their backyard. This field experience, combined with the use of technology aimed to provide a richer learning experience than the typical in-class instruction and result in a deeper understanding when compared to in-classroom methods.

The research focuses on three essential concepts. They are: 1) Geologic Formation of the Finger Lakes Area; 2) Geologic Time 3) the causal relation between extinction and environmental changes and adaptive characteristics of a species. These concepts were chosen because they are addressed in the New York State Science Learning Standards that have been adopted.

Methods

This research follows a quasi-experimental approach with a treatment group and a comparison group. Both groups of students learned the same content: Geologic Time, Formation of the Finger Lakes, and the causal relation between extinction and environmental changes and adaptive characteristics of a species. The two groups of students, ages 13-16, were actively enrolled in a high school Living Environment class. The two groups contained approximately the same number of general education students (18 in the experimental group, 17 in the control group) who were taught these concepts using different strategies. Upon returning from the field study, students spent 10 minutes journaling using prompts such as:

1. I learned …..
2. I was surprised by….
3. I wonder…
4. I want to know...
5. I saw…
6. I realized...

Students in the traditional class learned through lecture using PowerPoint presentations that included visual representations of geological processes including glacial activity, formation of the Finger Lakes, geologic time and the relationship between environmental changes and extinction. The traditional methods included a 60 minute lecture and note-taking process using a PowerPoint presentation. The PowerPoint included images of the Finger Lakes showing actual evidences of glaciation, digital topography showing geologic formations, and note slides showing evidences of the past geologic times in the Finger Lakes Region. Several slides showing the processes are attached in the appendix. The presentation was direct instruction with formative assessments utilizing purposeful questioning during instruction.

An outdoor activity on the football field showing geologic time scale and in-class discussions on how species become extinct followed (worksheet attached in appendix). Students used the length of the football field as an analogy for the history of the earth, with the goal line on one end the formation of the earth and the opposite goal line as present day. For the first round, students discussed where certain major events, such as when the first plants evolved, occurred in earth's history. Students discussed in small groups where on the football field they thought each event occurred and placed a flag at that location. Students did this for 16 events, ranging from the first formed rock to Columbus landing at Plymouth Rock. With all of the students' estimated locations on the football field, the teacher gave the students a conversion of 1 yard = 50 million years, and the actual years that these events took place and sent them to put a new flag where these events occurred in geologic time. A discussion followed based on the following questions:

1. How close were our estimations to the actual placement of these events?

2. What are the major trends in the actual placement of these events (specifically with life?)

3. How would you describe earth for the majority of geologic history?

4. What are your biggest takeaways from this activity?

Students in the experimental group were exposed to the classroom based instruction and a field study. During the field study:

1. Students used Google Earth to view a virtual field trip to future field trip locations. In the virtual field trip, students viewed locations of geological significance in the Finger Lakes area.

2. Students used Global Positioning Systems to find two EarthCache locations in the Finger Lakes area.
    a. EarthCache One is a glacial erratic known as “Council Rock.”
    b. EarthCache Two is a tributary stream to Canandaigua Lake where glacial till and Devonian and Silurian era fossils can be found.

Data Collection and Analysis

Data on student learning was collected using a pre- and post- test (Appendix A) measuring content knowledge of geologic time, formation of the Finger Lakes, and the causal relation between extinction and environmental changes and adaptive characteristics of a species.

The test consisted of five extended- response questions asking specifically about the three key concepts. Approximately half of the questions included diagrams or graphics that needed to be analyzed by the students. This method of data collection was utilized to measure student knowledge of the concepts under review. This strategy showed initial understanding and provided a measurement of learning received from the multiple strategies.

The questions were written in the format of "the art of the sentence" taken from *Teach Like a Champion* by Doug Lemov. Lemov (2010) writes, "The fundamental problem, for students who don't write or read as well as they could, is often that they aren't good enough at creating sentences that capture the nuances of a complex idea or the relationships of complex ideas and they similarly fail to successfully untangle the nuances and interrelations in such sentences when written by others." The Penn Yan Central School District Science Department has been working on techniques from this book to help students write more complex sentences using evidence to support a claim. This involves giving required vocabulary to be used in a response and having the answer be written in only two to three sentences. This type of response can be analyzed to discover the students' true understanding of the topic or concept and expose misconceptions.

Student responses to the pre/posttest were scored by a rubric (appendix) and compared for each case – traditional or field-based instruction – to determine learning outcomes and growth of knowledge on topics.

Students' journal entries were used to qualitatively examine their interaction with the environment and personal experiences during the field study. Journal entries were analyzed for content specific observations as well as identification of engagement level of the students on the field study.

Scoring of the pre- and posttests were compared for overall score increase. The highest score a student could receive for each question was 3, therefore the average score for the Experimental Group (n=18) and the Control Group (n=17) for each pre- and posttest question was calculated. The average pre-test question score was then subtracted from the average posttest question score to find the increase in score for each concept.

Each answer was based on three characteristics: Content, Evidence, and Grammar/Vocabulary. Evidence usage was calculated by taking the scores for each question with relation to usage of acceptable evidence (found on rubric) and calculating the average.

Ethics

The study participants had signed consent forms from parents/guardians of the students because they are under the age of 18. Students also signed an assent to the research, understanding any risks and benefits of the research. Students were exposed to a specific teaching style covering the same science content as another group who were exposed to a different teaching style. Therefore, there should not be any psychological or physical harm to participants. The study was approved by Michigan Technological University's Institutional Review Board for using human subjects in research.

Results

The control group and the experimental group both had similar pre-test scores, averaging 52 % and 57%, respectively. A one-tailed Student's t-test revealed no statistical significance between the two groups. Table 1 summarizes the pre- and posttest scores for each group. Both groups showed significant gains on the posttest. The control group post-test average was 62% (one-tailed, matched t-test; $p<0.01$), and the experimental group posttest average was 82% ($p<0.01$). However, the treatment group increased their average score by 25% ($p<0.01$), while the control group only increased their average score 10% ($p>.01$). A visual of both groups' growth can be seen in Figure 1.

Table 1: Average Percent Scores

	Pre	Post
Control	52%	62%
Experimental	57%	82%

Analysis of the individual questions shows where the most growth was with relation to specific concepts. Figure 1 shows the pre- and posttest scores for the each question. The first concept, dealing with the landscape of the Finger Lakes region during the Devonian Period, both groups averaged 41% on the pretest, indicating that neither group had a lot of previous knowledge on the Finger Lakes region's geologic history. On the posttest, the experimental group averaged 71% on this item, while the control group averaged 54%.

