Cruising Continents and an Awesome Asthenosphere:
How Convection and Geothermal Energy Fuel Earth's Ever Changing Surface!

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This curriculum unit is recommended for:
Middle Grades Science Earth Science

Keywords: Geothermal Energy, Theory of Plate Tectonics, Hypothesis of Continental Drift, Plate Boundaries, Convection Current

Teaching Standards: See Appendix One for teaching standards addressed in this unit.

Synopsis: This STEAM unit incorporates a study of geothermal energy and its uses through our exploration of plate tectonics. Students will engage with interactive technology as well as produce a technology based presentation. The unit will begin with an investigation of density and how this property helped shape Earth's structure. Students will create an edible model of Earth using an inquiry based method. Students will investigate the Hypothesis of Continental Drift and examine evidence presented to support this hypothesis. Through hands-on activities students will explore the Theory of Plate Tectonics and how the concept of plate movement contributes to geologic phenomena such as Earthquakes, Volcanoes, Rift Valleys, Coastal Mountains, etc. Students will model plate boundaries using candy bars and incorporate the Claim, Evidence, Reason framework as an explanation analysis throughout the unit. This unit will conclude with a culmination project featuring a technology based presentation and visual model. Students will select a topic incorporating overall concepts of Plate Tectonics, Landforms at Plate Boundaries, Geothermal Energy, or Geothermal Energy systems and uses. Students will create a technology and physical product and presentation. Incorporating geothermal energy into the study of plate tectonics will facilitate understanding of their interdependence.

I plan to teach this unit during the coming year in Sixth Grade Science to 180 students.

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"The Universe flows, carrying with it Milky Ways and worlds, Gondwanas and Eurasias, inconsistent visions and clumsy systems. But the good conceptual models, these serena tempa of intelligence on which several masters have worked, never disappear entirely. They are the great legacy of the past. They linger under more and more harmonious forms and actually never cease to grow. They bring solace to the great art that is inseparable from them. Their permanence relies on the immortal poetry of truth, of the truth that it given to us in minute amounts, foretelling an order whose majesty dominates time."

~Emile Argand
Tectonics of Asia (1924), 2, trans. Albert V. and Marguerite Carozzi

Introduction

Carmel Middle School serves over 1000 students in grades 6-8. Geographically, the school is located in an affluent suburban setting of Charlotte, NC in the Charlotte-Mecklenburg School District. 43% of our students qualify for free and reduced lunch. We are a racially diverse school of approximately 21% African American, 56% White, 14% Hispanic, 4% Asian, and 3% other students. For the 2012-2013 school year, 72% of our 8th grade students scored at or above grade level on the Science EOG. Carmel Middle School exceeded our expected growth standards as set by the state of North Carolina. We met 47 out of 47 of the state annual measurable objectives (AMO) and 33 out of 33of the federal AMO. Our school is fortunate to have an active PTSA and exceptional parental support. I teach sixth grade science on a rotating A day B day schedule. I teach the same lesson to six different classes over the course of two days. My classes are a heterogeneous group of students of varying abilities and science backgrounds. I create differentiated activities within the content objective to meet the diverse educational needs of my students.

My science curriculum is based on the North Carolina Essential Standards and paced according to the CMS yearly pacing guides. Activities are chosen that will create an inquiry based science experience for my students. Most lessons are interactive and are divided into teacher input, guided practice or additional investigation, independent practice or group inquiry activity, explanation of results or investigation and finally additional questions or ideas to explore. I incorporate the use of a SmartBoard and video clips from Discovery Education, Study Jams, You Tube, and National Geographic on a daily basis. CMS Science instruction in 2013-2014 will also include the use of Discovery Education's Tech Book. This online resource provides a variety of video clips, reading passages, and activities through which to engage students. Students use my classroom desktop and laptop computers to access a variety of web-based resources for both instructional input and interactive activities which supplement our informational text source. As a product of Bring Your Own Technology to school, students will be able to interact with our web resources in a more inclusive manner. My science department also has access to a set of Chrome Books with which to supplement student devices. Students visit the school computer lab often throughout the year for additional research or web activities. I use an iPad in my classroom and incorporate a variety of both content and product apps during classroom instruction. Throughout instruction I engage students by including hands-on activities, labs, and/or investigations during most class periods. Labs and activities include both teacher directed inquiry labs and student created labs which focus on a general inquiry question. Students frequently participate in learning stations consisting of both research and hands-on activities.

