Real Science:

How an Authentic Context for Learning Connects Students, Teachers, and Researchers in Inquiry-based Science

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Abstract

With the emphasis on inquiry-based science in the National Science Education Standards, classroom teachers increasingly seek to engage students in the exploration, questioning, and evidence-based argumentation that characterize research science. One way to strengthen connections between classroom learning and “real-world” science is through a formal partnership among educators and scientists. This inquiry uses the case of “Fossil Finders,” a pilot curriculum based on an authentic geological investigation, to explore how a science education partnership can impact student engagement, learning, and understanding of the nature of science, as well as teacher comfort with inquiry in the classroom.
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Context

This inquiry takes place in the context of a fifth-grade classroom where twenty-one (21) students recently learned about geology and the fossil record through a unique science education partnership. The classroom is located at Park Forest Elementary School (PFE) in the State College Area School District (SCASD) of central Pennsylvania, where I currently serve as an intern in the Penn State / SCASD Professional Development Schools program. The State College Area School District strongly supports inquiry-based science and has recently revised several science units to incorporate more inquiry into elementary classrooms. Located near Penn State University, the district also demonstrates a commitment to merging theory and practice to improve student learning, as evidenced by its nationally recognized professional development schools program and other educational collaboratives.

In early 2009, the mentor teacher in my fifth-grade partner classroom at PFE was accepted for participation in a science education partnership among the Cornell University Department of Education, the Paleontological Research Institute (PRI) of Ithaca, New York, and fifth-grade through ninth-grade classroom teachers around the country. Aiming to engage elementary and middle school students in authentic geological research, this partnership combines professional development for classroom teachers, a curriculum unit tied to a “real-world” paleontological investigation, and an interactive website for students to share data and communicate with scientists. The pilot curriculum, entitled “Fossil Finders,” uses the study of Devonian fossils from the Finger Lakes region of New York as the foundation for inquiry-based classroom learning about geology (Cornell University, 2009). Students focus their inquiry around the question: “How does sea life respond to changes in the environment?”
During the summer of 2009, my mentor teacher participated in a weeklong professional development course at an outcrop site in Ithaca. Working with Cornell and PRI faculty and staff, as well as fellow classroom teachers, she developed extensive content knowledge related to the curriculum by finding, identifying, and measuring fossils. She then introduced the Fossil Finders curriculum to her students in November 2009 and, with my assistance in planning and teaching, continued the investigation through February 2010. As the SCASD fifth-grade curriculum includes a unit entitled “Geological Processes,” my mentor taught the district geology unit concurrently with the Fossil Finders curriculum. During this period, the other fifth-grade classes at PFE completed the Geological Processes unit without the addition of the Fossil Finders curriculum or investigation.

The students in this classroom exhibit a wide range of science interest and ability, with several who actively pursue science learning outside of school and others who demonstrate only minor interest in fifth-grade science topics. Examples of the former group include a student who collects fossils and reads extensively about geology and paleontology, a student who has attended geology camps and maintains a rock collection, and a few students who have expressed interest in careers in science. The latter group, despite self-described lack of interest in science, does contain several students who excel in the subject. By bringing Fossil Finders to the classroom, my mentor teacher hoped to achieve increased motivation and learning in geology among her students, crossing their varied levels of interest and ability. By examining the use of a science education partnership in this context, I hoped to learn whether relating classroom science to “real-world” research would help students connect their innate curiosity about the natural world with the methods scientists use to answer authentic questions.
Wondering

My inquiry question grew from comparing the Fossil Finders curriculum to my own elementary science learning, in which I had experienced a disconnect between my wonderment in exploring the natural world and the emphasis on the rigid “scientific method” that I had encountered as a science student. By exploring Fossil Finders in action, I sought to learn whether developing a science education partnership in an elementary classroom would engage learners by allowing them to solve authentic problems with “real” scientists and make connections between their own curiosity and what it means to “do science.” Conversely, I wondered whether the duration and data requirements of real-world research would serve to demotivate elementary learners and reinforce student notions of science as external, artificial, and irrelevant to their learning. Since my preliminary research on science education partnerships had revealed a wide variety of forms for such collaboratives – from consulting relationships between teachers and scientists, to resident scientists in the classroom, to partnerships with local museums and private companies (Black, S., 2006; King, M.D. & Bruce, M.C., 2003; Weaver, A.J. & Mueller, A., 2009) – I also wondered which characteristics of a science education partnership were most influential in enhancing classroom inquiry and student learning. Ultimately, I was interested in whether developing such partnerships would be a worthwhile enterprise that could help me become a more effective science teacher in my own classroom. As a result, I settled on the following open-ended wondering that would allow the data to speak for themselves:

What happens when the local science curriculum is connected to “real-world” scientific research in a fifth-grade science education partnership?
However, to focus my data collection and analysis, I also developed the following key sub-questions:

- *How does a “real-world” context for science teaching impact student engagement in classroom science?*

- *How does a science education partnership enhance teacher comfort with inquiry in the classroom?*

- *How do students who experience contact with “real” scientists in the classroom understand the nature of science?*

- *How does participation in a science education partnership impact student ability to make meaningful connections between research questions and data?*

**Data Collection**

As Fossil Finders had commenced in the classroom prior to my beginning a formal inquiry, I utilized existing video data and student work products from the first six weeks of the unit as my baseline evidence. I began collecting additional data to address my sub-questions approximately halfway through the unit. I worked to employ a variety of collection methods – including video recordings, student work products, student surveys, teacher interviews, and student interviews – that would provide multiple sources of objective and subjective data over the course of the unit.

Video evidence provided the most complete picture of student, teacher, and scientist interactions during the unit. I obtained complete video recordings of multiple class periods, including introductory lessons on the research question and the nature of science, early activities on making observations and interpreting evidence, and culminating work periods for collecting, inputting, and analyzing data from fossils. My purposes in using video evidence were to make anecdotal observations of student engagement during the unit and to identify critical incidents in which interactions among student(s), teacher, and scientist impacted both student learning and teacher comfort with inquiry.
From several of the lessons for which I obtained video recordings, I also collected student work products, which provided additional perspectives on the same activities. First, I chose worksheets from an early lesson called “Tricky Tracks” that required students to write observations and interpretations of three images of animal tracks, revealed one at a time to complete a picture (see Appendix A-1). Second, I selected worksheets from a lesson called “Investigating Fossils” that required students to write quantitative and qualitative observations of sample fossils and sketch interpretations of how the fossilized organisms might have looked when alive (see Appendix A-2). Third, I obtained the final student work product of the unit, in which students completed an open-ended assignment of analyzing and interpreting class fossil data to answer the unit research question (see Appendix A-3). By collecting these artifacts, I intended to explore change over time in student understanding of the nature of science and the connections between research questions and data.

In addition to video recordings and work products, I designed multiple tools that allowed students to provide subjective input on the unit from their own perspectives, including a multiple-choice survey, a short-answer unit reflection, and open-ended interview questions. The student survey (see Appendix B-1), conducted approximately halfway through the unit, was administered to all students in both the Fossil Finders classroom and another fifth-grade classroom at PFE. This provided a comparison of self-reported student engagement in classrooms with and without the Fossil Finders curriculum (Barnegat Township Schools, 2009). Based on survey responses in the Fossil Finders classroom, five students who represented various levels of engagement were selected for follow-up interviews. The interview questions (see Appendix C-1) addressed not only factors affecting engagement, but also student understanding of the nature of science and the connections between research questions and data. The short-answer unit reflection (see Appendix B-2),
administered at the end of the unit in the Fossil Finders classroom only, invited students to share specific features of the curriculum that had impacted their engagement.

My final method of data collection involved interviews with teachers in both the Fossil Finders classroom and another fifth-grade classroom at PFE (see Appendices C-3, C-4). I also conducted a third in-depth interview with the Fossil Finders staff scientist who had conducted teacher professional development in Ithaca and had visited PFE to work with students during the unit (see Appendix C-5). These interviews were intended to provide additional perspectives on student engagement and understanding, as well as to reveal key features of a science education partnership that affect teacher comfort with classroom inquiry.

**Data Analysis Process**

My first step in analyzing the data was to explore student engagement by scoring and comparing survey responses between the Fossil Finders classroom and the other fifth-grade respondents (see Appendix B-3). I also created a spreadsheet to look for correlation among responses on the survey and answers to questions on the unit reflection (see Appendix B-4). I then examined video recordings and transcripts of student interviews to substantiate the survey findings and identify any themes in factors affecting engagement. In particular, I looked for critical incidents in which the “real-world” context or research question for the unit appeared to impact student engagement (see Appendix D-1).

