"Got Rocks?" An Inquiry-Based Geology Program for 3rd to 5th Grades in Conjunction with the Museum of Science

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"GOT ROCKS?"
AN INQUIRY-BASED GEOLOGY PROGRAM FOR 3RD TO 5TH GRADES IN
CONJUNCTION WITH THE MUSEUM OF SCIENCE

A Synthesis Project Presented

by

JENNIFER D. TODD

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Critical and Creative Thinking Program
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ABSTRACT

GOT ROCKS?* AN INQUIRY-BASED GEOLOGY PROGRAM FOR 3RD TO 5TH GRADES IN CONJUNCTION WITH THE MUSEUM OF SCIENCE

MAY 2005

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Directed by Associate Professor Carol Smith

How can the Boston Museum of Science be of help to classroom teachers when planning a field trip? The synthesis presents a set of lesson plans for 3rd to 5th grade science teachers in the Boston area, with an ultimate goal of promoting students' critical and creative thinking in their classroom units on rocks and minerals. The program was designed especially for those in the New England area because these states are within proximity to take a field trip to the Boston Museum of Science. The institution has many rocks and mineral samples from around the world and in the Northeast and interactive geology exhibits.

This curriculum guide is designed in a three-part system. This offers the students a chance to get acquainted with an inquiry-based program prior to their museum visit. A group of pre-visit lesson plans is devised in order to get the students oriented into thinking about rocks and minerals as a geologist would. They will be challenged to consider what the earth looked like a long time ago and how scientists determine the age of rocks. They will examine rock samples and work together in teams, the Great Rock Detectives, to try to classify their rocks as igneous, metamorphic, or sedimentary. Students also have the
opportunity to problem solve and try to decide what features of rocks give clues about how they were formed.

The second group of lesson plans is intended for classes traveling to the Museum of Science for a field trip. To carry through what the students started in the classroom, the collections the students brought from their classroom will be a part of their exploration in the museum. They will be challenged to use the exhibit activities and resources to figure out what types of minerals are in their rock and to figure out what type of rock it must be.

The last part of the program is for the return to the classroom after a field trip to the museum. Once the students have come to conclusions about their rock samples, they can further their creativity surrounding the rocks they collected by writing a newspaper, poem, or short story. This also gives the classroom teacher a chance to assess what the students have accomplished.
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After a bus ride from Medford to Worcester with forty screaming 6th graders, we got off of the bus to venture into our field trip- a science museum. The museum we attended did not supply a field trip guide and or profiles of the attractions and shows. This left for a lot of guesswork, the last situation a teacher wants to be in with forty hyped-up, sugar-high 12-year-olds, and required me to quickly decipher where all of the shows and attractions we were to attend. There were no clear-cut objectives provided by the science teacher, who happened to be me, and the museum staff liaison. Where do we start? What is the best area for lunch? Where is the planetarium show? Will the planetarium show keep a 6th grader’s attention? What will they learn while at the museum? How will I, the science teacher, relate this program back to the classroom? This ill-defined problem is what I want to try to solve- how do teachers plan a field trip that will allow the students to prosper with the information they are learning in school and have the school outing be fun?

I am an experienced teacher of three years. At the end of my three years of teaching 3rd and 6th grades, I decided to go back to school for a Masters in Arts for Critical and Creative Thinking. I was looking for an educational program that helped me accomplish my career goals and fit my personality characteristics. The whole attraction of the Critical and Creative Thinking department was to learn more about student thinking and learning so I could create my own learning objectives within the course objectives. I had thought about museum education,
but I was not positive it was for me; this was a great way to explore my career options.

My first semester of courses included Creative Thinking, and in this course, we had professional guest speakers. One of those was Lynn Baum, an educator from the Boston Museum of Science. During her presentation, she gave a detailed story about the educational programs at the museum. This instantly caught my attention. I had played around with the idea of museum education, but never took the risk, until then. I became a volunteer in the Human Body Connections exhibit. From that point, I focused on museum education in the rest of my Critical and Creative thinking courses—evaluation, practicum, and synthesis—this project.

After volunteering for six months, I became an intern at the Museum of Science, and taught an engineering activity on the exhibit floor for field trip groups. During this experience, I learned how most visiting groups function. There were no clear-cut objectives for the students and the visiting groups were not really sure where everything is in the museum. I concluded that a focused field experience would allow for a more effective out of school experience.

How can the museum be of help to teachers and their field trip planning? With these two forms of educational professions (classroom teacher and museum educator) as background and wearing these two forms of teacher hats, I am attempting to find a solution to this problem. There are several different approaches one could take in helping teachers plan field trips. One method is by publishing a simple guide that displays maps of the museum along with basic activities. This may be a simple solution and easy to write, although it would have some limitations. The quick museum guide would help, but allow for only
a short-term condition. These activities may or may not correlate with their classroom objectives. Within this program format, the lessons may just be time fillers for the teacher when visiting the museum. This solution will not allow the teachers to make connections between the classroom and the field trip along with the teachers and chaperones. It will not supply the same objectives from the classroom, and the goals from the Massachusetts and National Curriculum Standards. The main disadvantage to this type of quick fix is that it does not offer activities with creative and critical thinking skills.

The other possible approach is to create a program that will be a small, directed set of lessons (for classroom use and within the museum) with clear-cut objectives and goals. This will allow teachers to relate curriculum standards to the field trip. By tailoring the program, it will enhance the classroom lesson plans. This will have a lasting effect by having the student continue their thought processes outside of the classroom. Students will keep notebooks that they use in the classroom and at the museum. Thus, the students will be able to view their thought processes on paper, which will give the students the concrete information to change their conclusions. I want to help them in such a way that would allow for their freedom in planning, while keeping a set of objectives. Teachers deserve the guidance with problem based learning while building an effective field trip.

With this rationale in mind, I chose a specific type of program to create—using the 3rd to 5th grade curriculum—Earth sciences is a main topic, and the museum has a great deal to offer in this subject area. Knowing the busy lives of teachers, I wanted to create a program to help them in their classrooms, not necessarily to take over their current curriculum. The purpose of this program is
to connect the teachers, students and museum educators together, while
directing it towards the classroom teachers.

The reason why I am choosing to design this particular program is
because of my journey through the critical and creative thinking program. In
several classes, there were techniques that I acquired which will augment an
educational program. While designing the program, I am keeping in mind
critical and creative skills. The thinking skills and program is connected to the
classroom objectives. The students, while utilizing these thinking skills, will see a
connection between the lessons done in the classroom and on the field trip. This
program has clear-cut objectives that are included in lesson plans to take place in
the classroom before, during, and after the field trip.

All of this thinking led to my program, “Got Rocks?” This is a field trip
guide for a 3rd to 5th grade class. I would like to plan the field trip around the
thought, “I am a geologist for a day.” The program is coordinated with the
Massachusetts State Standards from the Department of Education. The standards
state that students are to learn about the characteristics that make up minerals
and to identify the difference between the three types of rocks. This is the
starting point I took while planning this program. It is important to keep in mind
the primary exposure to the geology curricula. In the pre-K to 2nd grades, the
students are learning about the Earth’s crust and sand, silt and soil.

The primary education strands in their curriculum match many aspects of
the Museum of Science. It is important to start with sand—the basic rock. In the
Discovery Center there is a craft to look at sand and how it can be art. The
Natural Mystery exhibit displays several types of sand that can be viewed under
a microscope. The Museum of Science exhibits that match this particular strand
of science with minerals and rocks: the Rock Garden, Earth: Inside and Out with many mineral and rock samples, and Natural Mysteries with microscopes to view rocks, the three types of rocks on display, and a mineral classification exhibit. The Discovery Center also clearly displays a mineral box kit that presents the basic characteristics to identify minerals. All of these exhibits clearly augment the curriculum because the rocks and minerals that are on display demonstrate the basic geology techniques. This will include the thought process of problem solving as a geologist, where to get this information in the museum, problem solving skills, and what can be done in the classroom in order to prepare for the trip to the museum and how to conclude once back in school.

This process has actually been in the making since I started the Critical and Creative Thinking Program. Creative Thinking allowed for me to open my thinking to new and wonderful opportunities, and Problem-Based Learning allowed me to view education from a new perspective. Children and Science pointed out that children do not always know everything that teacher's plan on before beginning a new curriculum unit. Practicum allowed for all of these previous courses to start to come together and for a guide for teachers, but now it has come together in a whole new light, so that I can help teachers and most importantly allow for the students to have a successful field trip with learning strategies.

While creating “Got Rocks?” I applied some creative thinking skills. To start off with, science is a creative endeavor. It requires taking different perspectives and being open to learning new perspectives. In terms of geology, there are differences in what current ideas can relate to the past and how the rocks were formed and this may be quite different than the student's initial
perspective. Using geology as a story-telling method for rocks has a creative and imaginative component. In order to make connections that are not normally made, it will take time and patience because when the students own their thinking, conclusions can be made, some of which the teachers will not expect. A new perspective may include making observations that will identify clues to indicate that the rocks had cooled over a slow time or if there is a conglomerate of stones and soil to make a sedimentary rock. There are also techniques that I learned to think outside the box, which I will implement in this program—brainstorming, visualization or drawing, and risk taking which will allow students to view things differently.

Critical thinking is just as important as creative thinking skills. The critical thinking skills are implemented in the same manner throughout this program. To be a scientist requires a certain type of problem solving where one has to use pieces of evidence in order to come to new conclusions. This is critical thinking because the students have to develop new trains of thoughts and examine their own thinking. This is called metacognitive thinking. This can guide the students through the scientist's problem solving method. Having the students use student-centered notebooks will allow for clear realizations. As long as the students will be given enough time to effectively write and reflect on what they learned, it will be beneficial. All of these methods will lead to getting reliable evidence in order to become consistent between theory and data.

There is more information to gain in learning about effective geology techniques and museum field trips. In the next chapter of this synthesis, the literature review, the experts bring in several different views that are helpful in creating "Got Rocks?" Since this program is based on problem solving, that is the
place to start. Problem solving is taking a question or quandary and working through steps in a process to try to answer the predicament. This process can include taking risks and learning how to re-work the problem. All the while problem solving includes creative and critical thinking, which is brainstorming, risk taking, questioning, communication and teamwork. This leads to chapter three- the development of this program with the lesson plans that I have created in which the students embody and utilize these critical and creative skills. These skills are challenging because these cannot be attained necessarily over night. Teachers have to remember to be patient and take time to allow students to develop.

Through this whole process, I keep in mind that the students who enter the Museum of Science are important to the museum educators, just as they are to their own teachers, because they are dedicated teachers who want the visitors to thirst for knowledge and drink it up. In planning, I want the teachers to have a good set of lesson plans before they take their school outing. They deserve to have prepared for the museum, time well spent in the museum, and closure once returning to the classroom. I have been a classroom teacher and now a museum educator; I see that there is a common ground, the students. The priority is to have the students thrive from their field trip. With the information I have gathered, there is evidence that when the students are prepared and ready for a connection between the classroom and their field trip experience it will lead to a thorough understanding of the information covered by their classroom teachers.
CHAPTER 2
HOW TO THINK OUTSIDE THE ROCK

While developing “Got Rocks?” I made the most of resources from all perspectives in critical and creative thinking, education, and geology. This chapter previews some of those resources. The most important factor in this program is the problem-based learning aspect. My purpose is for students to utilize both critical and creative thinking skills while problem solving in this curriculum. This is accomplished by the classroom teacher support and allowing the students to explore rocks freely. Creative thinking skills are used when students are generating new ideas or looking at them from a different perspective. Critical thinking skills are especially utilized when examining the current knowledge and looking for new information. In designing the curriculum, I also took account of the literature that focuses on some of the specific challenges students face in scientific problem solving, including the difficulties they may have with understanding key geological concepts. Finally, I consider the challenges of learning in informal environments such as a museum.

Any particular science will include the scientific process (a form of problem solving) that includes hypothesis building, testing, experimenting and concluding. In conducting the scientific process while managing problem-based learning, the students are given some freedom in their exploration and knowledge gaining. Because they do not already have expert concepts about geology and science this could lead to frustration and confusion, which is why teacher support and guidance is important. Further, in allowing the students to
collaborate and share information, they will benefit from the whole learning
process. The last perspective of this curriculum guide is to examine informal
learning and the museum environment because this program is based on taking
a field trip to the Museum of Science. The focus is on designing ways to use the
hands-on exhibits to enhance student exploration and learning.