Rationale

As all students do not come to me with the same Science background it is important that I provide opportunities for science discovery during which students "fill in the gaps" of their science content knowledge. To facilitate the combining of and building upon prior knowledge, I intend to incorporate student created learning teams for classroom activities and research. Students will be held accountable through a group evaluation process at the end of their research. As a function of the North Carolina teacher evaluation measure, learning teams contribute to a student's acquisition of twenty-first century skills and increase critical thinking practices. The learning teams will be created by students using a set criteria established by the teacher. Students will be set into groups according to learning styles and strengths and grouped accordingly. I feel that students work well when paired with a comfortable partner so student preference will be considered. Students will elect a team captain who will serve as a leader and monitor throughout group work. It is important for students to take ownership of their learning and creating a team with whom they will work and design is essential. Students will also evaluate their team members at the end of each major project or activity.

Plate Tectonics, Energy and the concept that Earth's surface is constantly changing are difficult topics for adults to articulate and thus even more so for the sixth grade student. I will make the concepts less abstract by encouraging my students to create models and diagrams through hands-on activities. I feel that this inquiry and activity based learning will enable my students to process the information more readily. Students are often confused by the interchangeability of the term Energy and how Energy transfer alters our Earth. I plan to facilitate an understanding of plate boundaries, forms of Energy transfer, and how heat in Earth's mantle facilitates the formation of various landforms. Students will also investigate renewable Geothermal Energy as it relates to convection within

Earth’s mantle. Students will complete a long-term project with their learning team by designing and creating a model to represent a landform related to Plate Tectonics, convection within Earth’s mantle, or a use of geothermal energy. Students may choose to model a volcano, earthquake, rift valley, island arc, plate boundary, or geothermal system. Students will also design a technology based presentation. Students may choose from a variety of documentation methods such as Mentor Mob, Glog, VoiceThread, or iMovie. To generate interest for our unit on Plate Tectonics and Geothermal Energy, students will manipulate the iPad application “Earth Viewer”. This application allows students to view Earth’s changing surface from the Cambrian period until present day. Students are able to manipulate the changing continents and also view the grid of current cities of the United States and other nations. This application displays a concrete view of our changing Earth. To aid student understanding of Earth’s changing surface, we will investigate convection as a method of energy transfer. Students will participate in hands-on activities to demonstrate and manipulate convection as a concept. Geothermal Energy is an exciting renewable energy source which is widely used in various parts of the world. Through our discussion of plate tectonics and convection students will investigate geothermal energy and its uses in various parts of the world. Students will explore Iceland and the Pacific Ring of Fire during this concept discussion. As a function of our study of energy resources, students will use interactive technology to research and explain this alternative energy source. Students will also use technology to interact with research and create an interactive method of presentation for their final project. Students may use edu.glogster.com website to create a Glog, incorporate digital images and actual photographs to create an iMovie or Voice Thread on the iPad or choose to create a Mentor Mob using www.mentormob.com. Mentor Mob allows students to use current digital images from the web, upload student created files and documents, link to applicable videos, and include assignments or research activities during the process of working through a number of steps. The use of relevant technology during the instructional and assessment phase of this unit further emphasizes the presence of energy in the world around us. Recognizing this application of scientific content to their personal environment is an important 21st century skill. Furthermore, the incorporation of energy sources as well as the geologic reasons for Earth’s changing surface encourages students to synthesize the unique meaning and characteristics of each concept.