Next, to analyze the effect of the partnership on teacher comfort with inquiry, I first reviewed notes from the interview with my mentor teacher for her reported level of comfort and the key features of Fossil Finders that she felt had impacted it (see Appendix C-3). Then, to substantiate her self-reported data, I looked for evidence of her comfort with inquiry among the video recordings of lessons and the assignments that she had designed for students.
(see Appendices D-1, A-3). As a final analysis method, I reviewed notes from the interviews with the second fifth-grade teacher at PFE and the Fossil Finders scientist to determine whether other classroom teachers had reported similar features of science education partnerships that impact teacher comfort with student inquiry (see Appendices C-4, C-5).

Finally, I sought to determine whether students had, in fact, grown in their understanding of the nature of science and their ability to make connections between the research question and their data. To do so, I identified baseline levels for these sub-questions by examining student work products from “Tricky Tracks” and “Investigating Fossils” (see Appendices A-1, A-2) and by reviewing video recordings of the introductory lessons. Then, to determine change over time, I compared the baseline levels with video evidence from later lessons and the final student work product of the unit, which I assessed using a rubric (see Appendices D-1, A-4). After establishing evidence of growth, I reexamined video recordings, student interviews, and unit reflections to identify critical factors that may have been influential.

**Explanation of Findings**

After analyzing my data in the context of my sub-questions, I discovered strong evidence to support three claims about the effects of connecting elementary science curriculum to “real-world” science through this particular science education partnership.

**Claim #1: When given a “real-world” context for studying science, students demonstrate a high level of engagement and enthusiasm for learning, but may also encounter a mismatch between expectations and experience.**

Within the Fossil Finders classroom, the majority of students self-reported positive attitudes toward science and the unit lessons, on both the mid-unit science attitude survey and the end-of-unit reflection. On the science attitude survey, 53% (10 students) reported
that they “really enjoyed the work” (score of 5) and 37% (7 students) reported that they “paid
attention” (score of 4), with only the remaining 10% (2 students) “doing what [they] had to
[to] get by” (score of 3). None reported being “bored” with the unit (score of 2) or getting “in
trouble” for not completing work (score of 1). On the unit reflection, over 71% of students
reported that they “loved” or “liked” the unit and found Fossil Finders “a lot better” or
“better” than other science units (scores of 5 and 4, respectively). Less than 29% reported
finding Fossil Finders “OK” and “about the same” as other units (scores of 3), and only one
student reported liking the unit “less” than other units (score of 2) (see Appendices B-3, B-4).

Comparing responses from the Fossil Finders classroom to another classroom where
geology was studied without a “real-world” context, scores on the mid-unit survey were
consistently higher in the Fossil Finders classroom. The average difference in scores between
classrooms was 0.5 points on a scale of 1 to 5, and twice the number of students working with
Fossil Finders (10 students) as with the standard unit (5 students) reported that they
“enjoyed the work” (score of 5). On the open-ended question where students could select up
to five favorite parts of studying science (see Appendix B-1 Question #12), students in Fossil
Finders selected an average of one more favorite part than students in the other classroom.

It is important to note, however, that even within the Fossil Finders classroom,
students exhibited a range of interest levels and attitudes in their self-reported data. As a
result, I examined the evidence from student follow-up interviews and video recordings not
only to substantiate the overall pattern in the survey data, but also to determine key factors
that led to diverse levels of engagement among students in Fossil Finders. From the
interviews, I determined that all students in my sub-sample found the data collection lessons
(in which they had examined rocks to identify fossils and logged fossil data into the online
database) to be the most engaging portion of the unit. Nevertheless, these students chose
different responses on their surveys and reflections based on how well the experience had aligned with their expectations. For example, the student who reported liking the unit "less" than other science units explained that she had wished there were *more* hands-on activities with fossils. Another student responded that the data collection was “frustrating” because her rocks did not have a lot of fossils, but that she had enjoyed an earlier opportunity to examine a collection of previously discovered fossils (see Appendix C-2). The video recordings of the lessons validated these findings by offering anecdotal evidence of student engagement that spanned the unit from introduction of the question through data collection and interpretation. On one side, video evidence confirmed student enthusiasm associated with the “real-world” context, including both helping scientists answer their research question (“They’re depending on us?”) and discovering new fossils (“I’m finding interesting layers!”). On the other side, recordings also provided evidence of student engagement falling when expectations for data collection were not met (“I don’t have fossils in any of these!”) (see Appendix D-1).

Seeing recurring patterns in multiple sources of data allows me to make the strong claim that providing this “real-world” context for studying science is associated with positive attitudes toward science and high levels of enthusiasm among most students. However, because this type of engaging context is also associated with high expectations among students, students may find a mismatch between their personal expectations and the realities of data collection, leading to potential disappointment or disengagement.

**Claim #2: A science education partnership is effective in increasing teacher comfort with inquiry when it bridges the gap between science and education by addressing both content and pedagogy.**

When reviewing interview transcripts of teachers and scientists describing science education partnerships, I identified a prominent theme across responses: *not all partnerships*
are created equal. While many formal and informal partnerships between teachers and scientists result in increased content knowledge for the classroom teacher, my mentor found Fossil Finders to be more effective in cultivating inquiry because it teamed educators and scientists to address both content and pedagogy in curriculum design (see Appendix C-3). My mentor explained that the professional development opportunities and curriculum design of Fossil Finders reinforced her understanding of the importance of coupling explicit instruction with student exploration in classroom inquiry. She also stated that Fossil Finders enabled her to scaffold the inquiry in a way that “led to productive science talks in which students drew their own reasonable conclusions” (Cody, J., personal communication, 2010).

I found evidence of this scaffolded approach to inquiry in multiple video recordings and unit work products, as both the classroom teacher and scientist modeled and guided students in first thinking about what they knew, then using what they knew to engage in scientific observation and analysis, and finally sharing what they learned through collaboration and argumentation (see Appendix D-1). This evidence of teacher comfort with scaffolding inquiry culminated in the final assignment, when the classroom teacher modeled and guided students in interpreting data from the database, then invited them to work in pairs on open-ended exploration, explanation, and argumentation of their data (see Appendix A-3).

My findings from recordings, work products, and interviews within the Fossil Finders classroom were bolstered by interviews with another fifth-grade teacher at PFE and a scientist from the Fossil Finders program. The other classroom teacher stated that, when seeking partnerships to improve science teaching, she is “more likely to reach out to science teachers than scientists” in order to find a balance between content knowledge and elementary teaching methods (Cullin, E., personal communication, 2010; see Appendix C-4). She also explained that, even though she has in-depth content knowledge of geology, she feels
that she still needs guidance on “how to make it real, hands-on, and inquiry-based” for students (Cullin, E., personal communication, 2010; see Appendix C-4). The visiting scientist suggested that Fossil Finders is effective because it combines multiple types of professional development for teachers, including opportunities to gain content knowledge, engage in research, and explore curriculum. In his own research, he has found that a key predictor of teacher comfort with inquiry is the teacher’s level of pedagogical content knowledge, or ability to translate content knowledge to students in effective ways (Shulman, L., 1986; Capps, D., personal communication, 2010). By teaming educators in the Cornell University Department of Education with scientists at the Paleontological Research Institute, the Fossil Finders program brings together content knowledge, classroom experience, and reflective practice in a developmentally appropriate curriculum (see Appendix C-5). The recurrence of this theme throughout teacher and scientist interviews and corroborated by data from the classroom provides strong evidence that effective science education partnerships address both content and pedagogy.

Claim #3: When students engage in the processes of scientific exploration and argumentation, particularly when doing so alongside scientists modeling these processes, students deepen their understanding of the nature of science and develop their ability to make meaningful use of data.

Near the end of the Fossil Finders unit, I conducted in-depth interviews with five individual students and collected student work products from the final data analysis assignment. In reviewing these summative data sources, I was struck immediately by both the sophisticated explanations that students provided for “what it means to... do science” (see Appendix C-1 Question #6) and the independence students demonstrated in analyzing and interpreting their fossil data (see Appendix A-3). During the interviews, several students astutely described science as a process of asking questions, collecting and interpreting data to
answer questions, and engaging in argument with other scientists to find better or best explanations of data. Several students also articulated that scientific knowledge is constantly changing based on new evidence ("discoveries") and argumentation among scientists with different interpretations of evidence ("I had my own reason, she had her own reason, and then I was thinking of that’s like how scientists do: all these people might have different reasons but they have to, like, bring it all together") (see Appendix C-2). I was similarly impressed when I analyzed the final, open-ended assignment on data interpretation and found that, according to my rubric, 75% of students had made meaningful use of the fossil data in the online database to support their hypotheses of how “sea life responds to changes in the environment” (rubric scores of 2 or 3 on a scale of 1 to 3) (see Appendix A-4). Through their choices of using numerical and graphical representations of data, diagrams of rock layers representing different time horizons, and written explanations of hypotheses and evidence, the majority of students demonstrated the ability to navigate the database, extract significant information and patterns, and connect findings to the main research question (see Appendix A-3).