Critical and Creative Thinking in Problem Solving and Problem-Based
Learning

"Got Rocks?" is based on problem solving. By basing the program on
allowing the students to gain knowledge through exploration and
experimentation, it is assumed they will understand and retain more
information. Problem-based learning centers learning on solving a murky or ill-
defined problem. It involves creative and critical thinking, affective dispositions,
and metacognition.

According to Feldhusen and Treffinger (1985) there are certain steps to
follow in all problem solving that include: setting an objective, clarifying the
problem, data gathering and gathering relevant background information,
defining and narrowing the problem, brainstorming possible solutions and ideas,
and identifying criteria to evaluate solutions. Both critical and creative thinking
are involved while problem solving.

For example, once an objective has been set, or a problem clearly
identified, then data-finding starts with learning about the topic at hand so that
the information needed to solve the problem is well understood. Once
information has been gained, it is then possible to narrow down and define the
problem. All of these steps call heavily on critical thinking; then idea brainstorming, which involves more creative thinking, can be begin.

The purpose of idea brainstorming is to allow for as many ideas in as many different ways. Divergent thinking, or to think of as many different ideas as possible without judging them, is the main purpose of brainstorming. In other words, the main concept is to STRETCH one’s mind to think in different ways that have not been approached in the past.

Once this list has been compiled, then solution finding can be exercised. The divergent thinking list should be the start of the criteria used for evaluation and the converging of one’s ideas, which again calls on critical thinking skills. With the previous idea list, weigh out which ideas are critical to evaluate in order to solve the problem. Once these ideas are brought to attention, then acceptance methods can start to form the final solution.

Problem solving and finding must also use what the students already know and build on their current knowledge base. For a classroom to be set up in this manner, a teacher has to be incredibly supportive and be able to provide unexpected supplies. Barell, Hopper and White (2001 p. 257) wrote about Ann White's experience with her 4th graders and their Rock Hound problem based learning unit. These students observed rocks at great lengths and then identified what they already knew about rocks and minerals. One technique they used was the KWHLAQ strategy to structure problem solving. In this strategy, they begin by focusing on what students know about a topic. Once, it is clear what the students know, it is then time to decide what they want or need to find out. After developing an adequate amount of questions, the students have to then ponder how to find out the answers to these questions. Once the students learn more
information, they then apply this new knowledge to their previous questions. Lastly, the students will be able to question even further and learn even more information.

As mentioned earlier, creative thinking is central to problem-based learning. Torrance (1974) defines creative thinking as

“A process of becoming sensitive to problems, deficiencies, gaps in knowledge, missing elements, and so on; identifying the difficulty; searching for solutions, making guesses, or formulating hypotheses about the deficiencies; testing and retesting these hypotheses and possibly modifying and retesting them; and finally communicating the results” (p. 8).

Creative thinking is the essence of "Got Rocks?" The elementary students are asked to try to find out what type of rock they own. This educational process is highly involved with creative and critical thinking dispositions. Creative thinking has been defined as thinking out of the box, but it is more than that. It is thinking of something, a true innovation, without imitating things heard or seen in the past. This is a difficult task.

There is a great deal of critical thinking correlated to creative thinking. There are many cognitive skills involved such as: judging significant from insignificant information, goal-setting with high priorities versus lower priorities, “elaborating, extending, or refining ideas, situations or plans, creating new ideas with brainstorming and changing the form of current ideas, and seeing how solutions can be combined or separated to change the alternatives.” (Puccio and Murdock, 2001, p. 70)

In Puccio and Murdock's "Creative Thinking: An Essential Life Skill," (2001, pp. 68-70) the authors delve into the affective and metacognitive skills that underlie the creative thinking behind problem solving. Affective skills or
methods where students become more aware of their surroundings are: sensing problems and opportunities, developing tolerance for ambiguity, becoming aware of one's creativeness, being open-minded, taking risks, building self-confidence, being curious and anticipating the unknown. Metacognitive skills, or thinking about your own thinking skills (in this case, the student's thinking about their own thinking), are necessary for creative problem solving as well.

Some skills that are utilized in this department are: strategic and goal planning, decision making, becoming aware of one's creativeness, and improving elaboration by strengthening solutions and planning.

As exploration continues for students, they become increasingly curious and knowledgeable about the researched topic. Nina Greenwald (1999) has suggested that it is important to use and cultivate key dispositions. Depending on the context of the learning environment and when acculturated in the thinking sense, students will naturally wonder about their rocks and minerals by being curious and wanting to take intellectual risks by exploring rock characteristics further and wider, thinking in a sequential manner and sustaining a central goal (p. 18). As the students experience this problems solving process, they will be experiencing mixed emotions and thinking skills. The teacher's responsibility is to keep the students in check and under control.

In "Got Rocks?", the most useful dispositions are curiosity and the desire to seek clarity of the problem- ultimately what kind of rock does the student own and why? The student will need to narrow their problem from their perspective, which involves becoming a reliable source. Swartz and Fisher (2001) point out that students need to become their own experts by learning how to compare and contrast and use other skills in order to determine the best way and method to
conduct experiments. Teachers have to model and encourage students through these dispositions. The students will not be able to complete this process on their own. Feedback from teachers has to be encouraging and leading students to correct information in a relaxed environment. "Mistakes" need to be viewed as stepping-stones toward discovering the central goal. They can even be viewed as involving humor and playfulness. (Swartz and Fisher, 2001).

Problem-based learning is important for several reasons. By giving students ownership of their information, it allows for an increase in self-confidence when solving the problem. It is a natural human behavior to solve problems. By involving students in the process of generating and evaluating alternatives, it helps them develop ideas and hence more deeply understand these ideas. It keeps the students motivated. As a fourth grade student in a problem-based learning geology class states, it is “fun, because you get to ask your own questions....I never knew that you could eat some minerals....I found out that the biggest rocks in the world are not as important as the oldest...the oldest rocks are millions of years old” (Barell, Hopper and White 2001, p. 260). Finally, it allows them the opportunity to develop important critical and creative thinking skills.

Challenges in scientific problem solving

Educators need to be aware of the possible scientific thought processes that the students are taking part in while experimenting. The students may make observations simply to see what happens or what works. The observer can propose a simple hypothesis about why something happens; for example the reason behind heat coming from a vacuum cleaner in a linear, more causal
sequence, and design a simple experiment to test their idea. In this process
different possibilities can be considered, but in a linear fashion. The hypotheses
that are assumed through this method can apparently be “proven” by careful
scientific thinking. Lastly, model-based reasoning uses a larger established
theory to base the specific hypothesis on, and the relationship between the
theories and the phenomenon being observed can be identified as difficult
because the process of problem solving is complicated. The analysis involves
comparing explanations using several different models to see which provides a
better account of the data. The reasoning is also a higher form of thinking
because it recognizes that theories are not necessarily correct (Driver, Leach,

Scientific problem solving involves a sophisticated epistemological
framework. Most children and educators plan activities that call on simpler
frameworks. There are three types of reasoning described by Rosalind Driver of
increasing complexity. Phenomenon-based reasoning is reasoning about the
basic properties of an observed phenomenon or natural object. In “Got Rocks?,"
the students in this stage may ask, what does this rock look like? Relation-based
reasoning is proposing a simple explanation in terms of variables. These student
questions may be: Why might this rock look like this? What might have caused
its appearance? The highest level of reasoning is theory-based reasoning which
uses theoretical frameworks to guide the search for explanation. The students at
this level will have a set of ideas about the rock cycle; the explanation would be
based on unseen events and hidden relations.

This epistemological model encompasses both creative and critical
thinking skills, although the heart of scientific problem solving is through critical
thinking. While using the scientific process, the critical skills are necessary to solve the problem along with thinking about the circumstantial factors that impede the central problem. The real challenge is to figure out how to engage the students in deeper reasoning. The problem of figuring out what type of rock this is (metamorphic, igneous, or sedimentary) involves figuring out what perceptual features are important in revealing the unseen features of how the rocks are made. Teachers need to consider a broad array of observed features and see which ones help.

Scientific problem solving and classification depends upon prior theories. Students have alternative ideas to scientists. Students need to be made aware of their initial ideas and the scientists' theories as well as the ambiguities within the field of geology. Geology is not an easy field; rock classification has been described as one of the 15 most-difficult topics in earth sciences (Westerback and Azer, 1991). First of all, there is a distinct difference between a rock and a mineral. There is a difference in how the two earth forms are classified by different properties. Minerals are named because of their chemical compositions, while rocks are named because of the mixture of the minerals that compose the rock substance. The gradation of the Earth's surface causes rocks to look like they have characteristics of similar rocks, although they may have a similar mineral that would change the composition to be a completely different rock. There are some visual characteristics that make rock identification somewhat easier. The texture includes particle and crystal composition. If the rock has a glassy texture, then it is easy to recognize that it is an igneous volcanic rock. A crystalline texture either has no crystalline structure or has the same composition throughout; it could be a metamorphic or igneous rock. Layering in sedimentary
rocks is easily recognizable because it has the appearance of a combination of many different substances (Westerback and Azer, pp. 326-27). Thus, with carefully chosen samples, children can be successful in identifying them.

Scientific Classification of Rocks

Teachers need to have a knowledge base on rocks and minerals. Rocks and minerals are not easy topics to understand for these naturally occurring objects have been in the Earth for millions of years. Minerals are the building blocks of rocks, and they are naturally occurring inorganic solid material with a defined crystal structure. Minerals combine to build rocks through different processes, creating the rock cycle. Rocks are classified according to the conditions under which they were formed. Igneous or volcanic rocks form when liquid rock or magma, which is very hot from the Earth's core, cools when being exposed to cooler temperatures. The hot liquid hardens to form a rock. The clearer igneous rocks, quartz with the crystal shape, can be cooled slowly or quickly. The rapidity determines how shiny the rocks appear. The shinier rocks cooled quickly, while those with larger, duller appearing quartz crystals cooled slowly (Gans, 1984, p. 10).

Once igneous rocks cool and are affected by weathering, erosion, and deposition, then sedimentary rocks form. Sediments are literally pushed together with the weathering and deposition until the rocks are solid. There are conglomerate pieces of other rocks on the Earth's surface. The presence of these rocks indicates that the area could have been an ancient body of water because it takes millions of years for the rocks to form with water. When there were pockets
of air trapped in the center of the rocks that then evaporated, it left the minerals behind which now gives the appearance of quartz crystals in the center of rocks.

The metamorphic rocks change by heat, pressure, and chemical activity, rather than weathering and deposition. This process occurs in the depths of the Earth’s layers, although using not enough heat to melt the rock as in the igneous rock evolution.

The amazing feat of rock formation is that it is a cycle. Generally, once magma cools, it forms igneous rock. Then with weathering and erosion the sediments are pushed together to form sedimentary rocks. With more heat and pressure, metamorphic rocks are formed. With even more heat, the rock is melted and magma forms again. It is important to note that there is methods by which sedimentary rock can become igneous, metamorphic rock can become sedimentary rock, and igneous rock can become metamorphic. This process is not clear-cut and direct for there are different patterns of formation (Gans p. 19).

With all of the slight changes in the rock cycle, there could be different characteristics that will give clues to the students while going through the “Got Rocks?” program. With the complicated rock cycle, it is plausible that students in the 3rd to 5th grade range will have some misconceptions. Geology information and concepts are difficult for professionals. Driver, Squires, Rushworth, & Wood-Robinson (1994) have identified some of these misunderstandings. First of all it is difficult for students to define what a rock is compared to other rock-like substances. For example, a brick is thought of as a rock because it is made of natural substances. Another misconception children face is when a natural marble counter-top is polished. They believe it is not a rock. Minerals are naturally occurring, have certain shapes (angels), usually a solid color, have a
certain chemical composition, and luster. Minerals appear to look like rocks, although rocks are made of minerals. Children will interchange rock and mineral terms for the same sample. Therefore they make no clear distinction between a rock and a mineral. It was also found that students sometimes referred to a rock as volcanic, even if it was sedimentary, or metamorphic rock (p. 112). There are a lot of common misunderstandings that educators have to compete with in their classrooms, so there needs to be strategies put in place in order to have the students learn the correct information.