Objectives

My science curriculum is rooted in the Essential Science Standards and objectives. Designing goals and activities based in these standards will create a unit more focused on the direction of science instruction within my district. These objectives will add relevance to the exploration of Plate Tectonics and destructive and constructive forces within Earth’s crust. The exploration of energy sources related to Earth’s geology will add relevance to the incorporation of Physical and Earth science concepts. In addition, I plan to address interdisciplinary essential and common core objectives during this unit.

During this unit I plan to address the following North Carolina Essential Science Standards:

Overall Standard 6.P.3
Students will understand the characteristics of energy transfer and interactions of matter and energy.

Substandard 6.P.3.1
Students will illustrate the transfer of heat energy from warmer objects to cooler ones using examples of conduction, radiation, and convection. Students will recognize the effects of energy transfer.

Within this standard students will have already studied the phases of matter and how thermal energy affects matter. Students will view a multi-media explanation of particle movement during heat transfer. Students will participate in a variety of hands-on activities to address particle movement during convection. Boiling water in a pan with Styrofoam cut-outs to represent the continents will allow students to view simulated plate movement. This may also be done with an aquarium pump. Students will investigate properties of matter including density as it relates to Earth's structure and plate movement. Students will interact with Discovery Education Tech Book to explore how temperature and pressure can cause matter to change states.

Students will have already completed our unit on energy and will have a basic understanding of potential and kinetic energy and the various forms of energy such as chemical, thermal, and mechanical. Students will understand the law of conservation of energy and that Earth's energy is rooted in the Big Bang expansion. Students will respond to questions relating to an object's density and how this property affects Earth's formation. How does an increase in thermal energy affect particle movement and how does this relate to plate movement? We will also investigate how an increase in temperature or variation of material affects convection. Students will describe conduction, convection, and radiation and identify how this energy transfer occurs in real life. Students will view a teacher created multimedia presentation depicting all methods of energy transfer and then focus on convection as it relates to plate movement. Students will use a heat-transfer kit to explore transfer of thermal energy from warmer to colder substances. It is important for students to understand that energy is not created nor destroyed, but merely transferred or changed.

Overall Standard 6.E.2
Students will understand the structure of the Earth and how interactions of constructive and destructive forces have resulted in changes in the surface of the Earth over time and the effects of the lithosphere on humans.
Substandard 6.E.2.1

Students will summarize the structure of the Earth, including the layers, the mantle, and core based on the relative position, composition, and density.

As we discuss the formation of the Solar System and the arrangement of materials into Earth's layers, students will conduct hands-on investigations of density and recognize that more dense material will sink below less dense materials. A simple activity to demonstrate this concept is the use of fresh water and salt water. Further explanation follows in the activities portion of this unit. Students will also use various food materials to create a model of Earth's layers. Students will model the core, mantle, asthenosphere, and crust. Students will be given the materials with the direction to create a model considering the thickness and density of Earth's layers. During this inquiry based lesson students will be expected to identify the item chosen to model each layer and explain their rationale for this choice. Students will be asked to identify the similarities and differences of their model to the actual layers of Earth. Students will respond to a lab analysis as well as illustrate, label, and describe Earth's layers.

Substandard 6.E.2.2
Students will explain how crustal plates and ocean basins are formed, move and interact using earthquakes, heat flow, and volcanoes to reflect forces within the Earth.

Students will create a model of plate movement using candy bars. Students will relate the layers of the candy to Earth's layers. Students will demonstrate a divergent boundary and continental-continental collision using the candy. Students will make inferences about land formations which occur at each boundary. To facilitate student understanding of this objective, I will provide kinesthetic learning cues. Hand motions depicting plate movement while wearing color coded socks on my arms (blue for oceanic crust and green for continental crust) will allow students a visual cue in addition to verbal explanation of the concept. Students will also complete a graphic organizer for the plate boundaries as they are introduced in class. Students will explain and illustrate plate boundaries and landforms thus providing differentiation of the learning process. Students will examine evidence of continental drift using activity sheets available from the United States Geologic Services website http://volcanoes.usgs.gov/about/edu/dynamicplanet/. One activity sheet provides a continent map depicting various animal and plant fossil evidence supporting the hypothesis that all continents were at one point connected as Pangaea.