Given this demonstrated understanding of the nature of science at the end of the unit, I chose to examine baseline data to look for evidence of student growth over time. Early in the unit, students had completed a lesson specifically focused on describing the “nature of science” and observing / interpreting data. Video evidence of this lesson revealed that students had struggled to articulate the nature of science and required multiple leading questions from their teacher to express how scientists “figure out the way the world works.” Although students eventually contributed terms and phrases like “estimating,” “making hypotheses,” “researching,” and “using what they know,” they required significant teacher facilitation and did not mention collaboration and argumentation as important aspects of
science (see Appendix D-1). Video also indicated that students initially perceived data as clues to finding the “right” answers to questions, with an emphasis on competition among scientists. When their teacher asked what might happen when scientists have differing interpretations of evidence, multiple students responded, “They fight!” (see Appendix D-1). When compared with the responses and work produced at the end of the unit, this baseline information provides strong evidence of student growth over time in understanding both the nature of science and how scientists use data.

While multiple factors influenced student growth over the course of the unit, video recordings indicate that there may have been “critical incidents” in which lessons or interactions helped students make connections between their own unit activities and what it means to “do science.” I first identified these incidents by exploring recordings from various lessons on data collection and interpretation that students had mentioned in their interviews as having made an impression. Although the lessons differed in content and design, all of them involved students engaging in the processes of scientific exploration and argumentation, following teacher modeling. In particular, when the Fossil Finders scientist visited the classroom, video recordings showed how he continually modeled scientific thinking with students, from connecting prior knowledge to the research context (“How does an ocean go away? What could have happened?”), to pushing questioning and collaboration during data collection (“What would you say it looks most like?”), to making reasonable interpretations of data (“If you were standing in a shallow sea... where would you expect the organisms to be larger?”) (see Appendix D-1). He also modeled the uncertainty, continual questioning, and argumentation that characterize the advancement of science by telling students “people have ideas of what happened” and “sometimes scientists don’t find what they’re looking for” (see Appendix D-1). The evidence from these lessons suggests that the growth identified in
student understanding of the nature of science and ability to make meaningful use of data may be attributable to teacher / scientist modeling and student practice of scientific exploration and argumentation. However, this possibility warrants further study to determine whether other factors in the unit were more influential and whether similar results could have been achieved without a visiting scientist in the classroom.

**Reflection and Implications for Future Practice**

When I began this inquiry, I wondered whether bringing research science to an elementary classroom would engage students through interactions with scientists and “real-world” questions or disengage students due to the stringency of data collection and, in this case, the remoteness of the geologic period. I was surprised to discover, however, that the majority of students found both the interaction with scientists and the data collection experience to be highly engaging contexts for learning. I had also expected teacher comfort with inquiry to be increased merely by having an expert source for developing content knowledge. I learned, however, that an effective science education partnership goes beyond consulting with scientists to integrating scientific knowledge, the process of scientific inquiry, and developmentally appropriate instruction into the science curriculum. Although I discovered that such integration enabled Fossil Finders students to grow in their understanding of the nature of science and their ability to make use of data, I am eager to learn how such a partnership would impact students in different grade levels and other science units. While I am inclined to agree with the program scientist that “a partnership approach... connects learning to real-world questions and can help [students] better understand the nature of science in any discipline” (Capps, D., personal communication, 2010;
see Appendix C-5), I hope to explore partnerships in greater depth to identify the key features that most strongly impact student learning.

I pursued this inquiry primarily to determine whether building science education partnerships could help me become a more effective science teacher, and I believe that my findings offer several implications for my future practice. First, I have learned that providing an authentic context for science learning, connected to the work of “real” scientists, can create high-interest learning opportunities for many students. At the same time, however, I have discovered that high expectations for partnership-based units can also lead to disappointment if students do not find the work as engaging as hoped. As a result, it will be important for me to maintain engagement by ensuring that all students have some role in class “discoveries,” by gauging levels of interest throughout the unit and adjusting lessons or work groups to prevent disengagement, and by modeling and debriefing data collection experiences where classroom “scientists” do not find what they had expected.

Second, I have learned that building an effective science education partnership requires more than consulting an expert on the unit topic. Teacher comfort with inquiry in the classroom increases from building not only knowledge of science concepts, but also pedagogical content knowledge that allows such information to be translated effectively to students. As a result, if I choose to seek out science education partnerships for my classroom, I must work to partner with both scientists and science teachers in order to increase my content knowledge and guide student inquiry in developmentally appropriate ways.

Finally, given the tremendous growth shown by students in understanding the nature of science and making meaningful use of data, I have learned that creating effective science education partnerships can positively impact student learning in my classroom. As my evidence indicates that practicing scientific exploration and argumentation may increase
student understanding of science, I plan to use future partnerships to inquire into curricular features and teaching strategies that facilitate these processes. While participating in Fossil Finders required significant time, effort, and commitment on the part of all scientists and educators involved, my findings in this study suggest that an effective science education partnership can result in heightened student engagement, enhanced classroom inquiry, and increased science learning that are well worth the investment.
REFERENCES


APPENDIX A

Student Work Products
Tricky Tracks

Part 1
Directions- Observe the diagram. Make a list of your observations below.

- Two animals walking; one lifeform is bigger than the other, walking slowly.
- Footprints not walking straight, not humans.

What do you think is happening in this diagram? Use your observations to make a prediction (interpretation).

Two animals are walking somewhere but not in a hurry. One of the animals is on hind legs.

How does your prediction differ from your neighbors? Why do you think there is more than one interpretation for the same picture?

Part 2
Directions- Observe the diagram again. Make a list of your new observations below.

- The animals got close to each other.
- Two sets of footprints got messed up.
- The animals start to walk up.

Now, what do you think is happening in this diagram? Has your original interpretation of the diagram changed?

Use your new observations to revise your prediction (interpretation).

The big animal is chasing a smaller animal because it wants to eat it but the big animal can't catch the small animal so the small animal is taunting the big animal.

Created by: Michelle Dormitzer Fall 2008
Part 3-

Use your observations to tell the story of these footprints. Here are some points to think about as you reconstruct the scene. Use your previous observations to make inferences as you think about some of these questions while telling your story:

-In which direction could the animals be moving? Do you think they were walking fast or slow? Why? Based on what you know about making footprints how might the environment have looked in order for the tracks to have been preserved? Do you think there is enough evidence (from your observations) to suggest these footprints were made by the same species of dinosaurs? Is it possible these dinosaurs could have had different feeding niches? Which of your observations leads you to that conclusion?

I think that the little dinosaur was just walking up towards a cave when the big dinosaur was sneaking up behind the small dinosaur. When the little dinosaur heard the big dinosaur and started going a little faster, then the big dinosaur saw the little one and sped up. Then boom, the two of them went into each other and the big dinosaur caught the little dinosaur, was eaten up and the big dinosaur felt much more satisfied.

Created by: Michelle Dormitzer Fall 2008
A Paleontologist - A paleontologist studies the remains of ancient organisms to learn about the past. 

1. Look at the rock at your station and record as many **qualitative and quantitative observations** as you can. You may use the tools to help you make more accurate observations.

<table>
<thead>
<tr>
<th>Qualitative</th>
<th>Quantitative</th>
</tr>
</thead>
<tbody>
<tr>
<td>2&quot; in length</td>
<td><em>multiple shells</em></td>
</tr>
<tr>
<td>2/3&quot; in width</td>
<td><em>shells are shuttered</em></td>
</tr>
<tr>
<td>0.78 oz.</td>
<td><em>rock is thin</em></td>
</tr>
<tr>
<td></td>
<td><em>shell imprints</em></td>
</tr>
<tr>
<td></td>
<td><em>made of shale</em></td>
</tr>
</tbody>
</table>
2. Use this space to draw a picture by making an inference about what the organism(s) in your rock may have looked like when it was (they were) alive. Be sure to include its natural environment.