Good Rock Curricula

To assist teachers competing with these misconceptions, there is a successful elementary program for rocks and minerals. From Science and Scope magazine, there is a program fully described for first graders. The main concepts of this program can be transferred to upper elementary grade curricula. The “Rock Day” program for first graders starts as a basic six-week classroom curriculum. The class learns all about the basics, sand, soil, and silt. Then the class moves onto the layers of the earth and learns the fact that rock is all around us. Eventually, the class leads up to the rock cycle and the three main different types of rocks. The daily lessons include a small dose of problem solving.

The actual rock day incorporates a lot of critical and creative thinking. The teachers set up activities for the students to review their thinking about the rocks and minerals unit. There were some kinesthetic activities for acting out the cycle. At other stations, teachers utilized cooking fudge to demonstrate different reactions, symbolizing the rock cycle. An important factor was to relate rocks and minerals to everyday life. The students had made murals showing where
rocks and minerals are found in homes and schools (Varelas and Benhart, pp. 40-45). The students in this program are involved in the process of the day by creating kinesthetic activities and making connections between rocks and minerals and everyday uses with the rock cycle.

A method of monitoring the students' thinking and learning is through journals. Science journals have been implemented in classrooms for quite a long time. It is the thinking that surrounds the journals that has changed in recent years. Science and Children has recently published an article titled "Student-Centered Notebooks" (Fulton and Campbell, 2004). By simply making the journals centered on the students' findings and exploration allows for the students to own their learning. In this way the students will take their problem-based learning to heart.

Lori Fulton (Fulton and Campbell, 2004), a project facilitator for math and science, claims that it is very important for science teachers to allow enough time for the students to write in their journals. There also needs to be enough time for the students to think about what they are trying to find out before the lesson. During an experiment or activity, journal writing allows for the students to have enough exploration and to take note of their findings. It is possible to leave the organization up to the students and to let them work together to figure out what methods work best for the student groups. When the students are asked to use their notebook as a resource for a classroom project or assignment, they may realize that they are not organizing their information with the best method.
Challenges of Informal Learning

The students' thoughts are affected by critical and creative thinking when solving problems about rocks and minerals. This can all be initiated by the power of informal learning. Education at the Museum of Science is to be informal, and the interpretative presentations done in a questioning manner. When audiences are asked questions in an informal and inquiry-based presentation, they may or may not know the answers. Throughout the presentation, they will discover the answers for themselves by the presenter leading them in the right direction. By modeling this form of presentation in the classroom, students should be able to discern the correct answers to classroom questions for themselves as well. In the classroom, informal learning would be using problem-based learning with inquiry for the students to own their knowledge. If the environment is such that the students are comfortable in owning their knowledge, this method will work very well, such as in the Rock Hound unit that Ann White has conducted with her 4th grade students. They took their current knowledge base and built on it.

The preparation and planning for a museum field trip needs a realistic plan. From a museum educator's perspective, effective school outings have essential tools. Bitgood (1993) states "evidence (from research) implies the field trip event is more effective if experience-driven rather than information driven. Interactivity with exhibits promotes effective teaching and leads to outcomes of enjoyment, satisfaction and curiosity as well as intellectual ones." The Museum of Science has many hands-on exhibits. The key is to use the exhibits effectively. Pop, Horak, and Hurlbut (2004) explore the different forms of learning through activities "There are different forms of learning, just as it is important to expose
the students to these in all programs—hands-on galleries and formal lecturing areas, so this is to help all of the different types of learners" (90), "Got Rocks?" is an exploratory, problem based program. The objective is to provide an impetus for the students to start thinking in a critical and creative manner. By starting in the classroom with the exploration of sand, silt and pebbles, and comparing rocks that are found in the same area, the students should be compelled to start to answer their own questions. The students will keep a central notebook for their own thoughts and observations through the process. The students will also correct misconceptions and learn new information about rocks and minerals by experiencing this program.

In scientific problem solving, critical and creative thinking skills are necessary tools. Thinking as an educator to carry out 'Got Rocks?' is essential because one has to learn all of the background knowledge and continually be aware of the students’ scientific process. To think from the perspective of the students is equally important because they will continually have misconceptions and epistemological issues. The two programs by Ms. White and Lori Fulton are excellent examples of how to make a successful geology problem-based curriculum work in a classroom. Now, I will move onto my curriculum and reasoning behind the lesson plans.
CHAPTER 3
"GOT ROCKS?": MY ROCK CURRICULUM STORY

“Got Rocks?” is designed to guide students through an inquiry-based geology curriculum, alongside taking an educational field trip to the Boston Museum of Science.

The Massachusetts State curriculum standards state geology objectives for 3rd to 5th graders. The standards describe what the students should be able to understand by the end of 5th grade, which includes:

1. Give a simple explanation of what a mineral is and some examples, e.g. quartz, mica.

2. Identify the physical properties of minerals (hardness, color, luster, cleavage, and streak), and explain how minerals can be tested for these different physical properties.

3. Identify the three categories of rocks (metamorphic, igneous, and sedimentary) based on how they are formed, and explain the natural and physical processes that create these rocks. (Science and Technology/Engineering Curriculum Framework, Massachusetts Department of Education, 2001, p. 44)

These curriculum standards are stated and utilized in my geology program.

There are many other states that bring students to the Boston Museum of Science other than Massachusetts. Therefore, the National Science Standards are important as well. The National Research Council content standards (available at
"Young children are naturally interested in everything they see around them—soil, rocks, streams, rain, snow, clouds, rainbows, sun, moon, and stars. During the first years of school, they should be encouraged to observe closely the objects and materials in their environment, note their properties, distinguish one from another and develop their own explanations of how things become the way they are."

When developing these lesson plans, it is also important to have students “experience the richness and excitement of knowing about and understanding the natural world; increase their [students] economic productivity through the use of the knowledge, understanding, and skills of the scientifically literate person in their careers.” (National Research Council Standards, 1996, p. 30).

These state and national standards reinforce the reasons to start inquiry curricula in schools. Developing “Got Rocks?” in accordance with these guidelines helps teachers utilize the Museum resources to meet these guidelines. The museum has several exhibit components that match these curriculum requirements. All of these necessities are highlighted in the teacher guide.

An important feature of “Got Rocks?” is the use of critical and creative thinking skills throughout. Each lesson plan is built to assist the students with their problem-based inquiry process. There is an initial problem for the students to focus on and solve during the lesson. As the guide follows the inquiry process, I recognize the appropriate methods to augment the critical and creative thinking for the suitable levels.

The organization of the teacher guide also enhances the field trip process. When the students are given a focus while on a school outing, it becomes easier for goals and objectives to be met. The teacher guide needs goal and objectives
for each type of lesson: pre-visit, during museum visit, and post-visit for supplying goals and objectives each step along the way. The pre-visit plans gets students oriented to the problem-based lesson plans and enables them to follow their own rock journey using thinking skills to identify and classify their rocks based on how they have been formed. During the museum visit students will explore rock samples in several different exhibits and learn more about their own rock sample by some comparing and contrasting. The Museum of Science also has effective activities involving mineral identification as well as rock information, which the students can explore. Once they gain more information, the students will return back to their classrooms for some post-visit lesson plans where the students will share their rock stories and conclusions from their inquiries.

The lesson plan structure is important for teachers because these lessons include critical and creative thinking skills. The objective provides a goal for both the student and teacher for each lesson. A problem is posed for the student to solve using thinking skills individually or in collaboration with their small rock exploration groups. The material list and background information provides teachers with valuable information for conducting the lesson.

The lesson plans start off with the pre-visit plans to get students acquainted with geology: examining rock features and geologic history. The lessons on the geology history can be optional for the curriculum because the current frameworks do not require this information for their student goals and objectives. However, it is important to include background information because it will give the students a good foundation to explore about earth’s history and lead to a better understanding of rock formation and identification. The objective
of this lesson is to learn about the past in relation to the students' lives and to understand that nature takes a long time to create things. In the sections that follow, I describe the rationale and focus for each lesson in more detail.

Previsit Lessons

Lesson 1. How long is a long time ago? - Part I (or What did the earth look like a long time ago?)

Objective: Students will gain an initial understanding of geologic change over time by visualizing the age of dinosaurs and how the Earth appeared without humans at that time. At that time, it was a large landmass with no divisions of continents (meaning that there was one large landmass called Pangaea) and the ocean covered most of the Earth. From there, students are to use the United States as an example and consider how the land changed to present day where there are mountain ranges, plains and beaches. Students will be expected to develop a timeline of the geologic events.

Problem: Students are asked to identify, represent, and order important events that happened a "long time ago."

Background Information:

Earth History

This geologic historical website gives detailed explanations for a basic understanding of Earth history

(http://gallery.intech.com/~earthhistory/geologic%20timepage.html) This website gives a wonderful earth history map including all of the major events that have been
explored with evolution. It includes an adult explanation of the different time periods with the slow development of how the land on Earth transformed from one large land mass with mostly ocean to the break up of the continents (starting in the Mesozoic time period). For the student’s understanding, I would focus on the Mesozoic time period (248 to 65 million years ago) because it was the start of life forms that the students can relate to, dinosaurs.

**Dinosaurs**

Enchanted Learning brings dinosaurs to life for the students. [http://www.enchantedlearning.com/subjects/dinosaurs/Dinotopics.html](http://www.enchantedlearning.com/subjects/dinosaurs/Dinotopics.html) website provides a good explanation of this time period in language that students can understand. For example, "During the Mesozoic, the Earth was very different than it is now. The climate was warmer, the seasons were very mild, the sea level was higher, and there was no polar ice. Even the shape of the continents on Earth was different; the continents were jammed together at the beginning of the Mesozoic Era, forming the supercontinent of Pangaea, but would start breaking apart toward the middle of the Mesozoic Era." Another way to explain this time period in a language that 3rd to 5th graders can understand is that the Tyrannosaurus Rex lived at the end of the Mesozoic time period and that is closer to the time period of humans than the beginning of the Mesozoic era, which means that the time of the dinosaurs was an extremely extensive time period in our Earth’s history.

**Mountain Ranges** ([http://www.americanparknetwork.com/parkinfo/index.html](http://www.americanparknetwork.com/parkinfo/index.html))

The mountain ranges in the United States have formed over several geologic time eras. The Rocky Mountains, for example, have formed over billions
of years. This mountain range formed due to melting of glaciers that melted over millions of years and, carved the rock ranges to form the range we have today with peaks and valleys, depending on the length of the melting period. This website has a list of several National Parks. Here you can find information regarding the Rocky Mountains and Grand Canyon. To use a mountain range that students can relate to in the New England area, the Appalachian Mountains, on www.appalachiantales.com/geologic_history.htm, you can read and study the history of this range. These mountains started their formation, about 900 million years ago, was a very long and arduous process. The continents were one landmass, which formed the Adirondacks in New York and then the continents separated and the sediments from the land settled in the ocean. Then 400 million years later, the continents slowly started to move back together and this formed the current Appalachian Mountain range that were under the ocean.

**Biological Fossils**

As far as biological events go, the oldest fossil that scientists can tell was a living thing (a salt water living creature) is called a Trilobite, which is from 590-500 million years ago. Gradually other oceanic creatures evolved. Then plants such as ferns came into development around 300 million years ago. At the end of the Paleozoic time period, the earliest reptile came into existence approximately, 250 million years ago. The Mesozoic time period started and then became the 'age of the dinosaurs.' Around 50 million years ago higher more oceanic animals evolved, then gradually lived on land and eventually mammal-like animals like the Mastodon. (http://www.childrensmuseum.org/geomysteries/timeline.html) This website is easy to navigate and understand, the 3rd to 5th graders can
understand the explanations and Earth History table with all of these fossils dated and explained.

**Critical and Creative Thinking Aspects:**

- **Brainstorming:** generating a lot of events that they think were “a long time ago”
- **Considering and researching a set of events presented by teacher** (appearance of first living things, appearance of first landforms, appearance of first plants, appearance of fish, reptiles, dinosaurs, birds..., human beings)
- **Creating representations for events** (e.g., drawing pictures)
- **Evaluate and order:** evaluate where events go on a time line: ordering events on a time-line. This may call for gathering additional information, discussion, and fact checking.