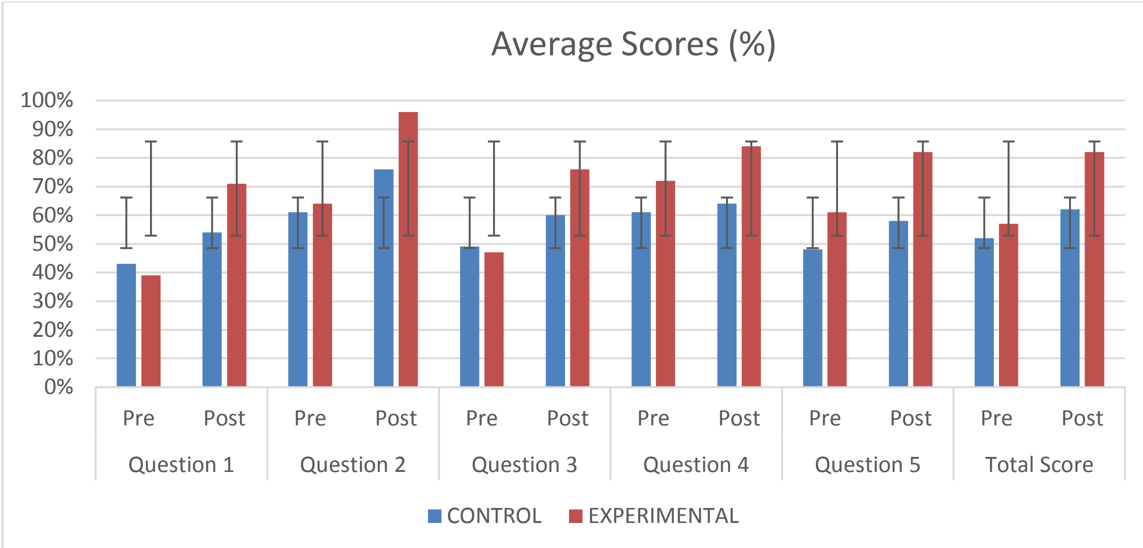

Figure 1: Students' pre and posttest scores for each question and the total pre and posttest scores

Even more impressive was the usage of evidence to support the marine type environment that the Finger Lakes region was during this time period. Both the control and experimental groups showed a clear lack of knowledge scoring on average 8% and 13% respectfully. The control group increased after the lesson 21% whereas the experimental group increased 41% (Table 2).

Table 2: Evidence Usage on Devonian Period inFinger Lakes		
	Pre-Test	Post-Test
Control Group	8.00%	29.00%
Treatment Group	13.00%	54.00%

The usage of evidence to support the marine environment in the Finger Lakes area during the Devonian era was impressive with the experimental group because the students' responses included specific examples from the field study. Responses such as "the fossils found at Deep Run" and "shell fossils in the bedrock" were prevalent in experimental responses while the control group responses were more generic such as "fossils" and "salt."

The second data point measured specific to content was the understanding that the Finger Lakes landscape was formed as a result of glacial activity, and the evidences to support this idea (question 2). Figure 1 shows the average scores for both groups with the percentage increase for this concept. Students in both groups appeared to have some

knowledge of glaciation in the Finger Lakes region, averaging a pre-test score of 63%, and both increasing their score by quite a bit. When looking at the difference between content and usage of evidence, however, the content knowledge increase had less than 1% difference in growth. The noteworthy increase in scores was the usage of acceptable evidence to support the idea that glaciers formed the landscape of the Finger Lakes. Students in the control group increased evidence usage from 37% to 67%, the experimental group on the other hand increased from a 49% average score to a nearly perfect 98%.

The experimental group showed a deep understanding of evidences to support glaciation in the Finger Lakes with their posttest scores, and again with specific examples that were explored during the field study. Students in the control group generally used "U-shaped valleys" and "the Finger Lakes" as evidence compared to detailed responses such as "rounded boulders like Council Rock from Canada deposited by retreating glaciers" or "The U-shaped valley seen from Bare Hill overlooking Canandaigua lake" and "northward flowing lakes with shallow Northern ends, such as Canandaigua."

The third data point measured was the concept of Environmental Changes and the role of Variation in Species Survival (question 3). Figure 1 shows the average increase of scores for both groups with percentage increase for this concept. Once again students in both groups had similar pre-tests scores, both falling on average at 48%. Students in the control group increased their score 11%, showing that knowledge was gained. However students in the experimental group, who experienced first-hand fossils of organisms that would not survive in the current landscape, increased their score by 29%.

The most interesting data found was the increased usage of evidence to support claims made by students. Table 3 averages the usage of acceptable evidence to support the claims made by the students on all questions/concepts.

Table 3: Usage of Acceptable Evidence		
	Pre-Test	Post-Test
Control Group	29.00%	55.00%
Treatment Group	39.00%	74.00%

The experimental group started with a higher average pre-test score when using evidence, however after experiencing the field study this group increased their score by an entire point, or 35% compared to the control group's increase of 26%. While both groups increased their usage of evidence in short response questions, the students in the experimental group appear to have increased their knowledge of applicable evidence more consistently with relation to the Finger Lakes geology, landscape and history than the control group.

What is not measured here is the specificity of evidence used by students who were in the experimental group versus the students in the control group. While students in the control group increased their usage of evidence to support the claims, their evidence was not as detailed as the experimental group's especially with relation to the local Finger Lakes area (Canandaigua or Keuka Lakes). Students who were in the experimental group consistently used specific vocabulary or examples such as: "The Finger Lakes were formed by glaciers by the evidence of glacial erratics such as Council Rock," or "Evidence to support the claim that glaciers formed the Finger Lakes are the U-shaped valleys, V-shaped valleys are made by rivers." These statements are very detailed, compared to correct responses from the control groups such as: "The evidence for glaciers forming the Finger Lakes are the large round boulders," or "The glaciers made the Finger Lakes because of U-shaped valleys." The control group's responses are correct, however the specificity is not as impressive as the experimental group responses.

Students' engagement and content based reflections were measured using post field study journals. The frequency of content based statements and statements that reflected positive engagement was tallied (Table 4).

Table 4: Journal Entries Post-Field Study	
	Frequency
High Engagement Statements	13
Content Specific Statements	19
Engagement and Content Based	4

The 18 students who were part of the field study reflected for approximately five to ten minutes post field study using prompts displayed on the board. Students wrote

more than one statement, therefore the frequency of some of the statements reached more than the number of students. Students reflected personally during this time, and the majority of the comments were based on content learned during the field study, 19 in total. Comments that were perceived as high engagement in the topic/field study experience reached 13 comments. The most interesting comments students wrote were those that reflected students' high engagement in the content learned. While only four of these comments were recorded, these comments show significance in students' engagement in geologic concepts.

A few of the comments were significant enough to include; one student wrote "going out and experiencing the landforms for yourself provides not only a great experience, but a better way to memorize information." This student demonstrates that for him/her personally coming into contact with the geologic landforms creates a more personal experience with the concepts and in turn allows him/her to learn the concepts in a more meaningful way. A different student had a similar experience, "I realized that being on a field study is more engaging than being indoors, this is true for me because I am experiencing the cool things about nature rather than someone telling me about it." Another student commented, "At Deep Run you could find fossils and experience different eras, which was a great way to learn about history." What is significant about these three reflection statements is the usage of the word "experience" by the students. These students are able to recognize that in the field, they are not only learning about the environment, but are actually involved in the learning as part of the environment. Visualization takes place as a student is standing in the environment and imagining it as something different than its current state. This helps create an understanding that what an environment is currently, is not always what it was, and the evidence to support that visualization surrounds the student.