![Shell with clam inside diagram]

3. What made you draw the organism the way you did? How did you decide what the natural environment of your organism was?

I had shell in on soil so I knew I should make it on the sea floor. I drew the shells apart from each other because in the past they use to scattered apart.

Uniformitarianism: It's a change that happened a long time ago that is still happening today. Like earthquakes, volcanoes, and mountains.

4. How old are the fossils found in the rocks you observed? 1 million year

5. Use the timeline to make some observations about the history of life on earth. Discuss your observations with your neighbor. Use this space to organize your thoughts.
How does sealife respond to changes to the environment?

<table>
<thead>
<tr>
<th>Clam Median Size</th>
<th>Brachiopod Size Median</th>
</tr>
</thead>
<tbody>
<tr>
<td>Horizon 2: Clam size 36 mm</td>
<td>Horizon 2: 28 mm</td>
</tr>
<tr>
<td>Horizon 4: Clam size 168 mm</td>
<td>Horizon 4: 56 mm</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Average Fragmentation</th>
<th>Average Rock Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>Horizon 2: 2.9</td>
<td>Horizon 2: 3</td>
</tr>
<tr>
<td>Horizon 4: 2.6</td>
<td>Horizon 4: 2.8</td>
</tr>
</tbody>
</table>

Hypothesis:

Fragmentation: The average rock fragmentation got smaller because the sediment builds up because it has no Oxygen so it will... NOT move. So it doesn't chip much and on the top water is moving organisms to smash together.

Rock Color: The sediment that built up did not have oxygen and it was a dark color. Also the sunlight hit the top layer but could not go through the sediment. So, Horizon 2 became darker than Horizon 4.
Questions

Why are there more brachiopods and clams found more than any other organism?

Size: The clams and brachiopods got bigger. Because at the top on Horizon 4, they got more food and oxygen, the top didn't have that so that caused the top to get bigger, and the bottom to get a little bigger.

Main Hypothesis: The water pushed the top Horizon so things started to smash together while the bottom couldn't move, and at the top they ate and got bigger and lighter with sunlight while the bottom only had a tiny amount of food and died not have any oxygen or sunlight so they were darker.
<table>
<thead>
<tr>
<th>Data / Hypothesis Link</th>
<th>Data / Wonderings Link</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strong connection w/ few misconceptions = 3</td>
<td>Wonderings clearly connected to data = 3</td>
<td></td>
</tr>
<tr>
<td>Connection but w/ obvious misconceptions = 2</td>
<td>Wonderings loosely connected to data = 2</td>
<td></td>
</tr>
<tr>
<td>Weak or no connection = 1</td>
<td>No wonderings or wonderings not connected to data = 1</td>
<td></td>
</tr>
</tbody>
</table>

1. Copied data, but unclear hypothesis, no wonderings, no connections

1. Hypothesis for size clearly based on data and demonstrates understanding of higher horizons representing younger fossils (rather than individual organisms that “swam up” toward the surface), appeared to run out of time for questions (wrote heading, but blank)

2. Hypothesis for color based on data (lighter in shallow water with more light and oxygen); misconception about organisms “swimming” up to the top and getting bigger because of oxygen; no wonderings

3. Hypothesis about size only, but clearly tied to data (possible misconception about individual organisms changing location versus change over time, but unclear); unique data-based wonderings include why median clam and brachiopod were about the same and why a darker color was recorded in a higher horizon than a lower one

2. Hypotheses for size based on data (larger in shallow water); unclear hypothesis on fragmentation; connected sunlight and water depth to coloration; no wonderings

1. Confusion about fragmentation and attributes color to “darker soil”; wonderings about why clams and brachiopods have the same median size and why the amount of fossils found varied across horizons

3. Clear understanding that horizons represent different time periods and that differences in horizons represent changes in organisms populations and earth processes over time; hypotheses on color and size clearly tied to data (as was fragmentation, but misunderstood the
APPENDIX B

Surveys & Reflections
PART I (Circle your response)

1. How much do you like doing science at school?
   - a whole lot
   - a lot
   - some
   - a little
   - not at all

2. How much do you think you learn about science at school?
   - a whole lot
   - a lot
   - some
   - a little
   - not at all

3. Compared to what you do now, would you like to do more or less science at school?
   - a lot more
   - more
   - about the same
   - less
   - a lot less

4. How often does your class do really interesting things in science?
   - always
   - often
   - sometimes
   - rarely
   - never

5. When it comes to science, I am...
   - excellent
   - pretty good
   - all right
   - not too good
   - struggling

6. How much of your own time (outside of school) do you like to spend learning about science or doing science?
   - a whole lot
   - a lot
   - some
   - a little
   - none

7. Do you want to keep studying science as you get older?
   - definitely
   - probably
   - maybe
   - probably not
   - definitely not

8. Do you think you would make a good scientist?
   - definitely
   - probably
   - maybe
   - probably not
   - definitely not
PART II

9. Looking back at your study of geology and fossils this year, which of the following best describes your personal work? (check only one)

☐ I really enjoyed the work in my class and did what I was asked because I liked what I was learning. Sometimes I didn’t want to stop because I was so “into it.” I can see how the work relates to my life.

☐ I paid attention because I wanted to get a good grade. I would rather have been learning about other things most of the time, but I finished the work I had to do.

☐ I did what I had to do so I could get by, but I didn’t put in any extra effort. I tried to stay out of trouble.

☐ I was bored and did little work in the lessons. I only worked when the teacher was watching. I did not cause any trouble.

☐ I got into trouble because I did not complete the work I was asked to do.

10. When it comes to science, I like it best when... (check only one)

☐ My teacher tells me what I need to know.

☐ I am able to complete an investigation or experiment and figure out what I need to know.

11. In science, I would rather... (check only one)

☐ Select the topic that I will study.

☐ Have my teacher assign me a topic.

12. My favorite parts of studying science are... (check all that apply)

☐ Being curious and asking questions

☐ Planning experiments to test ideas

☐ Running experiments and collecting data

☐ Analyzing data and drawing conclusions

☐ Applying what I am learning to real life
2009-2010 ~ Student Reflection ~ Fossil Finders Unit

1. Thinking back on the Fossil Finders unit, my overall feeling is that (circle one):

   [I loved it!  I liked it.  It was OK.  I didn’t enjoy it.  I really didn’t enjoy it.]

2. Some things I learned from Fossil Finders were:

   [How to measure fossils and to find out the color of fossils. I also learned to find the different creatures and the periods.]

3. Some things I still do not understand / have questions about are:

   [How do you find out the age of the fossils you find?]

4. Some of my favorite parts of the unit were:

   [When we really got to look at the fossils and break them. It was also cool to hear what Dr. Dan had to say!]

5. Some of my least favorite parts of the unit were:

   [All the work sheets. (Even though most were fun.)]

6. Compared to other science units I have completed, I liked Fossil Finders (circle one):

   [a lot better  better  about the same  less  a lot less]

7. Here are my suggestions for improving the unit:

   [Maybe you could learn about big dinosaurs and see their bones on the computer.]

B-2
### Student Science Attitude Survey Scores

1. **How much do you like doing science at school?**

<table>
<thead>
<tr>
<th></th>
<th>A Whole Lot = 5</th>
<th>A Lot = 4</th>
<th>Some = 3</th>
<th>A Little = 2</th>
<th>Not At All = 1</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cody - 19</td>
<td>//\ = 20</td>
<td>//\ = 32</td>
<td>//\ = 12</td>
<td>// = 6</td>
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<tr>
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</table>

2. **How much do you think you learn about science at school?**

<table>
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<th></th>
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<th>A Lot = 4</th>
<th>Some = 3</th>
<th>A Little = 2</th>
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</thead>
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3. **Compared to what you do now, would like to do more or less science at school?**

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<th></th>
<th>A Lot More = 5</th>
<th>More = 4</th>
<th>About The Same = 3</th>
<th>A Little = 2</th>
<th>Not At All = 1</th>
<th>Average</th>
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</thead>
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4. **How often does your class do really interesting things in science?**

<table>
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<tr>
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<td>//\ = 16</td>
<td>//\ = 24</td>
<td>//\ (+ 2.5) = 12.5</td>
<td>0</td>
<td>3.03</td>
</tr>
</tbody>
</table>

5. **When it comes to science, I am...**

<table>
<thead>
<tr>
<th></th>
<th>Excellent = 5</th>
<th>Pretty Good = 4</th>
<th>All Right = 3</th>
<th>Not Too Good = 2</th>
<th>Struggling Good = 1</th>
<th>Average</th>
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<tbody>
<tr>
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<td>//\ = 36</td>
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<td>0</td>
<td>// = 1</td>
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<td>Other - 19</td>
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<td>//\ = 33</td>
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<td>// = 1</td>
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</table>

6. **How much of your own time (outside of school) do you like to spend learning about science or doing science?**

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<th></th>
<th>A Whole Lot = 5</th>
<th>A Lot = 4</th>
<th>Some = 3</th>
<th>A Little = 2</th>
<th>Not At All = 1</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cody - 19</td>
<td>//\ = 5</td>
<td>//\ = 12</td>
<td>//\ = 33</td>
<td>// = 4</td>
<td>// = 2</td>
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<td>//\ = 15</td>
<td>// = 6</td>
<td>//\ = 6</td>
<td>2.53</td>
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</table>
7. Do you want to keep studying science as you get older?