**Materials:**

- Globe/relief maps (to see present day mountains and continent configuration)
- A 50/100-foot piece of rope- set up for a time line, marking decades or hundreds of year period of time
- Small square sheets of paper
- Color Pens
- Internet Access for researchable websites:
  - [http://volcano.und.nodak.edu/vwdocs/vwlessons/lessons/Pangea/Pangea.html](http://volcano.und.nodak.edu/vwdocs/vwlessons/lessons/Pangea/Pangea.html)
  - [http://www.childrensmuseum.org/geoqysteries/index2.html](http://www.childrensmuseum.org/geoqysteries/index2.html)
http://www.rocks-and-minerals.com/

✓ Geology Books for children:

*Earth explained: A Beginner’s Guide to Our Planet* by Barbara Taylor

*Fossils Tell of Long Ago* by Aliki

*Secrets From the Rocks: Dinosaur Hunting with Ray Chapman Andrews* by Albert Marrin

**Steps of the Activity:**

1. Brainstorm in the Great Rock Detective Groups: “What has happened to the land before you were born?” and “What did the Earth look like a long time ago? Were there continents? Were there mountains and canyons? Were there people? Dinosaurs?”

2. Now that the students have some questions about what the Earth looked like, they are prepared to research it further by investigating books and websites to find out more information. They can find specifics: when the Rocky Mountains formed, the Grand Canyon, and the Appalachian Mountains. From there, they can investigate the topic of living things: plants, dinosaurs and insects.

3. Once the students have a list of these geologic events from the first step of things located in the United States or North America ask them to focus on one specific place and how it changed through time i.e. dinosaurs and the loss of dinosaurs, then introduce the 50/100-foot piece of rope or ribbon; the students should draw the events throughout time with their geologic event and then attach the events they collected while researching the problem.
4. In their Great Rock Detective Groups the students will work with their definition of 'a long time ago.' While discussing the definition of 'a long time ago' the great rock detective groups can compare and contrast what they have discovered throughout their research. How long have the students been on Earth? How does this compare with the events over millions of years?

Lesson 2: How long is a long time ago? Part II- How old are rocks?

Objective: The students will come to understand that rocks were created at different times and have an "age". They will learn about some methods that scientists use to determine the age of rocks.

Problem: How old are rocks?

Critical and Creative Thinking Aspects:

- Brainstorming- The students will brainstorm to think about how they might figure out how long rocks have been on Earth. How would you tell if one rock is older than another?
- Investigating: Examine rock samples for the students to see if they do or do not have fossils
- Change of Perspective- The students expand their scientific thinking. How do geologists find out how old rocks are? What clues can the scientists get about the Earth through rocks?
- Representing and Creating- Students will be given some rocks to order, based on whether they have fossils and type of fossil. The students will continue time lines for rocks, building on the idea that
some rocks came before all life, while others have been more recently created. There are continual processes of rock formation and creation.

• Evaluating and ordering- The students will evaluate the relationship of their lives to how long rocks have been in existence.

Materials:

✓ Time lines from previous lesson
✓ Science Notebooks
✓ Science Texts
✓ Rock Samples (with and without fossils) (or pictures of rock samples with and without fossils from the website listed in Lesson 1.
✓ Websites:
  http://volcano.und.nodak.edu/vwdocs/vwlessons/lessons/Pangea/Pangea1.html
  http://www.childrensmuseum.org/geomysteries/index2.html
  http://www.rocks-and-minerals.com/
✓ Books:
  Rocks and Fossils by Chris Pellant
  How we Use Rock by Chris Oxlade
  Earth explained: A Beginner's Guide to Our Planet by Barbara Taylor
  Fossils Tell of Long Ago by Aliki
  Secrets From the Rocks: Dinosaur Hunting with Roy Chapman Andrews by Albert Marrin

Steps for activity:
1. The teacher asks the students: Do rocks have an "age"? Are some rocks "younger" and others "older"? If so, how might we find out how old they are? Then the teacher will hand out some rock samples (some with and some without fossils; some with fossils of different sorts of sophistication). Ask students to look at rocks to see if they have any ideas about their history. Hopefully, this might lead to an initial discussion of "fossils" and what they are. In addition, from previous lesson students might realize that some fossils might be of older life forms than others. Thus, students might initially propose that you can tell the age of rocks by the TYPE of fossil. The challenge for students is to see if they can figure out a way to determine the age of the particular rocks they have been given.

2. After this activity, the students will start by making a KWF and Q (which stands for Know, Want to know, Find out, and Question about rocks) chart in their science notebooks. Some might want to research about fossils.

3. Students research at website (http://www.childrensmuseum.org/geomysteries/index2.html) and discuss initial findings.

4. Teacher challenge and change in perspective: Suppose a given life form has been around for a long, long time. How can scientists tell if the rock is old or recent? Are there any other clues? As a lead in and analogy, the class can conduct an experiment with two cans of soda. The bubbles in soda come from Carbon Dioxide, which is different than the Carbon -14 used in carbon dating, although it can display the use of carbon for the passing of time. So, if the class sees 2 cans of soda, then the class leaves
one open for 24 hours. The opening of the can represents “dying” of a living animal. Then the next class, the 2 cans are shaken (the one that is already open needs to be ‘closed’) for the same time period of 3 minutes. Then the experimenters can hold the cans at a 90-degree angle and see how far the soda sprays on the floor and measure how many centimeters the liquid goes. Then the teacher can introduce the new idea about carbon dating of fossils: The reason why scientists know the approximate date of rocks is because they measure the amount of C-14 in the fossils within the rocks. This in turn gives an approximation of the age of the rocks around the fossil. Scientists measure fossil history by carbon dating. Science textbooks will explain the process. By having the students understand that the natural substances on Earth and a chemical test date it, then it will make more sense to them.

http://www.ukfossils.co.uk/guides/what%20is%20a%20fossil.htm is a great website for this explanation.

5. The students can start to order the rocks from oldest to newest (keep in mind that newest can be millions of years ago).

6. The groups can then start to make timelines of their rocks. Then as a class, they can review what the Rock Detective groups have learned and compare and contrast their information and fill in what they learned on their KWF chart in their science notebooks.

The creative aspects of these lessons are to follow certain objectives for students. One of the most important skills to learn is brainstorming; it’s essential
to any creative project. Representing their thinking to create an original product from previous knowledge is another important skill. When the students are able to see an analogy acted out, it makes more sense. The visual allows the students' current knowledge to gain a perspective that may have not been considered in the past. Evaluating is the process by which students will learn how to compare times—from a long time ago to recent years.

The next lesson is designed to relate to the subject matter—rocks and minerals.

**Lesson 3- Where did my rock come from? Rock Basics**

**Objective:** Students will start to get acquainted with rocks that have been provided by the teacher, in other words, have come from a science supply company so that the rocks are polished and have definite features. Students will work in groups to describe the properties of rocks in their samples, consider similarities and differences, and to think about what properties might give clues about how they were made.

**Problem:** Give students samples that include rocks from the three main groups. Tell them that rocks have been formed in different ways. Their challenge is to look carefully at the rocks and organize them into different groups that may reflect how they were made.

**Critical and Creative Thinking Aspect:** The students will start their rock classification (identification) journey with samples the teacher provides

- **Observing:** This requires the students to start making observations. The students need to start by thinking about the color and the texture.
Each of the three types of rocks—sedimentary, igneous, and metamorphic—has certain characteristics. The students can brainstorm all of the different characteristics. Then they will compare and contrast the rocks in their groups.

- Classifying/Organizing—The students will organize and start to classify their rocks in their groups.
- Metacognition (thinking about their own thinking) and Evaluation: The students will take into account what they have learned about rocks and gather more information through the museum visit and class discussion and hopefully work toward a rock identification that they are proud of and can present to other people.
- Critical Reflection—The students will create KNFL (Know, Need to know and Find out and learn) chart that will help the students get organized for the museum field trip.

**Materials:**

- *Rocks in His Head* by Carol Otis Hurst (a story about a man who collects rocks during the Depression and it ends up paying off even though he is ousted by the townspeople)
- Rocks that have been ordered from a science supply company (about 7 or 8 for each Rock Detective group, at least 2 for each of the rock types)
- Science Notebooks
- Hand lenses/Microscopes if they are available
- Books:
  - *Rocks, Fossils and Arrowheads* by Laura Evert
Let's Go Rock Collecting by Roma Gans

Eyewitness Books: Rocks & Minerals by Dr. R.F. Symes

Websites:

http://www.rocks-and-minerals.com/

http://volcano.und.nodak.edu/vwdocs/vwlessons/lessons/Pangea/Pangeal.html

http://www.childrensmuseum.org/geomysteries/index2.html

Steps for the activity:

1. Have the students take out their rocks and study them. Read Rocks in His Head to the class.

2. The Great Rock Detectives need to try to separate their rocks into groups by whatever characteristics they would like to use (color, texture, special markings, or patterns) and that they think give clues about how they were made. Then students will write in their notebooks the characteristics that they used to group the rocks. This will start the KNF and Q chart for the museum field trip.

3. Now have the students study the rocks again, and the students should focus on these questions and write them down in their science notebooks while evaluating the rocks together:
   • What colors are in your rocks?
   • What types of patterns do you see in the rocks?
   • What is the texture like in your rocks?
   • Are there any special markings on your rocks?
   • The students should use all five senses to observe the rocks, except perhaps taste, although I am sure some geologists taste soil and rocks.
What are the characteristics of the Rocks? Are they colors? Crystal shapes? Do the rocks have bands or stripes? The class can just start brainstorming their own questions as well for their chart in their science notebooks.

The students share their initial ways of classifying the rock with other class members and compare their classifications. Have they used similar or different characteristics in forming their groups?

Tips: If the students are able to view the inside of the rocks, it helps to identify them greatly. To be able to look at the parts of a rock under a microscope is a nice addition to this lesson because it will allow for them to examine their samples at even a closer range. There are dissecting microscopes in several exhibits at the museum. The students will be able to examine their rocks while on their field trip as well.

This lesson allows for the students to think from a different perspective—from a geologist's scientific mind. Experiencing a scientific process in this manner will give the students more of a first-hand experience, rather than a set-up experiment that is predictable. Science is not predictable in real-life, when students have a realistic science process will impact the students in such a way that will continue through their lives.

The next lesson gives the students a chance to use critical and creative thinking skills along with kinesthetic or thinking skills.

Lessons 4: The Rock Change

Objective: By using their creative and critical thinking skills, they will first brainstorm their ideas about how rocks might form, then research ideas about
how rocks form, and then do creative reenactments of the process of the rock cycle.

**Problem:** The students will be presented with three rocks that they are told geologists now think have been formed in different ways. Then the students will take note of their properties by observation, and then hypothesize about how the rocks might have been formed.

**Background Information:**

The students have a working idea that rocks have an age and were formed at some time in the past. They now need to gain information regarding the three types of rocks and the rock cycle. The three types of rock are igneous, sedimentary and metamorphic. Igneous rocks form when hot lava from volcanoes cools and solidifies, or in the Earth were magma cools and solidifies. Sedimentary rocks are from sediments like sand or shells and water applies so much pressure that the sediments solidify and make a rock. Metamorphic rocks are rocks that have changed from another type of rock, with a great deal of heat and pressure, for example, limestone (a sedimentary rock) can change into a metamorphic rock, marble, when enough heat and pressure have been forced on the rock. This event is a part of the rock cycle. Rocks can transform from a sedimentary rock to metamorphic, and then melt into magma, which will erupt from a volcano, and when the lava cools, it will be an igneous rock.

**Critical and Creative Thinking Aspects:**

- **Brainstorming**- The students will be trying to figure out how the rocks appear to be different. How could they have formed.
• Observations and Hypothesizing: The students will make observations and look at the rocks to see differences. Then the question can be asked, if rocks started out looking the same, then how did they get to these different textures and appearances? The students will also be able to observe fudge being made and cooled. Since fudge is made of different substances that will make it clear what can happen when different substances are heated and melt together, then they are cooled, similar to the rock cycle.

• Testing: The students will try to explore with basic materials, like a nail for a scratch test and a polishing material to polish the rock.

Materials:

✓ Rock Samples

✓ Fudge Recipe and supplies: 2 cups brown sugar, 2 squares of baking chocolate, pinch of salt, 1+ tablespoon of butter, walnuts and 1 tsp. vanilla (Mix together all ingredients in a saucepan, except the walnuts and vanilla, and bring it to a 'hard boil' and keep it at that for exactly 3 minutes. Then remove from the heat and stir in the vanilla and walnuts and 'beat' the mixture, then pour into an 8” x 8” pan.

✓ Rock testing materials: nail for scratch test and polishing material

✓ Science Notebook

✓ Construction Paper

✓ Art supplies-scissors, glue, etc.