Other statements included personal learning experiences such as, "Today I realized how learning and going to different places affects the way I personally learn. Learning outside in an actual environment helped me contain better and more information." One student reflected: "I realized that you can learn a lot from just looking at a rock and finding fossils, like what the environment used to be." The second statement shows that the student had a change in mindset to what learning can be. For most

students, learning can only exist in a classroom. For this student, and hopefully for all 18, the environment has now become a classroom.

For students who are reluctant learners, the field study was engaging and a change of pace from the normal classroom. “I was surprised that I can learn and have fun,” wrote one student. Another commented, “I was surprised by how much fun I had, it was fun yet educational.” Students that may not excel in a general education class were now experiencing learning in a different way, and enjoying it tremendously.

Students were not only engaged during the field study, but showed interest in furthering their education on the topics. One student wrote, “I want to learn more about the Finger Lakes, and how they were formed.” Intrigued enough by what we had learned at the locations, one student wanted to do it all over again in the future, “I wonder if we visited the area again in the future if the area would look the same.” An interesting idea by a student who now knows what the past looked like for this area, and wonders what the future holds for Canandaigua Lake.

Discussion

Teachers face the never-ending battle of engaging students in the concepts in a science classroom in a world where technology rules and students are constantly interacting with a screen. The research questions posed in this study were intended to clarify whether the usage of a well-organized field study utilizing current GPS technology, but focused on the students’ interaction with the physical environment, could provide a better learning experience for students when compared to traditional in-classroom methods. Further, the study was designed to investigate whether a field study would engage students in the concepts of Finger Lakes Geology.

Overall, the students who were part of the experimental group showed higher scores when compared to the control group. Students who participated in the field study were engaged in the landscape and retained more information on the formation of the Finger Lakes, the landscape of the region during the Devonian era and the causal relationship between environmental changes and species extinction. For those three concepts, students in the experimental group increased their scores 37% more, on

average, than the control group students. This increase is significant, showing that in relation to all three concepts, students who experienced a hands-on field study performed over a third better than the students who experienced traditional methods in class.

Most intriguing was the students' usage of scientifically accurate evidence to support the concept claim made by the student. In the inquiry process it is important that students have the ability to generate a convincing argument with supportive evidence (Driver et al., 2000). This is also emphasized as important in the newly adopted New York State Science Learning Standards (NYSSLS) and the Next Generation Science Standards (NGSS) as a Science and Engineering Practice:

> Engaging in Argument from Evidence Engaging in argument from evidence in 9–12 builds on K–8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about the natural and designed world(s). Arguments may also come from current scientific or historical episodes in science.

The students in both groups increased their usage of evidence to support their claims, which is to be expected when a concept is taught in a mainstream classroom. However the 23.7% difference in evidence used by the experimental group versus the control group exemplifies the argument that a student who interacts with the physical environment will relate that interaction with classroom concepts, and thus be able to articulate that data to a scientific argument.

Reflections:

The results from this study help me understand the importance of hands on inquiry based activities in the science laboratories. This experience showed that a well-planned purposeful field trip that is designed to be as close to real research as possible is highly engaging to students, even the traditionally disengaged student. In the field, students are not held back by the traditional desk and chair barriers and are more willing to ask questions and interact with others. It becomes an equalizing experience, the student-teacher relationship becomes less regulated and becomes a much more collaborative study in the interest of natural geologic phenomena.

For those that are limited by budgetary or physical barriers, the usage of the natural world to drive instruction could be used. Bringing in fossils to a laboratory or using Google Earth to take digital field trips can be used and still drive inquiry based experiences that can be both engaging and purposeful. As science teachers our job is to structure an environment that is driven by natural phenomena; our human nature is to learn and solve problems, we use the evidence that is left behind to try and explain what has happened in the past in order to predict the future. Utilizing what has been left behind in our environments to help solve problems is a very stimulating way to engage students into problem solving, and a side-effect is an appreciation in the aesthetic value of our landscape.

In speaking with the teachers that chaperoned the field study, the thoughts that were most prevalent were regarding student engagement and academic conversations. The biology teacher that chaperoned the trip's first thoughts were "an excellent example of observational phenomena." She also reflected on the benefits of outdoor education in general. "The physical movement of walking stimulated blood flow and the release of hormones, making the student better prepared physiologically and emotionally to learn." The other chaperone is the staff developer for our district, she reflected on how refreshing it was to have academic conversations with students who were many years younger than her, in such a natural manner. Not a science major, she reflected how meaningful some of the activities were on the field study and how she, as a student that day, had her own personal experience. "I am sure I learned this at some point in my student years, but seeing and feeling seashells imprinted on a rock in the middle of a creek left an imprint on my brain." Her final thoughts on this field study: "I want to know how we (the district) can make events like today happen on a smaller scale, more often."

Limitations and Considerations for the Future:

The biggest limitation to this study is the sample size; with both classes having less than twenty students, the amount of data was not ideal. However, the amount of data that was obtained was very promising for future studies on the effectiveness of field studies on the sciences of the Finger Lakes in high school students.

This research supports the teaching style of well-designed field studies where students are working in the field and teachers are observers/experts in the field who are there to lend a hand or guide, but not to answer specific content related questions. In the Penn Yan Central School District, where this study was performed, the results have pushed the science department into developing a course entirely based upon field studies. Coming in the 2018-2019 school year the Penn Yan Academy will be offering “A Field Study of the Finger Lakes,” a course based on the Geology, Ecology, Economy (viticulture) and History of the Finger Lakes region using field studies as a major component of instruction.

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Appendix A

Geology Pre/Post Test

Answers in red

Name ________________________

1. Using 2-3 well crafted scientific sentences, describe the Finger Lakes area during the Devonian Period (419 to 383 million years ago). Be sure to use at least two pieces of evidence to support your description of the region.

During the Devonian period the Finger Lakes area was an inland sea environment with salty water. The evidence to support this is the salt caverns found around the area such as Syracuse and Watkins Glen and the fossils of sea creatures such as shells and brachiopods.

2. Using 2-3 well crafted scientific sentences, explain IN DETAIL one piece of evidence that glaciers once covered the Finger Lakes area. Be sure to support your evidence with details.

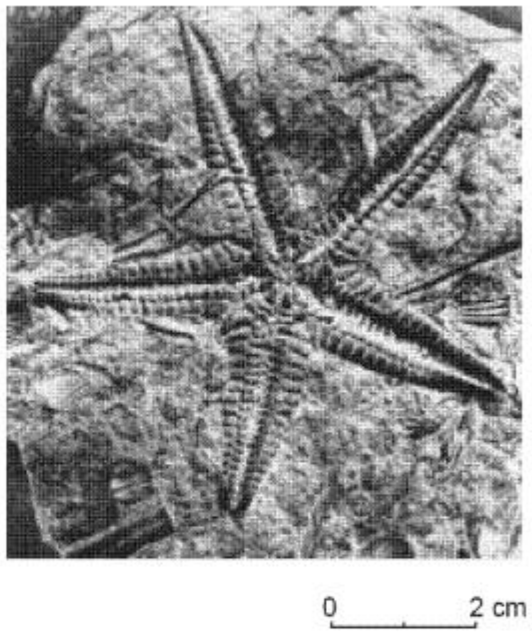
Glacial erratics can be found all over the Finger Lakes area in people's front yards, these are giant round boulders that originated from Canada. Glacial tilling is another evidence, this is the unconformity of soils, and for example when plowing a field we find lots of different size and age of rocks in the soil. U-Shaped valleys with the Finger Lakes are another evidence, these are different from river valleys because river valleys are V-Shaped, only glaciers could have left the U-Shaped valleys.