<table>
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<tr>
<th></th>
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<th>PROBABLY -4</th>
<th>MAYBE -3</th>
<th>PROBABLY NOT -1</th>
<th>DEFINITELY NOT -1</th>
<th>AVERAGE</th>
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</thead>
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<td>= 0</td>
<td>3.03</td>
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</table>

8. Do you think you would make a good scientist?

<table>
<thead>
<tr>
<th></th>
<th>DEFINITE -5</th>
<th>PROBABLY -4</th>
<th>MAYBE -3</th>
<th>PROBABLY NOT -1</th>
<th>DEFINITELY NOT -1</th>
<th>AVERAGE</th>
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</thead>
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</table>

9. Looking back at your study of geology and fossils this year, which of the following best describes your personal work? (check only one)

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<th></th>
<th>1</th>
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<th>3</th>
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<td>= 4</td>
<td>// = 4</td>
<td>0</td>
<td>4.03</td>
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</tbody>
</table>

10. When it comes to science, I like it best when...(check only one)

<table>
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<th></th>
<th>FIGURE OUT -5</th>
<th>TEACHER TELLS -1</th>
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11. In science, I would rather...(check only one)

<table>
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</tr>
<tr>
<td>OTHER -19</td>
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<td>= 2</td>
</tr>
</tbody>
</table>

12. My favorite parts of studying science are...

<table>
<thead>
<tr>
<th></th>
<th>Multiple Answers Allowed (Each = 1)</th>
<th>Being Curious / Asking Questions</th>
<th>Planning Experiments to Test Ideas</th>
<th>Running Experiments / Collecting Data</th>
<th>Analyzing Data / Drawing Conclusions</th>
<th>Applying to Real Life</th>
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<td>////////// = 6</td>
</tr>
<tr>
<td>Reflection #1 (overall FF)</td>
<td>Reflection #6 (comparison)</td>
<td>Survey #7 (study older)</td>
<td>Survey #8 (good scientist)</td>
<td>Survey #9 (personal work)</td>
<td>Survey #12 (favorites)</td>
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</tr>
<tr>
<td>---------------------------</td>
<td>---------------------------</td>
<td>------------------------</td>
<td>---------------------------</td>
<td>---------------------------</td>
<td>------------------------</td>
<td></td>
</tr>
<tr>
<td>Loved it = 5</td>
<td>A lot better = 5</td>
<td>Definitely not = 5</td>
<td>Definitely not = 1</td>
<td>Got in trouble = 1</td>
<td>A = Questions B = Plan experiments</td>
<td></td>
</tr>
<tr>
<td>Really didn't enjoy it = 1</td>
<td>A lot less = 1</td>
<td>Definitely not = 1</td>
<td>Definitely not = 1</td>
<td>Got in trouble = 1</td>
<td>C = Experiment / collect data, D = Analyze data, E = Apply to real life</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>4</th>
<th>3</th>
<th>2</th>
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<th>D, E</th>
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APPENDIX C

Interviews
STUDENT INTERVIEW QUESTIONS

1. On your reflection, when asked how Fossil Finders compared to other science units, you responded that it was “______”. Please tell me what made Fossil Finders “______” in your opinion.

2. In this unit, you learned about fossils and the geologic timeline. How interested were you in learning about these topics, as compared to learning about ecology and the animal kingdom? Did your interest level change at all throughout the unit? Was there anything in particular about this unit that did / did not peak your interest?

3. On your reflection, you mentioned that you really liked _______. Please tell me about this experience.

4. On your reflection, you mentioned that you really did NOT like _______. Please tell me about this experience.

5. On your reflection, you suggested that we change _____ for the future. Please tell me more about this suggestion.

6. In this unit, you had opportunities to think and act like a scientist, as well as to meet scientists from Cornell. After these experiences, please tell me how you would explain to someone what it means to “be a scientist” or to “do science.”

7. When you completed the Science Attitude Survey, you responded that you would _______ want to keep studying science as you get older and that you would _______ make a good scientist. Tell me about your thinking.

8. During this unit you had opportunities to collect data. Tell me how the data you and your classmates collected from the fossils will help answer the question “how does sea life respond to changes in the environment?”

9. During Dan’s visit and your final activity (show work product), you also had opportunities to interpret data. Tell me about these experiences. Please feel free to refer to your work.
...a lot better

Well, other ones we usually learn about volcanoes and everything, but we don’t do as much as, like, people don’t come and help us, we don’t break rocks. We learned a lot when we got the computers, we don’t really get to do that with any other science unit.

...interest

For fossils, there’s like so much more to learn. There might be so much other animals and environments that we don’t even know today. So, like, if one person finds it and then they actually get to, like, you don’t know what it is, it’s like when you get to look in the booklet, it’s like, what is this, I don’t know, and if you’re the first one to find it, you might even get to name it by yourself. I’m more interested [in this].

...favorite (computer) / least favorite (none)

That’s because we did a lot of research... We got to measure them, we got to see what color they are, and it actually felt like we were real geologists. / No, I actually liked all of them.

...scientist (definitely, probably)

Well, I wanted to – one of the things I’ve always wanted to do, like when I was little, is discovering something new. And then, like, when we did fossils, I was like thinking, if someone gets it, they get to do all these stuff with it. They can tell it to everyone else, and they’re gonna be, like, oh my god, great job finding this. We don’t know what it is, we can do some research and figure it out.

...do science

To be a scientist is discovering our lives, discovering nature, and discovering – it’s like researching about what happened before us or what will happen after us.

...collecting data vs. big question

Well, it matters where you find it if, like, some of the fossils they found was in New York and it was actually underwater fossils, so that’s how they realized New York was once all covered in water. [How will what you found help the scientists?] By seeing what organisms lived under there, in the water and they can have – how much food was under there. How much it has changed, like was it clean water, was it dirty water, how much layers did they have under.

...interpret (final sheet)
We picked Horizon 2 and Horizon 4 to compare, and so there was a lot of difference between them. Some of the clam size were bigger, some of them were smaller. And so me and [STUDENT #2] were trying to put this together. I had my own reason, she had her own reason, and then I was thinking of that’s like how scientists do: all these people might have different reason but they have to, like, bring it all together. So, for the clam size, I was saying there was more water, and then she was saying there was more oxygen, and I’m like there could have been both, we don’t know. So we put that together. And then for like the fragmentation along the top, it was smaller, and we were saying that at the top, like, the water would push and even there were, like, at the bottom there was all muck as Ms. Cody was saying it. But at the top they have more oxygen and the water is moving so, like, while they’re moving they’ll go and they can, like, lose their parts while they’re moving up in the water. So we were talking about that. And then the rock color, we said that Horizon 4 was lighter because we were saying down there, there was no sunlight and while the water moved it, the sun would be shining down on that. So, they can get a lighter color. And at the bottom it’s all dark, no oxygen, and so that will cause them to get darker.

[left out discussion about Tricky Tracks – misunderstood question]

...favorite parts (all – any one in particular?)

I would say applying what I am learning to real life because, like, after the end of the unit I started thinking and I’m like oh my god, wow, this really, I’m really amazed at how they can actually put this into real life. And then I took some of my data and I tried to make a story and, but like, then he helped us out and we started seeing like with the other one, with our data and we did a hypothesis and I really liked that because a lot of people had different reasons. Like, [two other students] were also doing Horizon 2 and Horizon 4 and they had WAY different reasons. And we’re like “could it be this?” and they’re like “I don’t know, could it be this?”

STUDENT #2 (10:57-19:29)

...better

Well, because we got to like learn more about fossils and how to like find them and like the layers and like that there could be a lot and stuff like that. And I liked graphing the things.