✓ Rock exploratory materials

Steps of the activity:
1) The students should be in their Rock Detective Groups with their notebooks and pencils and rock samples. The students will then be asked to compare and contrast the rock samples. The students will be thinking about the rocks with these questions- are there strong bands in the rock layer? Does the rock appear to be made of similar material that is the same color? Does the rock look as though it has a lot of other rocks in layers that make up the whole rock? Does the rock fall apart easily, or is it kind of crumbly? These questions will help lead the students to realizing some of the observable differences between metamorphic, igneous, and sedimentary. Basically, the metamorphic rocks would have the strong bands, the igneous appear to be uniform throughout the rock, and sedimentary look like several rocks all pushed together.

2) The students will be asked to hypothesize how rocks might have formed. Students might be reminded that some rocks have fossils trapped inside them. What does that suggest might have happened? See if they can realize that some rocks might have been in a molten form that solidified.

3) Teacher introduces fudge activity to give them further ideas: An adult can make the fudge at this point in front of the whole class. It would be beneficial for the students to see all of the ingredients layered in a clear bowl to signify sedimentary rocks, then with some heat and pressure, the batter symbolizes metamorphic rock (if it cooled at that point), then once the batter is well mixed, then the students can pretend it had exploded from a volcano and can cool to become an igneous rock. The students are asked: Could the fudge process be similar to something their rocks experience? The students should observe this process closely. How do the ingredients mix together? What is
necessary for the melting and blending into one substance? When the ingredients are not quite melted, are there streaks in the chocolate? Which rocks look like they were made in this way? What other ways could rocks be made?

4) After these activities, then introduce students to names of the three types of rock and assign students to groups to investigate the formation of one type of rock. The students' can do some research either on the Internet with the website suggested in the previous lessons (http://www.rocks-andminerals.com/; http://volcano.und.nodak.edu/vwdocs/vwlessons/lessons/Pangea/?Pangod1.html; http://www.childrensmuseum.org/geomysteries/index2.html) or with some textbook resources Using the information the Great Rock Detective Groups had learned, they can make posters or some form of presentation to the rest of their class on what they think with proof of how rocks have formed. This could lead to a class discussion on the similarities and differences of each rock group. To even further the students understanding of where they stand with their information, they could make a chart on poster paper describing each type of rock and its characteristics.

5) This is the ultimate goal for each group to understand: How each rock is formed. The Great Rock Detective Groups should try to examine each group of rocks.

6) Now, in each group, they are going to figure out how to act out how the rocks are changed into the next part of the rock cycle by researching their rocks using the suggested books and Internet sites from the previous lesson, http://www.rocks-and-minerals.com/.
7) Each rock detective group will pick one of the three rocks to act out how if formed. They can write a script and assign parts to each group member. Props will make for an even better performance.

8) Each group will perform, while paying close attention to each other group's performance.

9) Have the class review together what happened to form each type of rock. The class can compare the chart from earlier in the lesson, and then they can realize what they have learned from solving their own problem. The students can add more to their original KWFL and Q chart in their science notebooks.

Tips: Remember the students learn best by kinesthetic movement; it will make an impact on their memory, so this activity should be easily understood and fun!

Museum Trip

Once completing these four lessons (note: these lessons may each take several days to complete), the students will be asked to collect some rock samples from their backyards or schoolyard and then will be ready to make their field trip to the Museum of Science. The goal of the museum visit is to see other examples of three type of rock, to learn more about characteristics of three types of rock, and to use this information to figure out what type of rock they may have. (Note: This is an opened ended problem, and the teacher may not know the answer for their particular rock. It is also important they don't gather things like cement.) Now, this is not the only place to view and make connections with rocks and minerals, although it is very child-oriented with many hands-on exhibits. The explanation I give teachers speaks for itself:
Teachers (During your field-trip at the Museum of Science)-
The main goal of your field trip is for the students (either in the rock detective group or individually) to identify their rocks and try to tell the story of them—meaning where did it come from and how did it form? The students will need to carry their rock samples with them to the museum. I have separated this part of the program into the different sections of the museum where rocks and minerals are displayed.

Depending on what your focus has been in your classroom, you can choose what you would like to continue as you plan your field trip. Therefore, these lessons can be utilized however you like. Perhaps you could separate the different Great Rock Detective groups into each of these lessons.

The reason I have designed these lessons in a free form is because I want the teachers to let their students explore the museum and not be so concerned about filling out a worksheet.

Lesson 5- What can I find out about my rock? (at the museum)

GeneralObjective: The objective of the entire field trip is to learn more about the rock sample that each student has collected. The museum environment will allow for the students to compare and contrast their rocks to the samples and exhibits in the museum.

GeneralProblem: Find out as much information about the rock samples as possible while visiting the Boston Museum of Science. At the conclusion of the visit, students should have decided what type of rock they have and why. They should also try to identify what type of minerals their rock may contain and how they know.
Problem 1: What minerals are in my rock?

Background Information: Minerals are the basic building block for rocks. All rocks are made up from minerals which have are naturally occurring in the Earth and have a crystal shape, and have a certain chemical composition and physical properties. This is important to realize because these are the building blocks for rocks. Every rock is made up of certain minerals, and that is how they get their shape, composition and color. You may want to insert your own lesson to make sure the students know and understand the difference between rocks and minerals prior to the museum visit. A great suggestion is to have a picture of a rock and different minerals involved in its composition. For example, you could take granite and the minerals that make it up—feldspar, quartz and mica and have the students cut out different shapes for each mineral to have a clear distinction between the substances. Another analogy can be made with cooking: by making fudge from scratch the students can see the different ingredients (sugar with its crystal shape and chocolate) melt and mix together, then harden to form candy. Another possible activity is to grow crystals or melting materials—sugar or salt to compare to the rocks.

On your field trip- The Museum of Science has several exhibit components that allows the students to explore the minerals. I would suggest going to the Discovery Center, Natural Mysteries, and then Earth: Inside and Out in that order. It will allow for a sequential order to challenge the students' thinking. In the discovery center, the activity boxes present different ways to test the minerals. The visitor is lead to know the minerals by testing them in different manners, rather than having the label explain what the minerals are and how they are formed. Then students should experience the other two exhibits: Natural
Mysteries and Earth: Inside and Out where the explanations are given to the visitors will prove or disprove the students' thinking about the minerals in their rocks.

1. In the Discovery Center, there is an activity box center with shelving full of different themed boxes. There is a box solely on minerals. This box leads a visitor through several activities that will present to students how to identify minerals by conducting several tests. The students will observe the minerals, hypothesize what kind of minerals are in the box, test the minerals (scratch test and using their senses), and conclude what minerals actually are in the box. With a small guidebook, this box also shows the essential characteristics for minerals, the building blocks for rocks. The students can gather more information about the ingredients in rocks (minerals) and use this information to compare and contrast to their rocks. The students can test their rocks the same way they tested the minerals, and conclude if there are some of the minerals in the box in their rocks they brought from school.

2. Natural Mysteries- There is an excellent exhibit display, which takes the students through a mineral classification activity. There is a wall display with separate compartments to demonstrate how to classify different minerals by location, color, and the different chemical classes. It is shown by the descriptions in each of the boxes. The museum visitor moves the slides to view the different minerals across the world and different colors and chemical compositions. This exhibit complements the previous one by emphasizing visual observation and explanation, rather than active tests.
The students are observing minerals that are possibly in their rocks; they can then write down, which they think they might be in their rocks.

3. Earth: Inside and Out - There are many possibilities while working in this area. First of all - relating to the minerals - the students can try to examine one of the defining aspects of minerals, which are their angular shapes, and perhaps they can view some of these in their own rock sample. The students will be able to observe the process and view an exhibit with a good explanation of the building blocks from elements to minerals to rocks. This area also gives a list of minerals that are in rocks. This will demonstrate the formation of rocks in the natural world. There is also a hands-on activity to explore the angles that are naturally made in minerals. It allows for the students to try matching the different angle-shaped plates to the crystal shapes. If the students have magnifying glasses, they can observe the minerals and look for their angles and colors and compare those to the rocks. The students are hypothesizing, testing and concluding what angles are made when crystals form in rocks. One of the most eye-catching features of the exhibit is a case of minerals in all colors of the rainbow. The students can take note and draw some in their notebooks for further reference while solving their problem.

Problem 2: What type of rock is my rock? How was it formed?

In the exhibits that had been visited for the minerals, rocks can be explored and tested. Earth: Inside and Out only allows for observation, although in Natural Mysteries and the Discovery Center, there are dissecting microscopes that give the students the opportunity to observe their rock samples under close
view. There are also opportunities to learn about the three basic types of rock: sedimentary, igneous, and metamorphic and how they are formed.

1. **Earth Inside/Out.** In addition to minerals, the other part is the large samples of different types of rock. There is a clearly defined metamorphic rock with a strong band in it to show the change with heat and pressure and the result. Does their rock have any strong bands? If so, perhaps the students can sketch this in their notebooks. There is also a conglomerate rock, which shows the rounded rocks pushed together with sediments to form the sedimentary rock. Inside the exhibit room, in the display cases, there are igneous and volcanic rocks (they are just not quite as big of a sample as the conglomerate and metamorphic rocks). Does this appear to be similar to the students' rock samples? Why or why not? How do the rocks get to look so polished? Are all rock collections this beautiful?

2. **Natural Mysteries.** This exhibit explores classification and all forms of living things along with minerals and rocks. The rocks and minerals are displayed in drawers in the exploratory room. The rocks are labeled by the basic metamorphic, sedimentary and igneous. This will give the students a great opportunity to look closely at the rocks and minerals that are in them. Hopefully they will be able to spend enough time looking at the rocks that they will be able to make some observations that will help them to identify their rocks. The students are welcomed to open all of these drawers to observe these rocks and minerals. How do they compare to the rock sample that the students brought with them? Are they shinier? Rougher? What colors are in the rocks? Do they have similar minerals (hypothesize)? Now, have the students observe their rocks under the
dissecting microscope. What do they see? Sketch this in their science notebooks. Have the students write down their observations and details that are not included in the sketch. Do they see any properties that had already observed during the field trip?

3. **Rock Garden.** This collection of rock samples is awesome. There are rocks from all over the world. There are several from the New England area. This is a great area for students to really look at their rocks and see if there are any similarities between their rock and the ones in the rock garden. The garden also has such large samples that it will give the students an opportunity to see the different characteristics, which separates each of the rocks into the metamorphic, sedimentary and igneous groups. The students can ponder how geologists and archeologists discovered these rocks and got them to the museum. Also, do the rocks in the garden resemble their rock samples at all? How did the shifting of the Earth create such different rocks across the world? The students can sketch any rock that is interesting to them, if there are not any rocks that are particularly interesting, and then sketch the ‘Giant’s Causeway’ rocks from Ireland.

**A picture is worth a thousand words; imagine viewing the sample in real life.**

Here are some pictures:
Sedimentary rock sample near Earth: Inside and Out: Both of these samples show this side of the rock— a polished and clear view of the inside of the rock, and the side that is not as clear, the side that geologists see in the ground.

Critical and Creative Aspects:

- Observation: While at the museum the students need to be really observant while studying the rocks and minerals.
• Hypothesizing: What minerals are in my rock? What type of rock is it?
• Metacognition: The students will be constantly thinking about their own thinking because they will be filling out their KNF charts.

Steps while in museum:

1. The students, either in their rock detective groups or individually will go to the different exhibits and become geologists in their thinking process. While in this mode, the students will fill in the find out section of their KNF chart.
2. The students will observe what happens in the process from element to mineral to rock.
3. The students will continue with studying the rocks that are available in the museum. They will think critically and creatively by applying what they know to the museum rock samples and with their own samples.
4. The students need to fill out what questions they feel have been left unanswered.
5. Ask the students to take out your rock sample and compare it to the rocks in the garden. Find a rock in the garden that seems similar to their own sample.
6. Compare and contrast the two samples. Think about the colors, patterns in the rock, and the composition of the rocks. Suggest that they sketch the rock in the rock garden in your science notebook and on the students' KNF charts.
7. Ask the students to write down whether you think the rock is sedimentary, metamorphic or igneous and why. Then you may read the sign to see if the museum tells the student what kind of rock the sample is and where it came from in the world.

Once the students have experienced their rock and mineral explorations, hopefully they have come to some conclusions about their own rock sample. This last lesson will take the students to their final goal.