Other evidences: Moraines, drumlins, eskers, north-south gouging in bedrock etc.

3. Explain the role of genetic variability in a species' survival or extinction with relation to environmental changes. Be sure to use evidence to support your claim.

Species have variations caused by sexual reproduction or mutations, this variation is necessary for a species as a whole to survive because an environment can change and if that species does not have the ability to survive the changing environment the entire species could go extinct. For example when the inland sea in the Finger Lakes area began to dry during the Devonian period the species that were not adapted to the changing environment died, (brachiopods).

4. The Devonian-aged (419-383 million years ago) siltstone shown in the accompanying photograph occurs as surface bedrock near Hamilton, NY.



What does the presence of this type of fossil suggest about the Hamilton area's landscape during the Devonian era? In 2-3 sentences. Be sure to use evidence to support your claims.

This fossil is evidence that Hamilton, NY's environment must have been a sea or oceanic environment, or at the very least an aquatic environment. During the Devonian era in Hamilton this organism has adaptations to help it survive in an aquatic environment.

5. Using 2-3 really well-crafted sentences, explain why the organism in the previous picture (question 4) was unable to survive in Hamilton, NY. Be sure to use the following words in your answer: adaptation, extinction, change, landscape.

The aquatic organism in the previous picture was unable to survive because the landscape of Hamilton, NY changed from an ocean environment to a terrestrial environment. The organism has adaptations to help it survive only in an aquatic environment, when the landscape began to dry up this species could not survive and went extinct.

Appendix B

Rubrics for Response Questions:

Question 1: Using 2-3 well crafted scientific sentences, describe the Finger Lakes region during the Devonian Period (419 to 383 million years ago). Be sure to use at least two pieces of evidence to support your claim.

Parameter	Excellent (3)	Good (2)	Fair (1)	Poor (0)
Understanding of Devonian Era in Finger Lakes	Description of Inland sea or oceanic environment	Description of aquatic environment	Description of environment different than present	No Description given or cannot read
Usage of Evidence	Two evidences that are applicable to Devonian Era	One Evidence applicable to Devonian Era	Evidence used, but not applicable to Devonian Era	No evidence used
Vocabulary /Grammar	Correct scientific vocabulary, complete sentences	One grammatical error or incorrect vocabulary term	Two or more grammatical errors. Use of pronouns instead of scientific vocabulary	Unreadable or no scientific vocabulary used

Question 2: Using 2-3 well crafted scientific sentences, explain IN DETAIL one piece of evidence that glaciers once covered the Finger Lakes area. Be sure to support your evidence with details.

Parameter	Excellent (3)	Good (2)	Fair (1)	Poor (0)
Understanding of glaciers covering the Finger Lakes Region	Clear description of glacially covered Finger Lakes Region	Description of glaciers, but not clearly defined. Cancels self out or is confusing in nature	Description other than glaciers given	No Description given or cannot read
Usage of Evidence	One piece of evidence that is left by glacial erosion	One piece of evidence, not clearly explained	Evidence used, but not applicable to glacial erosion	No evidence used
Vocabulary /Grammar	Correct scientific vocabulary, complete sentences	One Grammatical error or incorrect vocabulary term	Two or more grammatical errors. Use of pronouns instead of scientific vocabulary	Unreadable or no scientific vocabulary used

Question 3: Explain the role of genetic variability in a species' survival or extinction with relation to environmental changes. Be sure to use evidence to support your claim.

Parameter	Excellent (3)	Good (2)	Fair (1)	Poor (0)
Understanding of genetic variability importance in survival of a species	Sexual reproduction or mutations cause variation. Variation is necessary for species to survive a changing environment	Variation is necessary for species to survive a changing environment	Mutation/Sexual reproduction causes variation in a species, no clear evidence of understanding how that helps a species survive a changing environment	No Description given or cannot read
Usage of Evidence	At least one piece of evidence applicable to survival of a particular species	One piece of evidence, not clearly explained	Evidence used, but not applicable to variation or survival in a species	No evidence used
Vocabulary /Grammar	Correct scientific vocabulary, complete sentences	One grammatical error or incorrect vocabulary term	Two or more grammatical errors. Use of pronouns instead of scientific vocabulary	Unreadable or no scientific vocabulary used

Question 4: What does the presence of this type of fossil suggest about the Hamilton area's landscape during the Devonian era? In 2-3 sentences. Be sure to use evidence to support your claims.

Parameter	Excellent (3)	Good (2)	Fair (1)	Poor (0)
Understanding of Hamilton's landscape as a shallow inland sea	Description of Inland sea or oceanic environment	Description of aquatic environment	Description of environment different than present	No Description given or cannot read
Usage of Evidence **(picture depicts starfish in siltstone)**	Explanation of starfish as evidence of an inland sea environment	Starfish used as evidence, but not explained correctly	Evidence besides the starfish used, but explains an inland sea	No evidence used
Vocabulary /Grammar	Correct scientific vocabulary, complete sentences	One grammatical error or incorrect vocabulary term	Two or more grammatical errors. Use of pronouns instead of scientific vocabulary	Unreadable or no scientific vocabulary used

Question 5: Using 2-3 really well crafted sentences, explain why the organism in the previous picture (question 4) was unable to survive in Hamilton, NY. Be sure to use the following words in your answer: adaptation, extinction, change, landscape.

Parameter	Excellent (3)	Good (2)	Fair (1)	Poor (0)
Understanding of a species being unable to survive in a changing environment	Description of an aquatic environment changing and the organism not being adapted to survive	Description of an organism not having the adaptations to survive a different landscape	Description of organism being unable to survive, but missing the landscape changing or adaptations not present	No Description given or cannot read
Usage of Vocabulary necessary **(adaptation, extinction, change, landscape)**	All four vocabulary words used appropriately	All four vocabulary words used, but not appropriately	Only 3 vocabulary words used	2 or less vocabulary words used
Vocabulary /Grammar	Correct scientific vocabulary, complete sentences	One grammatical error or incorrect vocabulary term	Two or more grammatical errors. Use of pronouns instead of scientific vocabulary	Unreadable or no scientific vocabulary used

Appendix C

Fossils at Deep Run Beach EarthCache

(includes condensed version of fossil resource for students)

GPS Coordinates: 42°49'15.89"N; 77°15'30.44"W

EarthCache Description: Deep Run Beach is a public beach on the Eastern Shore of Canandaigua Lake, it is the end of a tributary to Canandaigua Lake. The creek cuts through some very important rock that exposes the history of the landscape millions of years ago. If one searches he/she will find some fossilized creatures from this time period, which exposes the type of landscape that existed!