...interest

I’d go for the, like, not the timeline, but the other one [fossils]... Maybe the same, ‘cause like the one that we’re starting right now – this one seems fun.

...favorites (answers, graphing)
Well, I like putting the info in and finding all the little fossils and the big fossils – that was fun. And, like, studying the fossils and finding the answers to questions – that was fun because we got to like see the difference between horizons and that stuff.

...least favorite (Tricky Tracks)
'Cause it was kinda slow, you know, 'cause you wanted to know the end. And because, like, we had to think 'cause we hadn't seen the whole thing and we didn't like know if there were dinosaurs or animals and, like, we had to keep predicting... [Different with fossils] 'cause we actually got to see the things, like, developing and we got to, like, do it ourselves. And instead of just, like, seeing two tracks and just, like, waiting for the next part. [Why did we do Tricky Tracks?] Well, to learn how to predict.

...do science

To, like, learn about things that haven't been discovered yet. Or, like, learning about one topic a lot and observing and predicting and stuff like that.

...scientist (maybe)

Well, maybe because, like, um, oh, I do want to keep studying science, but I don't know if I would, like, make a good scientist because, you know, I haven't, like, there are tons of science, and I like a lot of kinds of science. Like, in 3rd-grade, I liked science a lot, and that was like the only subject I got an A on probably because I liked it the most. Well, just there are, like, so many subjects... I think I would be the most interested in fossils.

...collect data

Because, like, if you measure, like, the different sizes and, like, the fragmentation – that'll show what could've happened. Like, Dan – I think they were like making this 'cause the water was moving the sand up towards more land, and that's why they were getting bigger and more fragmentation because they were hitting more things.

...interpret data

Yeah, that was fun – I liked it the most. Well, I liked it because we got to make all these hypothesis and we got to, like, make pictures and we got to make our own hypothesis, like, with our partner. Yeah, we used the data 'cause, like, the 4 with the Horizon 4, that was like the high- newest one, I think. So, like, it got bigger than 36 'cause it was like 36.0 millimeters or something and it got bigger... Well, like, all this data – it supported our hypothesis about the water moving the clams and the brachiopods up. [How did you come up with these hypotheses?] We just looked – 'cause, like, we had talked a little bit about this before with Dr. Dan and Mrs. Cody, like, reminded us for that. And, like, we thought about it and, like, with the fragmentation, they had to be moving somehow to hit other things and maybe get, like, hit with things and, like, all this supported our hypothesis.

...other

I think we should do this again. I really liked this – the end project – that was a lot of fun.

STUDENT #3 (19:31-33:54)
...about the same

It's just with the fossils, with all my fossils, I was getting none at all, so I didn't have that much to record or anything. So it started to get more and more frustrating. And then with, like, other science, it's just like tasting stuff. So it just didn't move me that much more.

Our earth layer unit and our cupcake – that was fun. I liked how the cupcake was colorful and I liked how we got to stick it in and see all the different colors in the tube and take it out. Then, everybody was just looking at it like, “what is this supposed to be?” And then we got to the end and we opened it up and – when you stuck it in you only saw a few colors and so, we're like, OK, these are sprinkles. But when we got inside it was just different colored cupcake.

...interest

The human body.

...favorites (finding fossils, looking at designs)

When we were doing different batches. The finding fossils I liked when it was just us, like, ourselves 'cause then I could just look at it and say this is this and this is this.

...least favorite (measuring)

[doing the actual data collection, rather than fossil identification earlier in the unit]

...suggestions (make sure all students find fossils)

Maybe, um, if they find more and then, um, like look at 'em to make sure they have a fossil, like, at least on the top, like, it doesn't even matter if you have to crack it open.

...do science

I think it means to find information about, like, the earth – how the earth – what's the word – interacts with, like, the volcanoes and things like that. It's fun, too. I just think it's about learning about, like, the human body and the earth and, like, our community. Like, learning how long it's been alive and things like that.

...scientist (probably, probably not)

I do want to study science more so that I can learn about more, but I don't think I'd make a great scientist at all because – I don't know – I'd just be, like, not good with the measuring or finding fossils and stuff like that. [Others kinds of science?] The human body science part: I'd probably be good probably with that. I'd probably pay more attention with that.

...collect data
Um, well, I just think maybe, like, if you take little steps to what you’re finding, it makes it easier than taking big steps, so – can you repeat the question? Well, it helps them by knowing, like, how old the fossils are and if they were in water or not. And ‘cause most of the time if you’re in water you get darker than out of water – like in the summer when you swim you get darker. And it helps them with color and fragmentation [trails off].

...interpret data

I liked it because I got to compare other people’s data from what they found. And it was fun because it just – I just liked seeing how many clams they got and how many people found whole body. I compared 4 & 1 – I don’t know why, just 4 & 1. I’m still working on that sheet. I’m still trying to think through the big question. And so, I don’t know, it’s just – the two, they were very different. [Gets paper from desk] So, I compared 4 & 1. So Horizon 4 found 663 fossils and Horizon [1] found 465. So, when I got both of those, I subtracted to see how many more 4 had. 4 had 198 more than 1. And then I wrote down their average fragmentation, color [etc.]. And then, for these two – ‘cause you can’t really compare these two...

Fragmentation: I thought that 1 was bigger than 4 because when they get stacked 1 gets stacked with more segments than 4 because it would be at the top. So, the segments would build up and build up and make the fossils bigger, the rock bigger. And then for the color, I said 1 is darker because you get closer to the top where the sun shines, and when the sun shines on the things the things get lighter – with these kinds of things. [Still working on size] So, 1 had 1% trilobite whole, so I was very surprised by that – I didn’t think any of the classes would find a whole. And for this one, they didn’t find a whole – they found trilobite tail and rib. So, we didn’t find any rib or tail – we found, like, the head. And, my big question’s on the back. I was working with three other people, and this is what we have so far: I think that as the ocean was slowing evaporating the organisms were dying out, and then the oceans start to rise... the organisms start to, like, flow and start to get smaller ‘cause of all the other rocks. And if you pound, you get smaller. And then, they start to build up together and made layers. [In discussion at the end of this question, she confirmed that she enjoyed interpreting data more than collecting data; when asked about her original survey response that her favorite part of science was “running experiments and collecting data,” she agreed that she might change her answer now to “drawing conclusions.”]

[Omitted the end of the interview, where she repeated that she liked the unit, just not a lot, and would prefer if there had been more fossils to discover in her rocks].

STUDENT #4 (33:55-44:32)

...less

Um, I think we could have done some more fun activities, and I felt like some other units might have had a lot of fun activities that I can really remember. When we were doing our Natural Resource unit, we played this game with some giant wooden die.

...interest
It’s difficult to describe because science is not exactly a subject I usually like – I like history and stuff, and I really like animals. Actually, most of the time, I have a really big rock collection, so I thought that this unit would be pretty fun, but to me it wasn’t.

...favorites (observe / measure fossils, graphs, timeline posters)

I think when we observed fossils and measured them, I really liked that because I think, when you would grab a rock and then you would really look for that fossil, and once you found one, I know I was really excited to find out what that fossil was and it made it really fun. And when we were looking at the graphs, I mean some people would have some fossils, like unknown fossils and so on, and some people had more clams than brachiopods, and I think that was really cool and stuff because it was different. And then making the posters was really fun because I really like “craftsy” things – I think [the timeline] was a pretty cool part.

...least favorite (draw a picture about the organism)

It was a lot of writing down, and I think that most of the time science and social studies is at the end of the day, and I get kinda tired writing all these stuff things down, and it’s not exactly the most relaxing thing. The fact that we write a lot about what we think is kind of boring to me. I actually thought [Tricky Tracks] was pretty cool ‘cause then we got to figure out what they were and stuff. So, observing things is quite fun to me, but writing all this stuff down...

...do science

I think it means mostly to study something and probably discover something someday that you didn’t know, and that’s why you study it. So, I think a scientist is someone who studies something, mostly.

...scientist (probably, definitely)

Yeah, because, actually when I was little, I used to think of scientists as people with chemicals and I’m still kind of interesting. And I remember making baking soda volcanoes and that really interested me, so I wanted to see how chemicals react and so on. And I once went to this museum and they told me I’d be a great geologist because I was really good and brushing and finding fossils. [What kind of science would you like to do?] Um, I’d probably want to be a scientist that studies animals ‘cause I love animals a lot. [What does a scientist who studies animals do?] Well, they probably study the way of life that they have and what they do and how different they are from other animals, so they probably have to compare some things.