Post-museum Visit

Lesson 6- What did the Great Rock Detectives accomplish?

Objective: The groups are going to report back to the class what conclusions they came to in several different forms: writing a short story, a news story, or a visual/kinesthetic story like a play where they can act out the story of their rock.

Problem: It is time for the students to report what their findings are to the class. What type of rock do I have? How do I know? What happened during the problem solving process?

Critical and Creative Aspects:

- Taking Risks- The students are taking risks because they are taking a chance with the conclusions that the group agrees upon.
- Problem Conclusions- In going through the process of problem solving, there are conclusions to be made, although there may still be unanswered questions.
• Team work- The students are working together in their groups to create a story of their own in accordance with their understanding of rocks and the processes of their formation.

Steps for activity:

1. The rock detective groups will get together and look at their KNF charts, and see what conclusions they have come to and where they could have gone or what is left unanswered. They need to ask themselves these questions: What did I know before going to the museum? What did I find out while I was there? Did the museum rock samples look similar or different to my rock? Do I feel as though I have an idea of how my rock formed?

2. Once the groups have discussed the answers to these questions, they can see who in the group has come to conclusions that can be agreed upon in the group. Those stories that make the most sense will be used in their presentations.

3. The groups will then decide how they will present their story. If a short story is decided upon, then the students can break up into writing the different sections and drawing pictures for the story. If a news story is decided upon as the presentation, then the students can separate into different news stories- such as a headline, editorial, or day in the life- or write one together. If the group decides upon acting out the rock story, then the students can separate into working on the script and props.

4. The groups will then create their short story, newspaper story or short play.
5. The groups will present the creations.

6. The class should then discuss what steps they took to solve their problem. Are there any similarities between the thinking processes of the students? Did the students use the same methods to solve their problems? How were the rock stories different? And most importantly, what did the students learn that they did not know before starting this problem solving process?

This concludes the rock and mineral program for 3rd to 5th graders in the New England area. The lessons are planned in a logical manner and in such a way that the students will benefit from their critical and creative thinking in making conclusions about rocks and minerals. I am proud of my rock story. If I did not have it, then I would not be working toward more critical and creative thinking goals at the Museum of Science.
CHAPTER 4
THE ROCK, HARD TRUTH

“Got Rocks?” has been proposed as advancement in field trip planning and curriculum guides. It has been carefully researched, planned and thought out. This curriculum program provides pre-visit, during the museum visit, and post-visit lesson plans to the Museum of Science. All the lessons have critical and creative thinking objectives that will allow the students to develop their own thinking.

This program was written both from the perspective of a teacher and a museum educator. How well will it work in practice? Will it be effective for both teachers and students? At present I do not know. A further challenge is that I am not the one carrying out this program in the classroom. This is where the actual test will occur.

To begin to get some feedback on my lessons, I asked Noelle Taylor who has been teaching 5th grade for six years and instructing a geology unit in her science class for the equal number of years to review the curriculum guide I created for students in her grade. Here is what she has to say about “Got Rocks?”:

I enjoyed reading through your lesson plans. I have to say they seem to have a lot of interesting aspects for the students and cover all (and more) of the specifics that I would cover when doing rocks. I do think adding the critical and creative thinking information is a great addition. I believe it to be a useful and helpful tool in your lesson plans. My only question as I was reading was what you felt the time frame for completing these lessons might be. A month? 6 weeks? 9 weeks? I do realize you can pick and choose what you would like to do within your own class but did you have any thoughts in your mind about a time frame from start to finish? I
ask this with the 5th grade MCAS test (in science) on my mind. There is a lot of pressure to cover a lot of material for that test and any creative and quality lessons are a great asset.

Ms. Taylor’s comments are quite helpful. It is beneficial to know that the critical and creative thinking aspects would be useful in the classroom. The time frame depends on the intellectual level of the students and what is most important to the teacher in his/her planning.

I hope the students will get a large dose of creative and critical thinking while doing these activities. As Murdock and Puccio and Greenwald point out, the most important aspect of learning is asking questions and evaluating possible answers so that there can be a form of checks and balances with the students and their formal knowledge base. If this line of thinking is successful, the students will get a lot of information out of the program. On the other hand, if they do not take control of their learned information, then they may not be able to obtain the objectives that the teachers have in mind for the curriculum unit. If the unit is presented in such a way that the students can accomplish the goals needed to gain a clear understanding of rocks and minerals, then it will be a success.

To have a field trip that allows students to learn while staying focused and still have fun is a complex task that requires a lot of planning and thought. This curriculum is already set-up for teachers; they just need the books and resources for their classroom. Hopefully, this will benefit teachers, students, and their methods of thinking. This program will be available to teachers when they come to the museum. I would love for them to employ the information that I have researched and dedicated so much of my time and effort to. I would also love to work on improving it more from hearing from students and teachers.
about how well it worked for them. It is the least I can do to lead education in a new direction.
BIBLIOGRAPHY


APPENDIX

“GOT ROCKS?” CURRICULUM GUIDE

Teachers- Welcome to “Got Rocks?”

The most important materials for a unit on rocks and minerals are rocks and mineral samples! “Got Rocks?” is a problem-based curriculum guide for 3rd to 5th grade classes. Students collect rocks and minerals for exploratory purposes and are able to solve their own mystery. This program will allow students to build on the Foss kit “Sand, Silt and Pebbles” curriculum from kindergarten to second grade that is standard in Massachusetts’s public schools. Through these problem-based lessons, students will grow or utilize their critical and creative thinking skills to draw conclusions. In the Massachusetts area, there are many places where rocks are easily attainable and collectable. Anywhere land and water meet is a great area for rock collectors. It is possible to collect all three types of rocks- sedimentary, metamorphic, and igneous in these areas. Almost every town has some body of water that is easily accessed for collecting. Alternatively, you can order by mail from:

Ward's Natural Science Establishment, Inc in Rochester, NY (800) 962-2660
Frey Scientific in Mansfield, OH (800) 225-FREY (3739)

For your students’ samples it is recommended by Stories in Stone, 1995 to have specific sedimentary, igneous, and metamorphic rock samples. For my suggested lesson plans, it would be advantageous for the students to see and work with all three types of rocks. Minerals in their simplest viewing form, such as table salt, may be easier to order than find in the natural environment.

Once you have your rocks and minerals, it is time to start ‘Got Rocks?’ This program involves problem-based lesson plans. This means that the students will have knowledge about the topic. They will then be given a problem to solve, and are encouraged and assisted to solve the problem. The reason behind this type of curriculum is to have the students own their
knowledge that will in turn allow for the students to realize what knowledge they have gained.

The other part of this program is to take a field trip to the Boston Museum of Science. The museum is a wonderful place to view rocks from all over the country and even around the world. Locally, there is also a reputable rock collection at the Harvard history museum. The rock samples have been collected and display a variety of metamorphic, sedimentary and igneous rocks. It would also give the students an opportunity to view large samples that display the distinctive features of the three main kinds of rocks. There are several exhibit components that also allow exploration with rocks. The Boston Museum of Science can be used as a research lab and review of sand, silt and pebbles. There are many possibilities, read on to find out more...

The lesson plans are separated into three main groups- the pre-visit, during visit and post-visit lessons. This will allow the students to gain knowledge with certain lessons and build the knowledge base to be able to solve problems in the next lesson.

Good luck!

Jennifer Todd
The PRE-visit activities: Before starting these lessons, you may want to separate the class into groups of three to four students who work well together. Each group will form the Great Rock Detectives. These groups can work together for all of these lessons.

It is very important to keep in mind some ‘Brainstorming Basics’ for every time you conduct a brainstorming session:

- The students should be allowed to say whatever comes to mind with no criticism.
- It is a time for students to just free think.
- The optimal time for an adult is about an hour. The students, a shorter period of time is just fine.
- The students will brainstorm on their own in their groups or as a whole class.
- As a teacher, encourage wild ideas.
- The students also can always build on their previous ideas.

**Lessons one and two are optional and focus on geologic time and history. If this is not a part of your curriculum, please feel free to start with a different lesson. Lesson three will start with brainstorming of current ideas and ‘facts’ about rocks.**
Lesson 1: How long is a long time ago? - Part I (or What did the earth look like a long time ago?)

Objective: Students will gain an initial understanding of geologic change over time by visualizing the age of dinosaurs and how the Earth appeared without humans at that time. At that time, it was a large landmass with no divisions of continents (meaning that there was one large landmass called Pangaea) and the ocean covered most of the Earth. From there, students are to use the United States as an example and consider how the land changed to present day where there are mountain ranges, plains and beaches. Students will be expected to develop a timeline of the geologic events.

Problem: Students are asked to identify, represent, and order important events that happened a "long time ago."

Background Information: 

Earth History: this geologic historical website gives detailed explanations for a basic understanding of Earth history. (http://gallery.intch.com/-earthhistory/geologic%20timepage.html) This website gives a wonderful earth history map including all of the major events that have been explored with evolution. It includes an adult explanation of the different time periods with the slow development of how the land on Earth transformed from one large land mass with mostly ocean to the break up of the continents (starting in the Mesozoic time period). For the student's understanding, I would focus on the Mesozoic time period (248 to 65 million years ago) because it was the start of life forms that the students can relate to, dinosaurs.

Dinosaurs
Enchanted Learning brings dinosaurs to life for the students. http://www.enchantedlearning.com/subjects/dinosaurs/Dinotopics.html website provides a good explanation of this time period in language that students can understand. For example, "During the Mesozoic, the Earth was very different than it is now. The climate was warmer, the seasons were very
mild, the sea level was higher, and there was no polar ice. Even the shape of the continents on Earth was different; the continents were jammed together at the beginning of the Mesozoic Era, forming the supercontinent of Pangaea, but would start breaking apart toward the middle of the Mesozoic Era." Another way to explain this time period in a language that 3rd to 5th graders can understand is that the Tyrannosaurus Rex lived at the end of the Mesozoic time period and that is closer to the time period of humans than the beginning of the Mesozoic era, which means that the time of the dinosaurs was an extremely extensive time period in our Earth's history.

Mountain Ranges

The mountain ranges in the United States have formed over several geologic time eras. The Rocky Mountains, for example, have formed over billions of years. This mountain range formed due to melting of glaciers that melted over millions of years and, carved the rock ranges to form the range we have today with peaks and valleys, depending on the length of the melting period. This website has a list of several National Parks. Here you can find information regarding the Rocky Mountains and Grand Canyon. To use a mountain range that students can relate to in the New England area, the Appalachian Mountains, on [www.appalachiantales.com/geologic_history.htm](http://www.appalachiantales.com/geologic_history.htm), you can read and study the history of this range. These mountains started their formation, about 900 million years ago, was a very long and arduous process. The continents were one landmass, which formed the Adirondacks in New York and then the continents separated and the sediments from the land settled in the ocean. Then 400 millions years later, the continents slowly started to move back together and this formed the current Appalachian Mountain range that were under the ocean.

Biological Fossils

As far as biological events go, the oldest fossil that scientists can tell was a living thing (a salt water living creature) is called a Trilobite, which is from 590-500 million years ago. Gradually other oceanic creatures evolved. Then plants such as ferns came into development around 300 million years ago. At the end of the Paleozoic time period, the earliest reptile came into existence approximately, 250 million years ago. The Mesozoic time period started and then became the 'age of the dinosaurs.' Around 50 million years ago higher more oceanic animals evolved, then gradually lived on land and eventually mammal-like animals like the Mastodon.
This website is easy to navigate and understand, the 3rd to 5th graders can understand the explanations and Earth History table with all of these fossils dated and explained.

Critical and Creative Thinking Aspects:
- Brainstorming- generating a lot of events that they think was "a long time ago"
- Considering and researching a set of events presented by teacher (appearance of first living things, appearance of first landforms, appearance of first plants, appearance of fish, reptiles, dinosaurs, birds..., human beings)
- Creating representations for events (e.g., drawing pictures)
- Evaluate and order: evaluate where events go on a time line: ordering events on a time-line. This may call for gathering additional information, discussion, and fact checking.