Students will also demonstrate plate movement on the asthenosphere using a small ball, red toothpaste and cardboard pieces cut to look like the continents. With a partner students will manipulate the cardboard pieces to simulate plate movement and the resulting landforms. Students will use the Claim, Evidence, Reason explanation analysis described in the Instructional Strategies section of this unit to synthesize their observations. The use of hands-on activities creates a visual model for students to reference as they establish an understanding of the concept.

Overall Standard 6.P.3.3

Explain the suitability of materials for use in technological design based on a response to heat (conduction, expansion, and contraction) and electrical energy (conductors and insulators).

Students will investigate conductors and insulators and how they react to thermal energy. Students will explore a variety of objects and classify them according to their ability to conduct heat. Students will perform an exploration of materials to insulate heat transfer. Students will monitor heat transfer by temperature and rate of energy transfer. Students will work with their learning team to research geothermal energy and how it is facilitated by convection within Earth's mantle. Students will investigate parts of the world best suited to the use of geothermal energy and how this alternative source can be a substitute for fossil fuel consumption. Students may choose to create a model of geothermal energy for the culminating project. Students will explore convection within Earth's mantle as a source of volcanic and earthquake activity. Students will infer how energy transfer is affected by the medium through which it travels and as well as the substance facilitating the transfer.

The following Cross-Curricular Essential and Common Core Standards will be addressed within this curriculum unit:

Overall Technology Standard 6.TT.1

Students will use technology and other resources for the purpose of accessing, organizing, and sharing information.

Substandard 6.TT.1.1

Students will select appropriate technology tools to gather data and information (e.g., Web-based resources, e-books, online communication tools, etc.).

Substandard 6.TT.1.3

Students will select appropriate technology tools to present data and information effectively (multimedia, audio and visual recording, online collaboration tools, etc.).

Students will use text and web based resources to research geothermal energy and the landforms created by plate tectonics. Students will create a technology based presentation in addition to a three dimensional model of their chosen topic. Students will select and justify web and text resources for research and presentation. As a 21st century skill, it is essential that students recognize and select credible web sources. We will use an evaluation checklist to establish credibility of websites chosen for research. The following document by Kathy Schrock is available for reproduction for classroom use http://kathyschrock.net/abceval/5ws.pdf.[1] This basic guide provides students with direction when selecting a web resource and establishing its credibility.

Common Core Standard CCSS.ELA-Literacy.RST.6-8.7
Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., flowchart, diagram, model, graph, or table).

Common Core Standard CCSS.ELA-Literacy.RST.6-8.9
Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text on the same topic.

Students will conduct online and text based research on the hypothesis of continental drift and theory of plate tectonics. Students will view various diagrams and models displaying Earth's surface as it has changed over time. Students will manipulate three dimensional and web based models of plate movement. Students will analyze written text and visual models to determine elements of evidence to support the theory of plate tectonics. Providing students with a variety of resources will scaffold the instruction to meet the needs of all students. I plan to access various websites and iPad applications to allow for visual representation of plate movement and geothermal activity. EarthViewer is an iPad application that allows students to view the change in continent location over time. If the iPad application is unavailable, there is a suitable substitute available at the following website http://www.ucmp.berkeley.edu/geology/anim1.html. Students will also create a technology based product presentation as part of a culminating project.