...collect data

Well, I think that they can look at it and they can say, oh well, this person found that they think the color changed because of this and so on. So they can kind of like use it to compare with other ones and they can probably find one center point where it all meets. They have to talk about it and find something that would work.

...interpret data
Actually, I had to do mine by myself. I compared two horizons, and I noticed that the fragmentation had gone from pretty full pieces to a lot of small pieces and the rock color had changed which I think means that there was a lot of life in that section. Well, it kind of all went together. Because I said brachiopods and clams were swimming toward the top and if they got bigger than the fragmentation would go down, but they would get bigger because of oxygen. And if they would get bigger, more would probably come because there was probably a lot of food in that area. So they would come up and they would eat it, and that’s why the fragmentation would go down. And since there’s a lot in that section, they could weather against the sand. And if there’s layers of sand, the first layer could wash off and then other ones – there was more oxygen available to the rocks so the rocks get lighter. It kind of all wrapped up, and I was like “oh, cool.” I compared mine with Sana and Gloria and they didn’t use the same horizons as me, but actually our hypotheses were really close to each other.

...favorite parts of science (running experiments and collecting data)
Running experiments are actually quite fun to me, but collecting the data of it gets pretty annoying to me. Um, about Fossil Finders, I think planning experiments to test ideas were pretty cool.

STUDENT #5 (44:34-END)

...about the same

[Science] is interesting.

...interest

Water cycle. [Geology / Fossils] is probably somewhere in the middle.

...favorite (seeing fossils, breaking fossils)

‘Cause I like to see what cool rocks look like, and I like to see what’s inside of them.

...least favorite (having to do all the charts)

I think it’s kinda hard to record all the stuff ‘cause I can’t keep up with it. Putting it in the computer was pretty easy.

...do science

Be able to learn something interesting and be able to see cool stuff.

...scientist (definitely not, definitely not)

Well, I just don’t like science because it’s too hard for me to understand. [What parts are hard?] Having to figure out where parts of something goes, like sorting it and stuff – it’s confusing.
...parts of science (running experiments and collecting data)

[still true – just didn’t like having to fill out the charts]

...collect data

Well, they could probably look at what we did and then they could try to look at similar pieces, probably, to figure it out. Probably rocks – well, of course rocks... I don’t really know that question. I don’t know.

...interpret data

[Did you get to do one of these?] I don’t think so. [What did you learn from looking at the graphs?] I don’t remember.

...other

I think other kids might enjoy it. Probably getting to actually do experiments with it, instead of just reading about it and writing stuff [is better].
FOSSIL FINDERS TEACHER INTERVIEW NOTES (2/18/10)

1. Please describe your professional development in science [prior to Fossil Finders].
   While I was an intern, I learned from Carla about inquiry-based science, engaging students in authentic problems. I also have the inherent ability of asking questions. I’ve taken the initiative to get professional development on my own, such as Governor’s Institute for Environment & Ecology (covered inquiry & state standards, authentic assessment, assessment anchors, hands-on field experiences) and Wetlands (grant-funded). These courses were taught by environmental scientists. District unit planning is typically implementation-driven, not content-driven. Change in units is often teacher-driven to make them more inquiry-based.

2. Aside from formal professional development, how do you obtain content knowledge about the science topics you are required to teach?
   If you want to teach the content on the surface, you can get all the information you need from the curriculum materials. If I want to teach more depth than breadth, I go to journals and web sites or get guidance from a fellow teacher or CST. Liz’ husband lends kits and knowledge. Field trips for waste management and UAJA were really helpful, but lack of funding is requiring us to cut back on these.

3. Do you have contact with community and/or university scientists who help you develop content knowledge? If not, would you use this resource if it were available?
   Carla is a huge resource for me.

4. How would you describe your level of knowledge and comfort with the science topics in your curriculum?
   Environmental, Human Body and Animal Kingdom are relevant to my life; after teaching Fossil Finders for one year, I have been able to internalize it more than four years of the Geology unit because I am making connections to the material. Ranked in order of knowledge / comfort:
   #1 Environmental: know it really well, differentiation, extension, etc.
   #2 Human Body
   #3 Animal Kingdom
   #4 Geology: I have to do a lot of preparation

5. About which topic are you most knowledgeable? How do you feel that this knowledge impacts your teaching?
   I am completely engaged in the first three (Question 4 above), so my passion naturally comes out in my teaching.

6. About which topic are you least knowledgeable? How do you feel that this lack of knowledge impacts your teaching?
   It can be hard to summon up excitement for Geology; I would never let on that it is not my favorite area, but I feel that sometimes they can read it in me.
7. **Explain how professional development in science is different in Fossil Finders than in other programs.**

   Compared to other training, Fossil Finders had a very focused inquiry basis. Other professional development has been extremely engaging and investigative, but Fossil Finders had lots of components that all came together to achieve the goal. Professional development in Fossil Finders was intense and intensive, including inquiry and geology content. In addition, it was “two-way” professional development that allowed us to provide feedback on the lessons as *learners*, compared to the typical one-way model of other professional development.

   The online forum has added another layer of seeing the lessons through student and teacher eyes. It has been stressful to write reflections, but so helpful to have them. Feedback has allowed me to tweak lessons in the moment. I haven’t had to use the PRI web site too much, but I use Dan and Barbara as sources of knowledge (they also post their feedback to teacher reflections).

8. **How has Fossil Finders impacted how you teach geology in the classroom?**

   As a teacher, Fossil Finders has helped reinforce the importance of explicit instruction coupled with exploration: they should fit together in a way that leads to productive science talks in which students can draw their own reasonable conclusions. We talk a lot about history in Social Studies, but I’ve never applied that to Science, i.e., how the things that have happened in the past impact what is happening now AND that there are multiple perspectives that weigh in on evidence.

   For the students, they loved the investigation part of Fossil Finders, but when it came to filling in the sheets, they did not like that (showed up as a suggestion on surveys). Look at the difference between handing them a blank piece of paper versus a worksheet with blanks. There is often a difference between informal assessment (science talks, conversations, etc.) and summative, formal assessments where students have to fill in blanks.

9. **What aspect of the program was most helpful to you as a professional: offsite professional development, online collaboration with other teachers, email / phone / visit with scientists, other? Why?**

   See #8

10. **After your experience with Fossil Finders, would you actively seek out science education partnerships for other science topics in your curriculum? Why or why not?**

    First point: Not all partnerships will be like Fossil Finders. Second point: You must have your team, principal, and CSTs on board to make it work. Third point: I would love to have a partnership for every unit (even if it’s just field trips). We are lucky that Cornell Ed partnered with PRI first! Scientists don’t have to think outside of the lab [because they have partners in education].
1. Please describe your professional development in science.

Formal professional development in science has been through PDS methods courses and relationships formed out of them. Husband is a science educator. Reaches out to former professors, specifically Carla, for support. Theoretically, Schoolyard is science-based professional development. Unit planning does not typically provide content knowledge.

2. Aside from formal professional development, how do you obtain content knowledge about the science topics you are required to teach?

Husband’s science texts, other people’s lesson plans online, other teachers in the district, internet, Carla

3. Do you have contact with community and/or university scientists who help you develop content knowledge? If not, would you use this resource if it were available?

Lock Haven (husband) & Penn State (Carla). More likely to reach out to science teachers than scientists. Need a balance of content knowledge AND teaching methods geared toward elementary students.

4. How would you describe your level of knowledge and comfort with the science topics in your curriculum?

Prior to teaching, had deep pockets of knowledge, but the curriculum is extremely broad. Rather than studying breadth of topics to build content knowledge, tends to use a more focused approach (e.g., pick a central question or idea and teach unit concepts around it based on the standards; introduce broader content points as they intersect with the primary inquiry).

5. About which topic are you most knowledgeable? How do you feel that this knowledge impacts your teaching?

Geology, believe it or not. Self-taught a college-level online course from a major textbook. However, feels that while she knows more than what 5th-graders need to know, she needs more knowledge about how to make it real, hands-on, and inquiry-based for them.

6. Would you actively seek out science education partnerships (with university or community scientists) for science topics in your curriculum? Why or why not?

Working with Carla to retool Animal Kingdom around a driving question. Provides expertise, sounding board, but must be someone with science knowledge AND understanding of how children learn and make connections. It takes time.
1. Did you ever experience a program like Fossil Finders while you were a classroom teacher? What sparked your interest in this research question?

I never experienced a scientist-classroom partnership while I was teaching. My interest was sparked by wishing to take this term “inquiry” (that is often thrown around in various methods classes, leaving a lot of people confused about what it means and how it looks in the classroom) and help teachers bring it to their elementary science teaching.