Fossils: the remains or impression of a prehistoric organism preserved in petrified form or as a mold or cast in rock.

Questions:

1. What is the general rock type at this location?

2. Search for fossils in the creek bed (you may have to get wet). Once you find one take a picture!

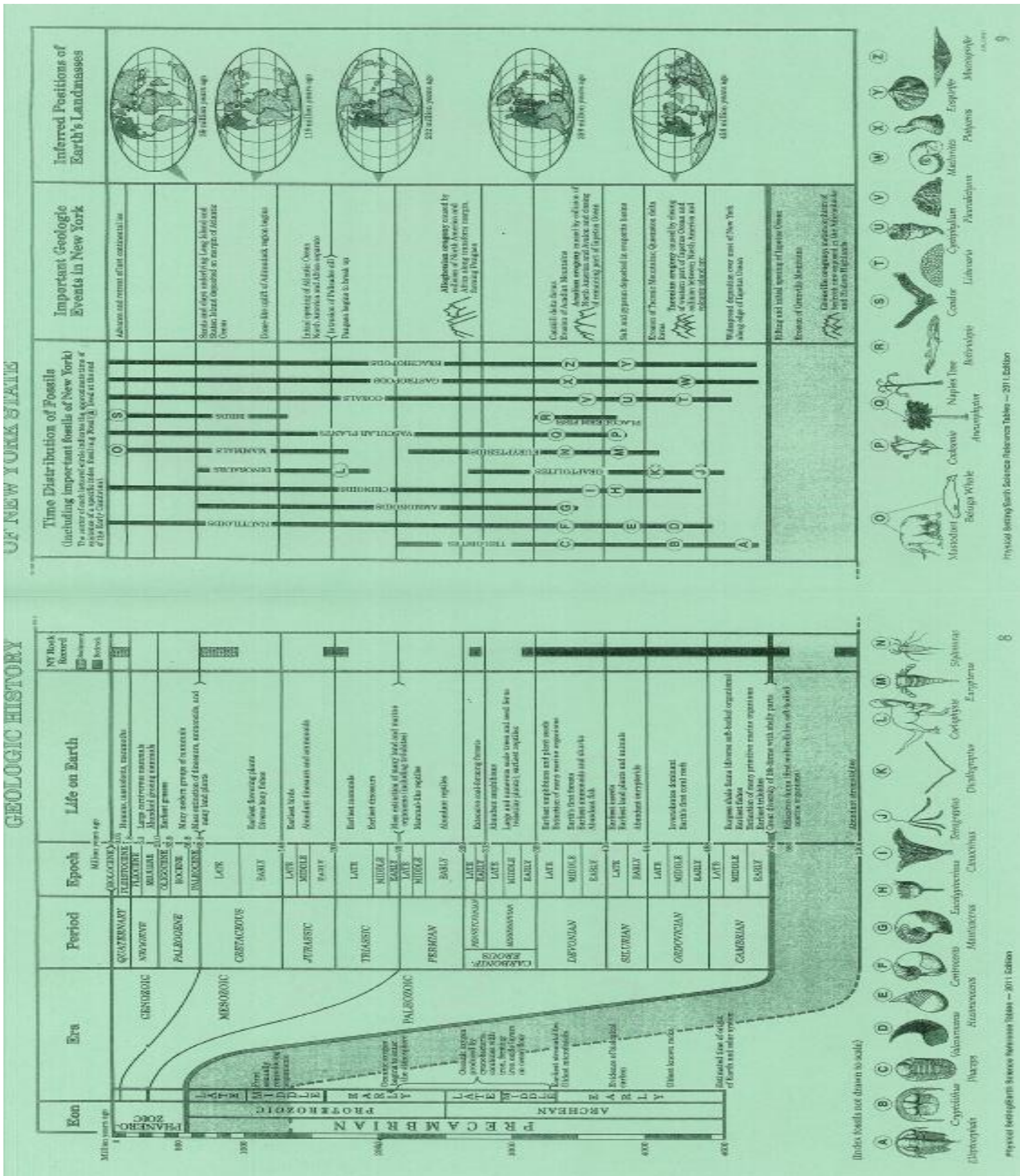
3. Use the document to classify this fossil (do your best).

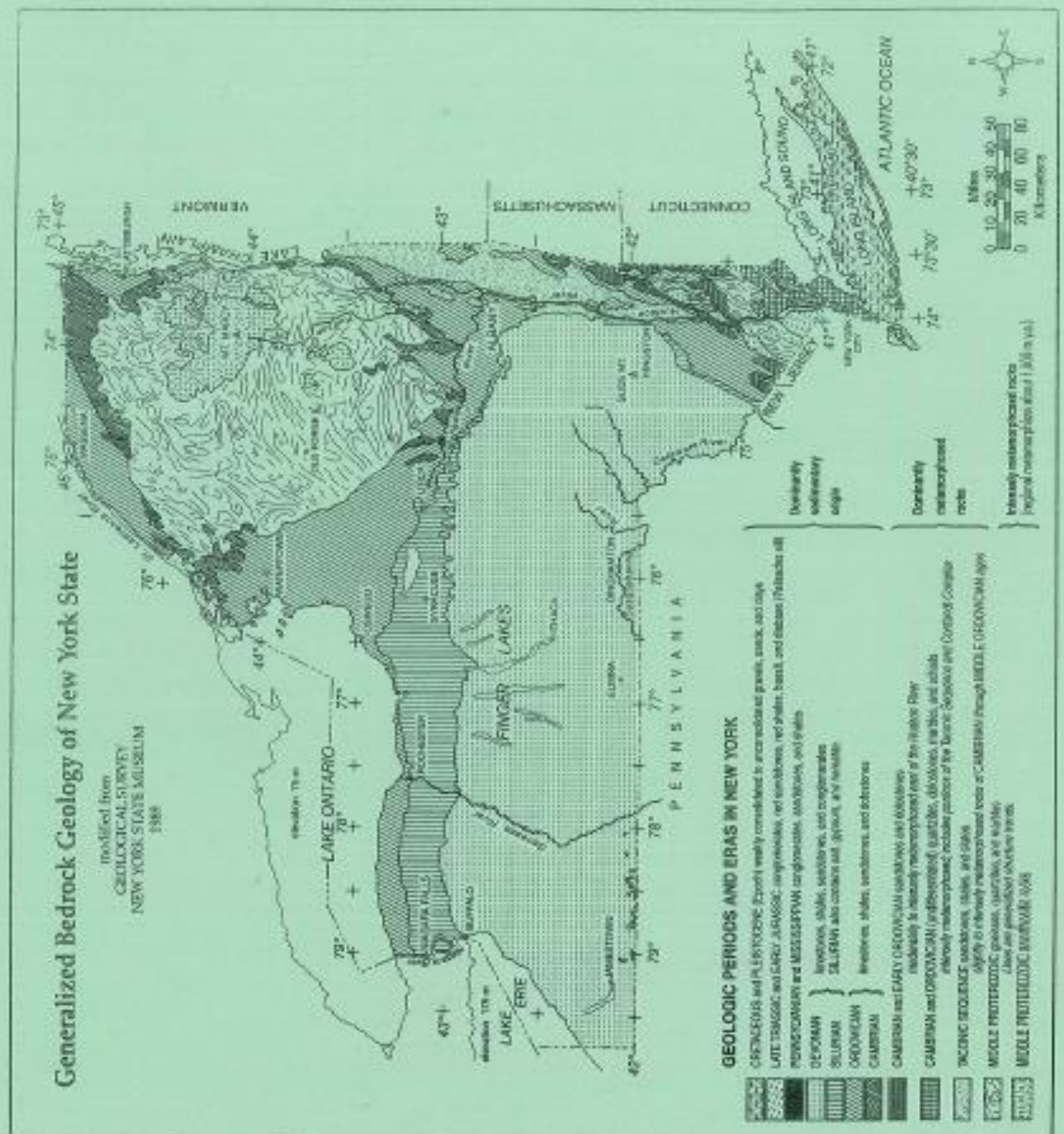
4. What geologic time era does this fossil belong to? Give era and MYA (millions of years ago)