Scientific Content: Overview for Teachers

Vocabulary

Matter: any substance that has mass and takes up space
Conservation of Energy: Energy is neither created nor destroyed; the total amount of energy in the universe is finite and constant
Energy: the ability of a system to do work
Potential energy: Energy due to an object's position in relation to another object or system or forces between the two
Kinetic Energy: Energy related to motion
Big Bang: Accepted theory explaining the origination of the Universe billions of years ago from an expansion of a dense mass of matter; created hydrogen and helium and the ultimate energy source of the universe
Temperature: Average kinetic energy of the molecules in a substance or system
Conduction: Transfer of heat energy by direct physical contact
Convection: Transfer of heat energy by bulk movement of a substance

Radiation: Energy transfer during which electromagnetic and/or light energy may travel through a vacuum as well as matter containing media
Conductor: Material or substance which allows the flow of energy
Insulator: Material which stops or slows the flow of energy
Thermal Energy: Total kinetic energy of a substance or system
Subduction Zone: Plate boundary where one plate which is older, colder, and/or denser subducts or slides under the newer less dense plate
Geothermal Energy: heat from the Earth; clean, renewable energy source
Pangaea: concept of a super-continent; at one time millions of years ago all of Earth's landmasses were connected

Science Concepts

According to the United States Department of Energy in its July 2012 publication, "Energy Literacy: Essential Principles and Fundamental Concepts for Energy Education,"[2] there are Seven Basic Principles that are necessary for Energy literacy in the United States. They are as follows:

1. Energy is a physical quantity that follows precise natural laws.
2. Physical processes on Earth are the result of energy flow through the Earth system.
3. Biological processes depend on energy flow through the Earth system.
4. Various sources of energy can be used to power human activities, and often this energy must be transferred from source to destination.
5. Energy decisions are influenced by economic, political, environmental, and social factors.
6. The amount of energy used by human society depends on many factors.
7. The quality of life of individuals and societies is affected by energy choices.

Each Essential Principle is further explained by a set of Fundamental Concepts which provides additional details and unpacking of the broad content addressed in the principle. Teachers may order this publication for free via mail at http://www1.eere.energy.gov/library/viewdetails.aspx?productid=6482

Hypothesis of Continental Drift

Alfred Wegener, a meteorologist by trade, re-introduced the idea that Earth's continents were in constant motion in 1912[3]. He was first drawn to the idea of Continental Drift when he noticed the jigsaw like fit of South America and Africa. Wegener stated that at first the supercontinent of Pangaea separated into two continental landmasses called Laurasia in the northern hemisphere and Gondwanaland in the southern hemisphere. These landmasses are speculated to then have further broken apart into the continents as they exist today. Wegener cited three key pieces of evidence to support his hypothesis of continental drift.

Fossils: Plant and animal fossils were found on South America and the western coast of Africa, thus supporting the idea that the continents were at one point connected. One such animal is the *Mesosaurus* lizard. This small reptile is believed to have lived about 270 million years ago. Fossils of its kind have not been found anywhere else in the world. The idea that the lizard crossed the large area of water between the continents seems impossible.

Geology: Some of the most convincing evidence to support the hypothesis of continental drift comes from rock formations found on the continents. Basalt found again on the coast of South America was found to exactly match the type and age of basalt found on the Western coast of Africa. Additionally, limestone layers found in rock formations of the Appalachian Mountains in North America matched limestone found in the Scottish Highlands. This geologic evidence further explains the existence of Pangaea and the hypothesis that these continents have moved apart over time.

Climate: The presence of tropical plant fossils on Greenland and ice scrapings on rock formations in South Africa provide further evidence to support Wegener's hypothesis of continental drift. Greenland, which is now located near the Arctic Circle, does not have a climate which could support the growth of tropical plants. The supposition is that Greenland had at one time, many million years ago, been located near the equator. Ice scrapings on the rock formations in South Africa supports the idea that at one time Africa was located much closer to the South Pole, but has moved north over time. As the glaciers on its surface melted, deep gouges were created along its rock formations.

Alfred Wegener's Hypothesis was not widely accepted during his time because he lacked a fundamental explanation for how continental drift occurred. He could not provide evidence of a force on Earth strong enough to create and sustain the movement of such massive land continents. Although he died on an expedition in 1930 while crossing the Greenland ice cap[4], Wegener's ideas took hold when evidence discovered during exploration of the ocean floor provided a possible explanation for his theory. This discovery is thought to have led into development of the Theory of Plate Tectonics.