Materials:
- Globe/relief maps (to see present day mountains and continent configuration)
- A 50/100-foot piece of rope- set up for a time line, marking decades or hundreds of year period of time
- Small square sheets of paper
- Color Pens
- Internet Access for researchable websites:
  - http://volcano.und.nodak.edu/vwdocs/vwlessons/lessons/Pangea/Pangea1.html
  - http://www.childrensmuseum.org/geomysteries/index2.html
- Geology Books for children:
  - Earth explained: A Beginner's Guide to Our Planet by Barbara Taylor
  - Fossils Tell of Long Ago by Aliki
  - Secrets From the Rocks: Dinosaur Hunting with Roy Chapman Andrews by Albert Marrin

Steps of the Activity:
1) Brainstorm in the Great Rock Detective Groups: "What has happened to the land before you were born?" and "What did the Earth look like a long time ago? Were there continents? Were there mountains and canyons? Were there people? Dinosaurs?"
2) Now that the students have some questions about what the Earth looked like, they are prepared to research it further by investigating books and websites to find out more information. They can find specifics: when the Rocky Mountains formed, the Grand Canyon, and the Appalachian Mountains. From there, they can investigate the topic of living things: plants, dinosaurs and insects.

3) Once the students have a list of these geologic events from the first step of things located in the United States or North America ask them to focus on one specific place and how it changed through time; i.e. dinosaurs and the loss of dinosaurs, then introduce the 50/100-foot piece of rope or ribbon; the students should draw the events throughout time with their geologic event and then attach the events they collected while researching the problem.

4) In their Great Rock Detective Groups the students will work with their definition of 'a long time ago.' While discussing the definition of 'a long time ago' the great rock detective groups can compare and contrast what they have discovered throughout their research. How long have the students been on Earth? How does this compare with the events over millions of years?

Lesson 2: How long is a long time ago? Part II- How old are rocks?
Objective: The students will come to understand that rocks were created at different times and have an "age". They will learn about some methods that scientists use to determine the age of rocks.

Problem: How old are rocks?

Critical and Creative Thinking Aspects:
• Brainstorming- The students will brainstorm to think about how they might figure out how long rocks have been on Earth. How would you tell if one rock is older than another?
• Investigating: Examine rock samples for the students to see if they do or do not have fossils
• Change of Perspective- The students expand their scientific thinking. How do geologists find out how old rocks are? What clues can the scientists get about the Earth through rocks?

• Representing and Creating- Students will be given some rocks to order, based on whether they have fossils and type of fossil.) The students will continue time lines for rocks, building on the idea that some rocks came before all life, while others have been more recently created. There are continual processes of rock formation and creation.

• Evaluating and ordering- The students will evaluate the relationship of their lives to how long rocks have been in existence.

Materials:
- Time lines from previous lesson
- Science Notebooks
- Science Texts
- Rock Samples (with and without fossils) (or pictures of rock samples with and without fossils from the website listed in Lesson 1.

Websites:
- http://volcano.und.nodak.edu/vwdocs/vwlessons/lessons/Pangea/Pangea1.html
- http://www.childrensmuseum.org/geomysteries/index2.html

Books:
- Rocks and Fossils by Chris Pellant
- How we Use Rock by Chris Oxlade
- Earth explained: A Beginner's Guide to Our Planet by Barbara Taylor
- Fossils Tell of Long Ago by Aliki
- Secrets From the Rocks: Dinosaur Hunting with Roy Chapman Andrews by Albert Marrin

Steps for activity:

1) The teacher asks the students: Do rocks have an "age"? Are some "younger" and others "older"? If so, how might we find out how old they are? Then the teacher will hand out some rock samples (some with and some without fossils; some with fossils of different sorts of sophistication). Ask students to look at rocks to see if they have any ideas about their history. Hopefully, this might lead to an initial discussion of "fossils" and what they are. In addition, from previous
lesson students might realize that some fossils might be of older life forms than others. Thus, students might initially propose that you can tell the age of rocks by the TYPE of fossil. The challenge for students is to see if they can figure out a way to determine the age of the particular rocks they have been given.

2) After this activity, the students will start by making a KWF and Q (which stands for Know, Want to know, Find out, and Question about rocks) chart in their science notebooks. Some might want to research about rocks.

3) Students research at website [http://www.childrensmuseum.org/geomysteries/index2.html](http://www.childrensmuseum.org/geomysteries/index2.html) and discuss initial findings.

4) Teacher challenge and change in perspective: Suppose a given life form has been around for a long, long time. How can scientists tell if the rock is old or recent? Are there any other clues? As a lead in and analogy, the class can conduct an experiment with two cans of soda. The bubbles in soda come from Carbon Dioxide, which is different than the Carbon-14 used in carbon dating, although it can display the use of carbon for the passing of time. So, if the class sees 2 cans of soda, then the class leaves one open for 24 hours. The opening of the can represents "dying" of a living animal. Then the next class, the 2 cans are shaken (the one that is already open needs to be 'closed') for the same time period of 3 minutes. Then the experimenters can hold the cans at a 90-degree angle and see how far the soda sprays on the floor and measure how many centimeters the liquid goes. Then the teacher can introduce the new idea about carbon dating of fossils: The reason why scientists know the approximate date of rocks is because they measure the amount of C-14 in the fossils within the rocks. This in turn gives an approximation of the age of the rocks around the fossil. Scientists measure fossil history by carbon dating. Science textbooks will explain the process. By having the students understand that the natural substances on Earth and a chemical test date it, then it will make more sense to them. [http://www.ukfossils.co.uk/guides/what%20is%20a%20fossil.htm](http://www.ukfossils.co.uk/guides/what%20is%20a%20fossil.htm) is a great website for this explanation.
5) The students can start to order the rocks from oldest to newest (keep in mind that newest can be millions of years ago).

The groups can then start to make timelines of their rocks. Then as a class, they can review what the Rock Detective groups have learned and compare and contrast their information and fill in what they learned on their KWF chart in their science notebooks.

Lesson 3- Where did my rock come from? Rock Basics

Objective: Students will start to get acquainted with rocks that have been provided by the teacher, in other words, have come from a science supply company so that the rocks are polished and have definite features. Students will work in groups to describe the properties of rocks in their samples, consider similarities and differences, and to think about what properties might give clues about how they were made.

Problem: Give students samples that include rocks from the three main groups. Tell them that rocks have been formed in different ways. Their challenge is to look carefully at the rocks and organize them into different groups that may reflect how they were made.

Critical and Creative Thinking Aspect: The students will start their rock classification (identification) journey with samples the teacher provides

- Observing- This requires the students to start making observations. The students need to start by thinking about the color and the texture. Each of the three types of rocks- sedimentary, igneous, and metamorphic has certain characteristics. The students can brainstorm all of the different characteristics. Then they will compare and contrast the rocks in their groups.
- Classifying/Organizing - The students will organize and start to classify their rocks in their groups.
- Metacognition (thinking about their own thinking) and Evaluation: The students will take into account what they have learned about rocks and gather more information through the museum visit and class
discussion and hopefully work toward a rock identification that they are proud of and can present to other people.

• Critical Reflection- The students will create KNFL (Know, Need to know and Find out and learn) chart that will help the students get organized for the museum field trip.

Materials:
Rocks in His Head by Carol Otis Hurst (a story about a man who collects rocks during the Depression and it ends up paying off even though he is ousted by the townspeople)
Rocks that have been ordered from a science supply company (about 7 or 8 for each Rock Detective group, at least 2 for each of the rock types)
Science Notebooks
Hand lenses/Microscopes if you they are available
Books:
Rocks, Fossils and Arrowheads by Laura Evert
Let's Go Rock Collecting by Roma Gans
Eyewitness Books: Rocks & Minerals by Dr. R.F. Symes
Websites:
http://www.rocks-and-minerals.com/
http://volcano.und.nodak.edu/vwdocs/vwlessons/lessons/Pangea/Pangea1.html
http://www.childrensmuseum.org/geomysteries/index2.html

Steps for the activity:

1) Have the students take out their rocks and study them. Read Rocks in His Head to the class.

2) The Great Rock Detectives need to try to separate their rocks into groups by whatever characteristics they would like to use (color, texture, special markings, or patterns) and that they think give clues about how they were made. Then students will write in their notebooks the characteristics that they used to group the rocks. This will start the KNF and Q chart for the museum field trip.

3) Now have the students study the rocks again, and the students should focus on these questions and write them down in their science notebooks while evaluating the rocks together:
• What colors are in your rocks?
• What types of patterns do you see in the rocks?
• What is the texture like in your rocks?
• Are there any special markings on your rocks?
• The students should use all five senses to observe the rocks, except perhaps taste, although I am sure some geologists taste soil and rocks. What are the characteristics of the Rocks? Are they colors?
• Crystal shapes?
• Do the rocks have bands or stripes? The class can just start brainstorming their own questions as well for their chart in their science notebooks.

The students share they initial ways of classifying the rock with other class members and compare their classifications. Have they used similar or different characteristics in forming their groups?

Tips: If the students are able to view the inside of the rocks, it helps to identify them greatly. To be able to look at the parts of a rock under a microscope is a nice addition to this lesson because it will allow for them to examine their samples at even a closer range. There are dissecting microscopes in several exhibits at the museum. The students will be able to examine their rocks while on their field trip as well.

Lesson 4: The Rock Change

Objective: By using their creative and critical thinking skills, they will first brainstorm their ideas about how rocks might form, then research ideas about how rocks form, and then do creative reenactments of the process of the rock cycle.

Problem: The students will be presented with three rocks that they are told geologists now think have been formed in different ways. Then the students will take note of their properties by observation, and then hypothesize about how the rocks might have been formed.

Background Information:
The students have a working idea that rocks have an age and were formed at some time in the past. They now need to gain information regarding the
three types of rocks and the rock cycle. The three types of rock are igneous, sedimentary and metamorphic. Igneous rocks form when hot lava from volcanoes cools and solidifies, or in the Earth were magma cools and solidifies. Sedimentary rocks are from sediments like sand or shells and water applies so much pressure that the sediments solidify and make a rock. Metamorphic rocks are rocks that have changed from another type of rock, with a great deal of heat and pressure, for example, limestone (a sedimentary rock) can change into a metamorphic rock, marble, when enough heat and pressure have been forced on the rock. This event is a part of the rock cycle. Rocks can transform from a sedimentary rock to metamorphic, and then melt into magma, which will erupt from a volcano, and when the lava cools, it will be an igneous rock.

**Critical and Creative Thinking Aspects:**

- **Brainstorming** - The students will be trying to figure out how the rocks appear to be different. How could they have formed?
- **Observations and Hypothesizing** - The students will make observations and look at the rocks to see differences. Then the question can be asked, if rocks started out looking the same, then how did they get to these different textures and appearances? The students will also be able to observe fudge being made and cooled. Since fudge is made of different substances that will make it clear what can happen when different substances are heated and melt together, then they are cooled, similar to the rock cycle.
- **Testing** - The students will try to explore with basic materials, like a nail for a scratch test and a polishing material to polish the rock.

**Materials:**

- **Rock Samples**
- **Fudge Recipe and supplies:** 2 cups brown sugar, 2 squares of baking chocolate, pinch of salt, 1+ tablespoon of butter, walnuts and 1 tsp. vanilla (Mix together all ingredients in a saucepan, except the walnuts and vanilla, and bring it to a ‘hard boil’ and keep it at that for exactly 3 minutes. Then remove from the heat and stir in the vanilla and walnuts and ‘beat’ the mixture, then pour into an 8” x 8” pan.
- **Rock testing materials:** nail for scratch test and polishing material
Steps of the activity:
1) The students should be in their Rock Detective Groups with their notebooks and pencils and rock samples. The students will then be asked to compare and contrast the rock samples. The students will be thinking about the rocks with these questions: are there strong bands in the rock layer? Does the rock appear to be made of similar material that is the same color? Does the rock look as though it has a lot of other rocks in layers that make up the whole rock? Does the rock fall apart easily, or is it kind of crumbly? These questions will help lead the students to realizing some of the observable differences between metamorphic, igneous, and sedimentary. Basically, the metamorphic rocks would have the strong bands, the igneous appear to be uniform throughout the rock, and sedimentary look like several rocks all pushed together.

2) The students will be asked to hypothesize how rocks might have formed. Students might be reminded that some rocks have fossils trapped inside them. What does that suggest might have happened? See if they can realize that some rocks might have been in a molten form that solidified.