5. Using the information from your fossil and others around you, please describe the environment of this area at the time that these organisms were alive:

6. Why do these organisms no longer exist? (Use the environment around you for supporting details)

Fossils at Deep Run Reference Booklet


GEOLOGIC HISTORY
OF NEW YORK STATE
Eon
Era
Period
Epoch
Life on Earth
Time Distribution of Fossils
Important Geologic Events in New York
Inferred Positions of Earth's Landmasses


Generalized Bedrock Geology of New York State
modified from
GEOLOGICAL SURVEY
NEW YORK STATE MUSEUM
1989
LAKE ONTARIO
LAKE ERIE
FINGER LAKES
PENNSYLVANIA
VERMONT
MASSACHUSETTS
CONNECTICUT
ATLANTIC OCEAN
GEOLOGIC PERIODS AND ERAS IN NEW YORK

Appendix D

Bare Hill Erratic EarthCache

Coordinates: N 42° 44.300 W 077° 18.609

Description: Short (4.5 mile) hike to the top of Bare Hill to for view of Glacial Erratic (Council Rock) and a Canandaigua Lake Valley view. Council Rock was the location of the Seneca Nation council fires, it is of Geologic Interest for the formation of the Finger Lakes area, specifically Canandaigua Lake. The boulder is located on the Bare Hill Unique Area which is now owned by the Department of Environmental Conservation. (http://www.dec.ny.gov/lands/37438.html)

This EarthCache involves a Seneca Nation Legend:

The Serpent of Bare Hill: The Senecas lived in peace until one of the young Seneca boys found a two-headed snake in the woods on Bare Hill, which was called Genundowa by the Natives. At its Summit, 865 feet above the lake, the Seneca Indian held council fires. The young boy made a pet of the snake, named it Osaista Wanna and initially fed it flies and frogs. As the snake grew, he gave it raccoons, squirrels, and woodchucks. Soon he was feeding it large cuts of venison, but the serpent's appetite appeared to be unlimited. The boy could not find enough food to satisfy its appetite and the tribe began to fear it. They suspected that it was a monster. Eventually, the immense snake surrounded the hill. As the people of the tribe attempted to leave the hill to obtain food they were devoured by the large two-headed serpent with the insatiable appetite. Finally, a young brave and his sister were the only remaining members of the tribe. One night the young brave had a dream that if he fletched his arrows with his sister's hair instead of feathers, the arrows would possess a lethal power with which to subdue the serpent. The next day he fired his charmed arrows into the reptile's heart. The snake, which was fatally wounded, writhed in agony as it rolled down Bare Hill. It tore out all of the bushes and trees before finally sliding into the lake while disgorging the skulls of all the Senecas that he had devoured. This is the Native's explanation for the large numbers of round head-shaped stones found at the base of Bare Hill and the absence of large hardwood growth as a climax community.

Adapted from Finger Lakes Unit Storybook by Rob Hughes

See more of the Seneca Nation Legends here:
http://www.nytimes.com/2006/10/01/travel/01explorer.html?_r=0

Bare Hill is the site of the beginning of the Ring of Fire, a celebration of peace and bountiful harvest by the Seneca Nation. You will see the site of the fire that is lit on Labor Day. The Ring of Fire is now celebrated as the end of summer by cottage owners and back to school time for children.

Questions:

1. The Seneca Nation believed the round boulders at the bottom of Bare Hill were the skulls of people who were eaten by the large serpent. Propose a geologic based explanation for the round boulders.

2. At the site of the first coordinates, you have an amazing view of the North End of Canandaigua Lake. Is the valley U-Shaped or V-Shaped? What does that tell you about its creation?

3. At the second coordinates you can see an area where fires are held. This place is the beginning of the Ring of Fire every year. (click here to learn more about the Ring of Fire). Why might this be a good place for the Natives to begin the Ring of Fire?

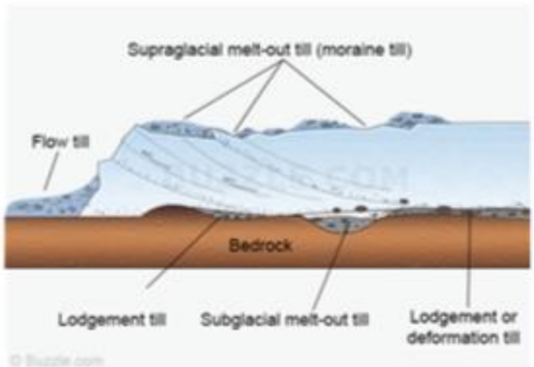
4. At the second coordinates lays Council Rock. Is this boulder a sedimentary, igneous or metamorphic rock? How can you tell?

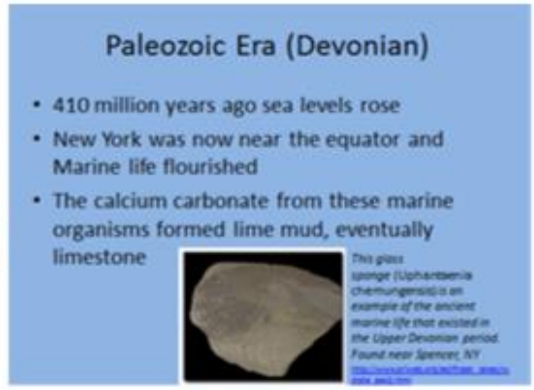
5. Council Rock is an excellent example of a Glacial Erratic, explain how this boulder helps explain the formation of the Finger Lakes.