Theory of Plate Tectonics

Plate tectonics is an established theory that Earth's outer layer, its crust, is made up of large sections of continental and oceanic plates which are in constant motion. This theory explains how mountains are formed, why volcanoes erupt, and even why earthquakes occur. The plates are moving because of a method of energy transfer called convection within Earth's mantle. As the molten rock in Earth's mantle that is closest to the core heats up, it becomes less dense and begins to rise. Conversely, the molten rock farther away from Earth's core will be cooler and thus denser and begin to sink. This flow of energy through particles in the molten rock creates convection current. This convention current in Earth's asthenosphere fuels plate movement. The asthenosphere is the uppermost part of the mantle in which convection is most prevalent. The asthenosphere acts as the base and allows the continental and oceanic tectonic plates to move. The theory of plate tectonics provides explanation for the existence of similar fossils on continents now far away from each other as several million years ago all of Earth's landmasses were thought to have formed one supercontinent called Pangaea.

Convergent Boundary

Where tectonic plates come together a convergent boundary is created. At a convergent boundary a variety of landforms may result. At a continental-continental collision, mountains will form. The two continental plates will bend and fold as they are of equal density. This type of boundary is responsible for the formation of the Appalachian Mountains in North America and the Himalayas in Asia. While the Appalachian Mountains have stopped growing, the Himalayas are continuously being pushed upwards as the Indian and Eurasian continental plates collide. This collision is thought to have started 50 million years ago and results in the rise of the Himalayas by more than 1cm per year. This growth is offset however by weathering and erosion.

Oceanic and continental plates may also come together at a convergent boundary. This will form a subduction zone as the colder, denser oceanic plate is forced down and under the more buoyant continental plate.[5] During oceanic-continental subduction, Coastal Mountains may form as the subducted oceanic plate melts in the asthenosphere, creates additional magma and a buildup of pressure. This pressure pushes on the crust above and causes the crust to rise thus creating a mountain. Oftentimes these mountains are volcanic in nature. The oceanic plate does not slide smoothly beneath the continental plate therefore earthquakes may result.

Oceanic-Oceanic subduction is the third type of convergent boundary. During this subduction, similar to oceanic-continental subduction, one plate moves beneath another plate. In this case the older, denser oceanic plate will subduct. The process is like oceanic-continental in that excess magma is formed and thus a buildup of pressure. This may result in the formation of mountainous islands call Island Arcs. These islands generally form along the plate boundary in an arc. The Aleutian Islands in Alaska and the Islands of Japan are Island Arc formations. It is common for these formations to also be volcanic in nature. An area of oceanic-oceanic subduction is commonly known as the Pacific Ring of Fire. This area in the Pacific Ocean is home to the majority of Earth's volcanic activity and is geologically volatile.

Divergent Boundary

The boundary where two plates move away from each other is a divergent boundary. The North American and Eurasian plates are moving away along the Mid Atlantic Ridge. This movement is called sea floor spreading and results in a symmetrical alignment of rocks on the ocean floor. At a divergent boundary the crust is stretched thin and rising magma can result in underwater volcanic activity. The Mid Atlantic Ridge actually rises above sea level in Iceland and provides a source of geothermal activity that is often harnessed for power. Also occurring at a divergent boundary is a rift valley. In Africa a currently active rift system is where the Arabian Plate is moving away from the African Plate.[6] This movement will stretch the continental plate until it will eventually fall below sea level and possibly create new oceanic lithosphere and ocean basin.

Transform Boundary

When plates are sliding past each other a transform boundary is the result. Earthquakes are very common at transform boundaries because the movement is anything but smooth and peaceful. Often large blocks of rock become stuck and an immense amount of pressure is created. When those blocks move, that pressure is released in the form of Earthquake waves. The energy released during an earthquake can have devastating results to the area. While crust is neither created nor destroyed at a transform boundary, the release of energy in the form of earthquake waves can be of considerable magnitude. The most commonly known transform boundary is the San Andreas Fault in California. This is one of the few places on Earth where a transform boundary can be seen above sea level. Rivers, roadways and other landscape features are noticeably displaced by this plate movement.