3) Teacher introduces fudge activity to give them further ideas: An adult can make the fudge at this point in front of the whole class. It would be beneficial for the students to see all of the ingredients layered in a clear bowl to signify sedimentary rocks, then with some heat, and pressure, the batter symbolizes metamorphic rock (if it cooled at that point), then once the batter is well mixed, then the students can pretend it had exploded from a volcano and can cool to become an igneous rock. The students are asked: Could the fudge process be similar to something their rocks experience? The students should observe this process closely. How do the ingredients mix together? What is necessary for the melting and blending into one substance? When the ingredients are not quite melted, are there streaks in the chocolate? Which rocks look like they were made in this way? What other ways could rocks be made?
After these activities, then introduce students to names of the three types of rock and assign students to groups to investigate the formation of one type of rock. The students can do some research either on the Internet with the website suggested in the previous lessons (http://www.rocks-and-minerals.com/; http://volcano.und.nodak.edu/vwdocs/vwlessons/lessons/Pangea/Pangea1.html; http://www.childrensmuseum.org/geomysteries/index2.html) or with some textbook resources. Using the information the Great Rock Detective Groups had learned, they can make posters or some form of presentation to the rest of their class on what they think with proof of how rocks have formed. This could lead to a class discussion on the similarities and differences of each rock group. To even further the students' understanding of where they stand with their information, they could make a chart on poster paper describing each type of rock and its characteristics.

4) This is the ultimate goal for each group to understand: How each rock is formed. The Great Rock Detective Groups should try to examine each group of rocks.

5) Now, in each group, they are going to figure out how to act out how the rocks are changed into the next part of the rock cycle by researching their rocks using the suggested books and Internet sites from the previous lesson, http://www.rocks-and-minerals.com/.

6) Each rock detective group will pick one of the three rocks to act out how it formed. They can write a script and assign parts to each group member. Props will make for an even better performance.

7) Each group will perform, while paying close attention to each other group's performance.

8) Have the class review together what happened to form each type of rock. The class can compare the chart from earlier in the lesson, and then they can realize what they have learned from solving their own problem. The students can add more to their original KWFL and Q chart in their science notebooks.
Tips: Remember the students learn best by kinesthetic movement; it will make an impact on their memory, so this activity should be easily understood and fun!

Teachers (During your field-trip at the Museum of Science)

The main goal of your field trip is for the students (either in the rock detective group or individually) to identify their rocks and try to tell the story of them—meaning where did it come from and how did it form? The students will need to carry their rock samples with them to the museum. I have separated this part of the program into the different sections of the museum where rocks and minerals are displayed.

Depending on what your focus has been in your classroom, you can choose what you would like to continue as you plan your field trip. Therefore, these lessons can be utilized however you like. Perhaps you could separate the different Great Rock Detective groups into each of these lessons.

Lesson 5- What can I find out about my rock? (at the museum)

General Objective: The whole objective of the entire field trip is to learn more about the rock sample that each student has collected. The museum environment will allow for the students to compare and contrast their rocks to the samples and exhibits in the museum.

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General Problem: Find out as much information about the rock samples as possible while visiting the Boston Museum of Science. At the conclusion of the visit, students should have decided what type of rock they have and why. They should also try to identify what type of minerals their rock may contain and how they know.

Problem 1: What minerals are in my rock?

Background Information: Minerals are the basic building block for rocks. All rocks are made up from minerals which have are naturally occurring in the Earth and have a crystal shape, and have a certain chemical composition and
physical properties. This is important to realize because these are the building blocks for rocks. Every rock is made up of certain minerals, and that is how they get their shape, composition and color. You may want to insert your own lesson to make sure the students know and understand the difference between rocks and minerals prior to the museum visit. A great suggestion is to have a picture of a rock and different minerals involved in its composition. For example, you could take granite and the minerals that make it up—feldspar, quartz and mica and have the students cut out different shapes for each mineral to have a clear distinction between the substances. Another analogy can be made with cooking: by making fudge from scratch the students can see the different ingredients (sugar with its crystal shape and chocolate) melt and mix together, then harden to form candy. Another possible activity is to grow crystals or melting materials—sugar or salt to compare to the rocks.

On your field trip—The Museum of Science has several exhibit components that allows the students to explore the minerals. I would suggest going to the Discovery Center, Natural Mysteries, and then Earth: Inside and Out in that order. It will allow for a sequential order to challenge the students’ thinking. In the discovery center, the activity boxes present different ways to test the minerals. The visitor is lead to know the minerals by testing them in different manners, rather than having the label explain what the minerals are and how they are formed. Then students should experience the other two exhibits; Natural Mysteries and Earth: Inside and Out where the explanations are given to the visitors will prove or disprove the students’ thinking about the minerals in their rocks.

1. In the Discovery Center, there is an activity box center with shelving full of different themed boxes. There is a box solely on minerals. This box leads a visitor through several activities that will present to students how to identify minerals by conducting several tests. The students will observe the minerals, hypothesize what kind of minerals are in the box, test the minerals (scratch test and using their senses), and conclude what minerals actually are in the box. With a small guidebook, this box also shows the essential characteristics for minerals, the building blocks for rocks. The students can gather more information about the ingredients in rocks (minerals) and use this information to compare
and contrast to their rocks. The students can test their rocks the same way they tested the minerals, and conclude if there are some of the minerals in the box in their rocks they brought from school.

2. Natural Mysteries- There is an excellent exhibit display, which takes the students through a mineral classification activity. There is a wall display with separate compartments to demonstrate how to classify different minerals by location, color, and the different chemical classes. It is shown by the descriptions in each of the boxes. The museum visitor moves the slides to view the different minerals across the world and different colors and chemical compositions. This exhibit complements the previous one by emphasizing visual observation and explanation, rather than active tests. The students are observing minerals that are possibly in their rocks; they can then write down, which they think they might be in their rocks.

3. Earth Inside and Out- There are many possibilities while working in this area. First of all- relating to the minerals- the students can try to examine one of the defining aspects of minerals, which are their angular shapes, and perhaps they can view some of these in their own rock sample. The students will be able to observe the process and view an exhibit with a good explanation of the building blocks from elements to minerals to rocks. This area also gives a list of minerals that are in rocks. This will demonstrate the formation of rocks in the natural world. There is also a hands-on activity to explore the angles that are naturally made in minerals. It allows for the students to try matching the different angle-shaped plates to the crystal shapes. If the students have magnifying glasses, they can observe the minerals and look for their angles and colors and compare those to the rocks. The students are hypothesizing, testing and concluding what angles are made when crystals form in rocks. One of the most eye-catching features of the exhibit is a case of minerals in all colors of the rainbow. The students can take note and draw some in their notebooks for further reference while solving their problem.
Problem 2: What type of rock is my rock? How was it formed?

In the exhibits that had been visited for the minerals, rocks can be explored and tested. Earth: Inside and Out only allows for observation, although in Natural Mysteries and the Discovery Center, there are dissecting microscopes that give the students the opportunity to observe their rock samples under close view. There are also opportunities to learn about the three basic types of rock: sedimentary, igneous, and metamorphic and how they are formed.

1) Earth Inside/Out. In addition to minerals, the other part is the large samples of different types of rock. There is a clearly defined metamorphic rock with a strong band in it to show the change with heat and pressure and the result. Does their rock have any strong bands? If so, perhaps the students can sketch this in their notebooks. There is also a conglomerate rock, which shows the rounded rocks pushed together with sediments to form the sedimentary rock. Inside the exhibit room, in the display cases, there are igneous and volcanic rocks (they are just not quite as big of a sample as the conglomerate and metamorphic rocks). Does this appear to be similar to the students' rock samples? Why or why not? How do the rocks get to look so polished? Are all rock collections this beautiful?

2) Natural Mysteries. This exhibit explores classification and all forms of living things along with minerals and rocks. The rocks and minerals are displayed in drawers in the exploratory room. The rocks are labeled by the basic metamorphic, sedimentary and igneous. This will give the students a great opportunity to look closely at the rocks and minerals that are in them. Hopefully they will be able to spend enough time looking at the rocks that they will be able to make some observations that will help them to identify their rocks. The students are welcomed to open all of these drawers to observe these rocks and minerals. How do they compare to the rock sample that the students brought with them? Are they shinier? Rougher? What colors are in the rocks? Do they have similar minerals (hypothesize)? Now, have the students observe their rocks
under the dissecting microscope. What do they see? Sketch this in their science notebooks. Have the students write down their observations and details that are not included in the sketch. Do they see any properties that had already observed during the field trip?

3) Rock Garden- This collection of rock samples is awesome. There are rocks from all over the world. There are several from the New England area. This is a great area for students to really look at their rocks and see if there are any similarities between their rock and the ones in the rock garden. The garden also has such large samples that it will give the students an opportunity to see the different characteristics, which separates each of the rocks into the metamorphic, sedimentary and igneous groups. The students can ponder how geologists and archeologists discovered these rocks and got them to the museum. Also, do the rocks in the garden resemble their rock samples at all? How did the shifting of the Earth create such different rocks across the world? The students can sketch any rock that is interesting to them, if there are not any rocks that are particularly interesting, and then sketch the 'Giant’s Causeway' rocks from Ireland.

**A picture is worth a thousand words; imagine viewing the sample in real life.**

Here are some pictures:

![Metamorphic rock sample near Earth: Inside and Out](image-url)
Sedimentary rock sample near Earth: Inside and Out: Both of these samples show this side of the rock- a polished and clear view of the inside of the rock, and the side that is not as clear, the side that geologists see in the ground.

Critical and Creative Aspects:

- **Observation:** While at the museum the students need to be really observant while studying the rocks and minerals.
- **Hypothesizing:** What minerals are in my rock? What type of rock is it?
- **Metacognition:** The students will be constantly thinking about their own thinking because they will be filling out their KNF charts.

Steps while in museum:

1) The students, either in their rock detective groups or individually will go to the different exhibits and become geologists in their thinking process. While in this mode, the students will fill in the find out section of their KNF chart.

2) The students will observe what happens in the process from element to mineral to rock.
3) The students will continue with studying the rocks that are available in the museum. They will think critically and creatively by applying what they know to the museum rock samples and with their own samples.

4) The students need to fill out what questions they feel have been left unanswered.

5) Ask the students to take out your rock sample and compare it to the rocks in the garden. Find a rock in the garden that seems similar to their own sample.

6) Compare and contrast the two samples. Think about the colors, patterns in the rock, and the composition of the rocks. Suggest that they sketch the rock in the rock garden in your science notebook and on the students' KNF charts.

7) Ask the students to write down whether you think the rock is sedimentary, metamorphic or igneous and why. Then you may read the sign to see if the museum tells the student what kind of rock the sample is and where it came from in the world.

Post-museum Visit

Lesson 6- What did the Great Rock Detectives accomplish?

Objective: The groups are going to report back to the class what conclusions they came to in several different forms: writing a short story, a news story, or a visual/kinesthetic story like a play where they can act out the story of their rock.

Problem: It is time for the students to report what their findings are to the class. What type of rock do I have? How do I know? What happened during the problem solving process?

Critical and Creative Aspects:
• Taking Risks- The students are taking risks because they are taking a chance with the conclusions that the group agrees upon.
• Problem Conclusions- In going through the process of problem solving, there are conclusions to be made, although there may still be unanswered questions.
• Team work- The students are working together in their groups to create a story of their own in accordance with their understanding of rocks and the processes of their formation.

Steps for activity:

1) The rock detective groups will get together and look at their KNF charts, and see what conclusions they have come to and where they could have gone or what is left unanswered. They need to ask themselves these questions: What did I know before going to the museum? What did I find out while I was there? Did the museum rock samples look similar or different to my rock? Do I feel as though I have an idea of how my rock formed?

2) Once the groups have discussed the answers to these questions, they can see who in the group has come to conclusions that can be agreed upon in the group. Those stories that make the most sense will be used in their presentations.

3) The groups will then decide how they will present their story. If a short story is decided upon, then the students can break up into writing the different sections and drawing pictures for the story. If a news story is decided upon as the presentation, then the students can separate into different news stories- such as a headline, editorial, or day in the life- or write one together. If the group decides upon acting out the rock story, then the students can separate into working on the script and props.

4) The groups will then create their short story, newspaper story or short play.

5) The groups will present the creations.
6) The class should then discuss what steps they took to solve their problem. Are there any similarities between the thinking processes of the students? Did the students use the same methods to solve their problems? How were the rock stories different? And most importantly, what did the students learn that they did not know before starting this problem solving process?

This concludes the "Got Rocks?" curriculum guide. Thank you so much for being a part of a new learning strand. If you have questions or need a contact for this information, please email: jenne262@yahoo.com.
Bibliography