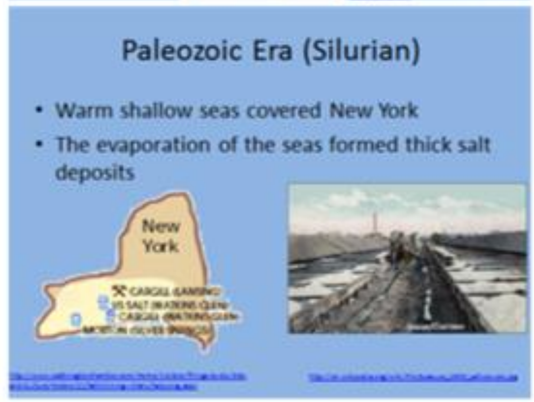
6. Take a picture with the boulder and submit it!

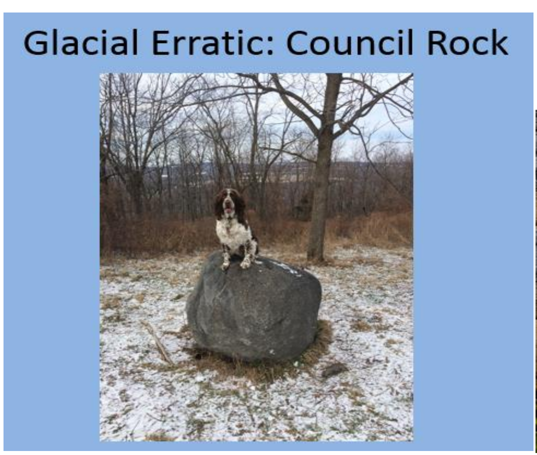
Appendix E

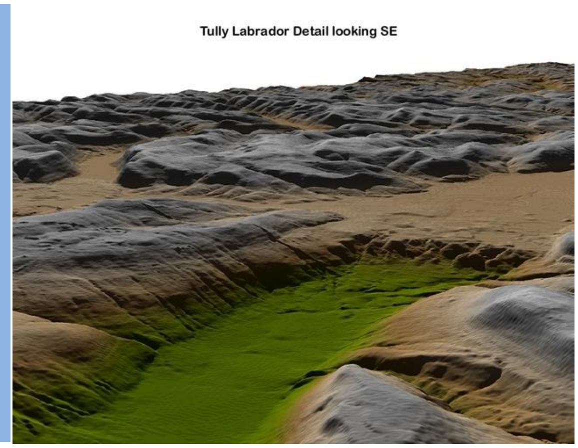
Example Slides from Traditional Methods

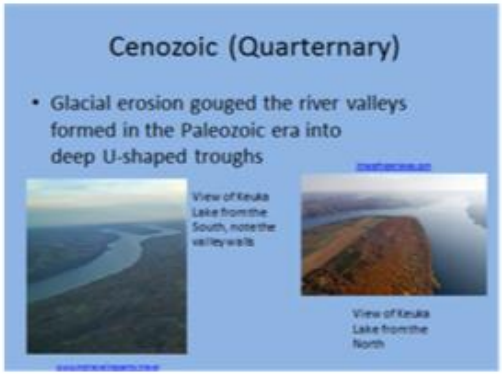


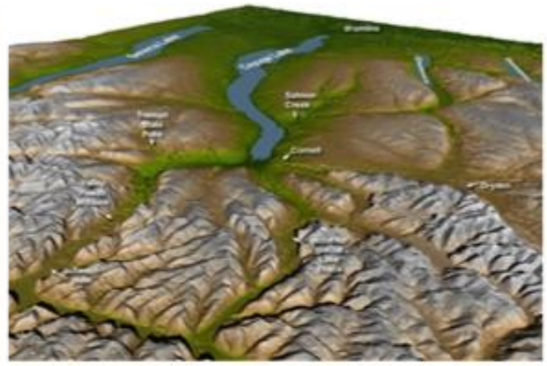


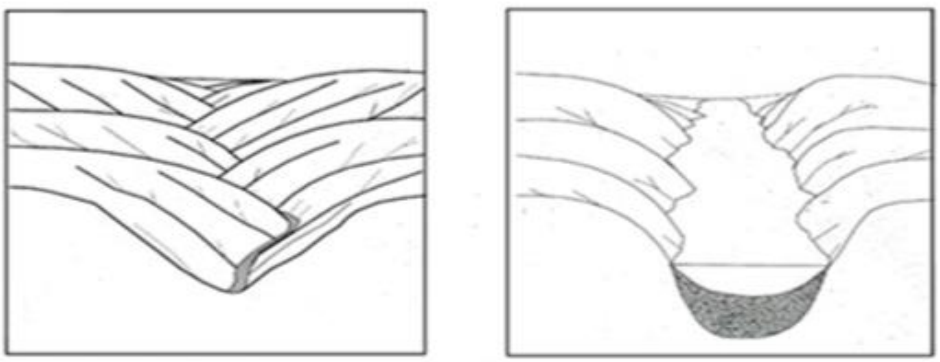












The streams and rivers of the Finger Lakes region were scoured by advancing glacier, creating characteristic U-shaped glacial valleys. Today the Finger Lakes exist in those valleys.