2. Explain how professional development in science is different in Fossil Finders than in other programs.

There are a lot of different types of professional development out there: curriculum workshops, Research Experience for Teachers (send teachers out to investigate a question, bring the experience back to the classroom), etc. => Fossil Finders combines a number of types of professional development by having teachers explore new curriculum, but also actually engage in research.

3. From your experience observing and interacting with Fossil Finders teachers, how does the program impact their content knowledge and classroom practice? Have you found evidence that this approach leads to greater teacher comfort with inquiry-based geology? Please describe.

I find that, for most teachers, the Fossil Finders experience eventually gives them the practice and confidence with inquiry to explore other questions and design inquiry experiences for their students. While most teachers must have guidance in this type of teaching for several years before they “run with it,” some teachers seem able to do so after only one year. The key seems to be what Shulman calls “pedagogical content knowledge,” or the ability of a teacher to translate content knowledge to students in effective ways. The term implies an intersection of teacher philosophy, content knowledge, and teaching context. Although a teacher does not have to have all three in equal measure to bring effective inquiry to the classroom, the more he/she has of each component, the more quickly he/she appears to be successful.

4. Do you think this type of partnership would be as critical / as effective with other science units that lend themselves more easily to student inquiry (e.g., simple machines)? Why or why not?

I believe that a partnership approach lends authenticity to a unit, regardless of topic. Even with a unit like simple machines, students may feel the tasks they are completing are inauthentic; a partnership connects their learning to a real-world question and can help them better understand the nature of science in any discipline.

5. How important is it for teachers interested in science education partnerships to seek out partners in science education rather than research science? Why?
Interestingly, the Museum of the Earth had previously created a curriculum program called the Devonian Seas; however, by partnering with the school of education at Cornell, the team now hopes to bring a conduit of reflective practice and classroom experience to improve the curriculum (many team members have elementary and secondary teaching experience). While many of the scientists also have teaching experience, theirs is typically at the college level. Although certain scientists have the ability to translate the material to an elementary level, the partnership with the school of education helps to ensure that the curriculum is developmentally appropriate.

6. **Do you have evidence that Fossil Finders improves student learning and/or motivation? If so, please describe.**

Last year, Fossil Finders was only taught in New York. Based on pre- versus post-assessment data, we found that elementary students in Fossil Finders outperformed the control in student learning. However, 9th-graders showed no difference, possibly because all classes were being prepared for the same material on the Regents exam. As for motivation and “feelings about science,” there is substantial anecdotal evidence that the program is having a positive effect. Teachers feel that students are more motivated and engaged by collecting data for a “real” purpose and engaging in hands-on learning.

7. **From your experience with Fossil Finders, do you find evidence that students are able to connect the big question (“How does sea life respond to changes in the environment?”) with the fossil data they are collecting? Please describe.**

The answer is that the learning must be scaffolded for students of all ages. When writing the curriculum, I did not expect 5th-grade students to go beyond using the data to describe a snapshot of the environment. I would expect them to make connections between what they see in the rocks (types of fossils, size) with what the environment was like in the location at a specific point in time. (For example, students should be able to make data-based claims about the environment at their sample location and time being aquatic, rather than populated by T-rexes). They could take their analysis further by examining data from another class and describing the differences between their observations and what “Mrs. Smith’s” class found. A next step might be to take what they know about predatory species and examine relative populations of clams versus brachiopods based on the abundance of their predators, and so on. Older students would still need scaffolding, but might be able to extract and manipulate their own data rather than making observations directly from database graphs.
APPENDIX D

Video Recordings (Notes)
Key:

** VIDEO **

<table>
<thead>
<tr>
<th>Nature of Science</th>
<th>Teacher Comfort</th>
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<tbody>
<tr>
<td>Use of Data</td>
<td>Learning</td>
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<td></td>
<td>Engagement</td>
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** Tape 1 **

5:50 - are we going to do this for the rest of the day?

7:25 - intro of main question after free exploration

8:30 - connection to prior knowledge of ecosystems

10:00 - “real-life” research; the “real deal”

12:00 - “We’re gonna hammer ‘em out.” “Do science”

13:00 - Conclusions to who the scientists are (real people we can talk)

15:25 - intro “the nature of science” → USE AS BASELINE!

17:35 - things that are common to science/scientists

18:30 - 23 coming up w/ ways to describe (w/ assistance)

24:35 - make observing/evidence/Inferencing

38:40 - 43:40 Argumentation BASELINE, engagement

Teacher comfort → multiple perspectives

** Tape 2 **

10:30 - 12:59 reflection on multiple perspectives of evidence

12:40 - 14:09 reflection on Tricky Tracks

15:24 - have to have evidence can’t just say

17:15 - (plus: this response) different interpretations

18:25 - reiterates main question

20:30 - What we think we know about Fossil? Teacher Inquiry

Wonderings

Make a list of these!

Compare to final questions w/ Dan?

30:30 - “How do paleontologists date fossils?”

Long discussion of paleontologists v. geologists

38 = paleontologists use evidence from the past to predict the future
51:16 - qualitative/quantitative explorations
53:20
esp. 55 explaining her hypothesis
56:10 explaining his hypothesis (using prior knowledge)

Tape 3
1:07-2:18 explaining hypothesis
10-11 Jen clarifying how scientists take what they know about today and apply it to discoveries from the past; help w/science?

Start Geologic Time @ 11:30ish
37 - priming for geologic time (me): if dinosaurs didn’t come right after the beginning of the earth, what could have been happening beforehand?

Jen helping w/misconception

Tape 4
0:47-1:57 discussing helping an attach his label
3 - discussion about Pangaea
8:30 showing “timeline”
14:30-15:11 connection that organisms can create oxygen
17-18 more events happening near the end of time

27 mins - shot of oxygen “pollution” square (in video)
28-30 - shots of timeline groups

*Add in Timeline Art facts* (differentiated)
JC part 1 (1-19) ⇒ critical incident + sequencing

15:15 How could the land have changed so much?
2. Dan responds ⇒ "Draw your student ideas + personal connections (evaporation, continental drift, sedimentation, sea floor rising) "people have ideas of what happened" "we still don't exactly know!"
3. Just prior to data collection - important!

24. Dan teaching Jen something on board: look at this for possible critical incident for teacher confidence
29:30 Dan working w/ group: look at this for possible critical incident for student learning engagement/
modeling (what I see...)
5. Audio clips for Dan pushing/confirming/encouraging collaboration with group members
TRANScribe! (make connection to frustration)
⇒ sometimes scient. don't find what they're looking for! can make a claim about engagement # of students asking questions of Dan/parent
45. Critical incident w/ key people + data from key

6:33 "I don't have fossils in any of these." (off-task almost entirely through data collection)
Tape JC Part 3 (1-19)

4:20 - review quantitative/qualitative in context of data
7:20 - review types of rocks ⇒ connection to their data
9:00 - intro database
13:20 - explore database, connection to data
18:20 - Dan’s connecting knowledge of ocean life to organism size

→ helping students make sense of the data constructively
21:23-22:33 superposition: older @ bottom, younger @ top

→ Jen helping students make sense of the data

→ connections to rock color + water depth // personal

23:21 - connections to shore experiences; differences in rock in shallow vs. deep water

Data Entry & Discussion (3-28)

11:30-11:55 Engagement in Data Entry ⇒ triangulate w/ interviews & reflections from unit

20:25 reveal of our data

25:30-26:35 describing our data + comparison to others

26:52-28:02 "really surprised" by data

28 interaction w/ Dan was procedural (finda)

34-34:15 binding interesting "layers" + share w/ class

45:24 - 47:40 trying to make sense of patterns ⇒ a hypothesis about oxygen led Dan to help students understand how rock color speaks to oxygen + helped students "test" the reasonableness of hypothesis

Jen previously asked Dan to comment on the reasonableness of a hypothesis
Discussion w/ Jc, Dan

2:10 - Dan connection to geologic time. How do you know the sea bottom changed over 10 million years by looking at dates? Rock color, clam size, rate of erosion. Clams vs. brachiopods.

Connecting to the main question! How students are helping scientists answer it. Student question.

Leaves them w/ the question of why. Wonders if you could figure out if your hypotheses are true.

Predator, disease, natural disaster.

8:45: established that the sea has changed over time (cool), now asking why.

Lead in to Jen’s final exercise.

Finish Collection

3 - brachiopods when downhill skiing
4 - group engaged
9:30 - disengaged