Appendix F

Geologic Time on Football Field

Understanding Geologic Time

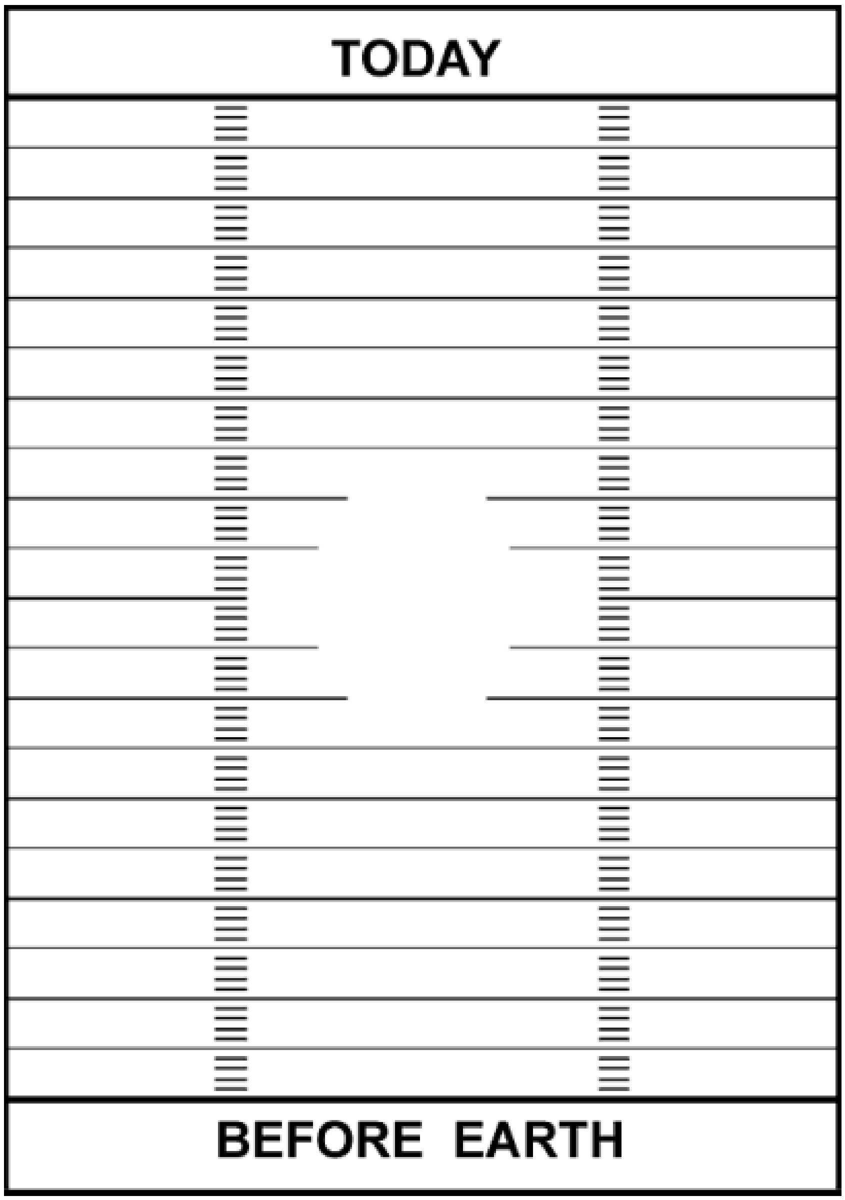
Geologic Time Activity Worksheet

Instructions

Go to http://pubs.usgs.gov/gip/fossils/numeric.html and use the geologic time scale to find the missing dates and fill in the blanks under the Approximate Age category. Next, calculate the corresponding distance on a football field that each event represents and fill in the blanks under the Distance category. For this activity, 1 yard = 50 million years. Mark the events on the Geologic Time Football Field. One end zone is labeled "TODAY" and the other is "BEFORE EARTH." As you place your events on the football field, pay close attention to which end is which. Place events at the nearest yard.

Geologic Event	Approximate Age	Distance (yds)
Rocky Mountains are formed	80 million years	
First known fish	510 million years	
Paleozoic Era begins		
Earliest humans	2 million years	
Formation of the Earth	4.6 billion years	
First known mammal	200 million years	
Proterozoic Eon begins		
First single-celled organism	1.2 billion years	
Columbus discovers America	506 years	
Oldest rock	3.8 billion years	
Extinction of the dinosaurs	65 million years	
First known plant	498 million years	
First known reptile	325 million years	
First multi-celled organism	700 million years	
First known amphibian	375 million years	
First known bird	160 million years	

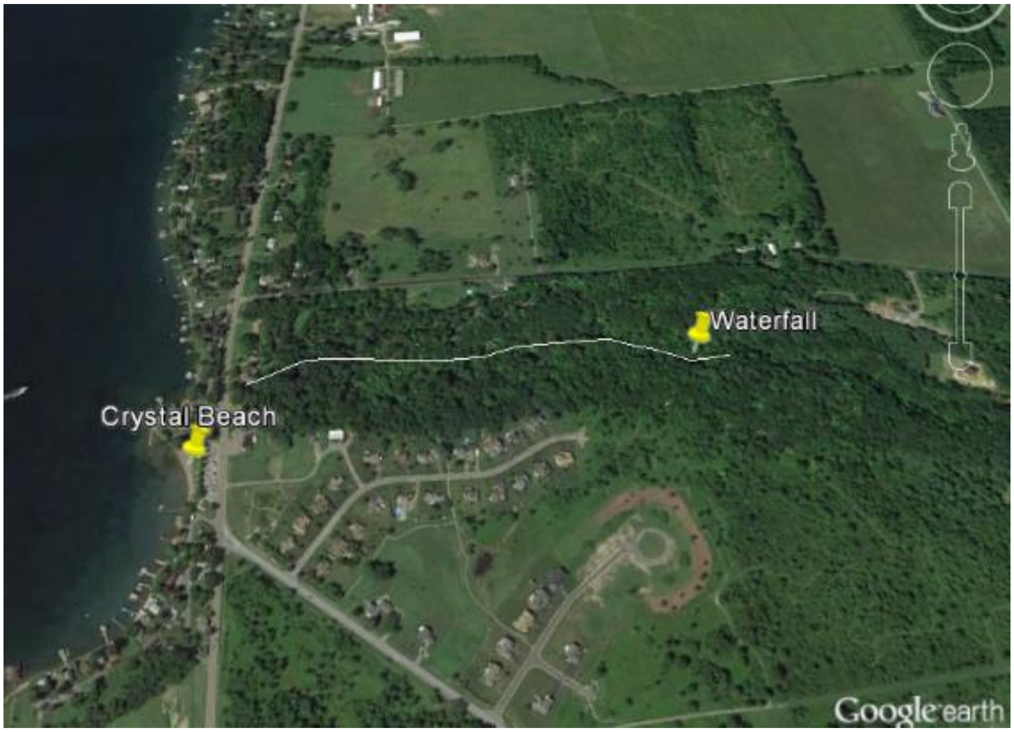
Geologic Time Football Field



Appendix G

Pictures of EarthCache Locations

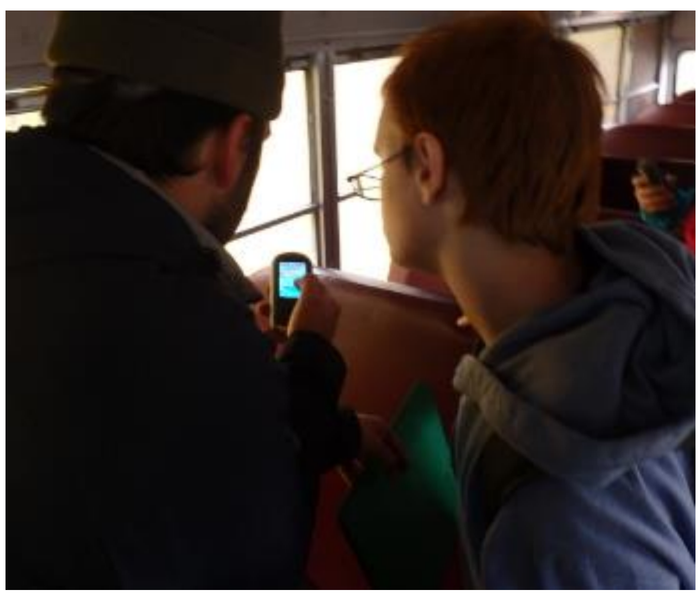
Locations of the two EarthCaches (Crystal Beach and Council Rock) along with the West River in the Middlesex Valley. Penn Yan Academy is the school the participants attend daily.



EarthCache Location 1: Fossils at Crystal Beach (Deep Run Cove)

Fossils from the Devonian Era found in rocks at Deep Run Cove

EarthCache Location Two: A glacial erratic (Council Rock) found on Bare Hill



Setting up a GPS with a student at Bare Hill

Students using GPS's to find the location of Council Rock

Students find Council Rock

Location Number 3: West River in the Middlesex Valley. Views of U-shaped valley, northward flowing river and similarities to other Keuka Lake

Location Number 4: Northward views of Canandaigua Lake from Conklin's Gully.