Geothermal Energy

Geothermal Energy is thermal energy contained in the bedrock and fluids beneath Earth's surface. Geothermal energy can be found in shallow ground as well as several miles beneath the surface. This energy can be harvested to generate electricity or used with a heat pump system capitalizing on the steady temperature below ground to provide efficient heating and cooling. An excellent, easy to understand video demonstrating the basics of geothermal energy can be found at http://bcove.me/j8ao87j1. This video, offered by the Renewable Energy World.com website, offers an overview of geothermal energy, how it is created within Earth's crust, and how it can be harvested.

Many countries are already using geothermal energy as a renewable energy source. Geothermal energy has been used for thousands of years as naturally occurring hot water from mineral springs was used for bathing, cooking, etc. Geothermal energy can still be used in this way through direct use technology. During this process a well is drilled to access the reservoir of hot water under Earth's surface. This water is pulled into a system of piping and an exchanger which allows the hot water to provide heat for a variety of uses. Geothermal direct use heating can be used to heat buildings, warm greenhouses for plant growth and warm the water in fish farms. Most geothermal reservoirs in the United States are located in the western states, Alaska, and Hawaii.

Another use for geothermal energy is the production of electricity in a dry steam or flash steam power plant. In both instances, geothermal energy from Earth in the form of hot water or water vapor (steam) is used to generate electricity as steam turns a turbine and thus generates electricity. The mechanism is similar to a traditional power plant in that the water is boiled to produce steam. However a traditional power plant often uses fossil fuels to boil the water.

Geothermal Energy at Use in the World

Currently many parts of the world are expanding their use of geothermal energy as a means to combat dependence on fossil fuels and reduce its environmental impact. Currently geothermal plants produce 25 percent or more of the electricity in the Philippines, Iceland, and El Salvador. In the United States, the state of California uses over 40 geothermal plants to provide nearly 5 percent of the state's electricity.[7] Internationally, Iceland has gone from one of Europe's poorest nations, dependent on imported peat and coal for its energy, to a prosperous nation where practically all stationary energy is gained from renewable resources.[8] According to Iceland's own National Energy Authority website, www.nea.is/geothermal, roughly 66 percent of Iceland's primary energy use was geothermal in nature.[9] Iceland is geologically ideal for geothermal energy as it sits on the Mid-Atlantic Ridge. At this location the divergent boundary rises above sea level and the rift valley is visible on the continental surface of Iceland. Excellent photos of this visible continental divide are accessible at Iceland on the Web under the photogalleries.[10] Visit this informative website at www.iceland.vefur.is/Photogalleries.

Strategies

Our unit on Plate Tectonics and Geothermal Energy will be taught after our Physical Science unit on the basics of energy, forms of energy, and methods of energy transfer. The hypothesis of continental drift and the accompanying evidence to support this explanation of change in Earth's surface over time is an exciting concept for students to investigate and manipulate. The unit will begin with a review of The Big Bang and formation of the Solar System and source of Earth's energy. Students will participate in a variety of hands-on activities to reinforce the concept of continental drift and plate tectonics. Differentiation of instruction will include lessons focused on kinesthetic cues, inquiry based labs providing opportunity to create models of important concepts, lessons linked to manipulative materials, and extensive use of interactive technology.

Students will begin their investigation into the energy behind Earth's forces by first investigating Earth's layers and its density. I work to incorporate inquiry based lessons within my science classroom where appropriate. Oftentimes at the sixth grade level students are not fully prepared for a complete inquiry approach but instead are given guided instructions to facilitate their understanding of an overall theme. The National Science Education Standards defines scientific inquiry as "the diverse ways in which scientists study the natural world and propose explanation based on the evidence derived from their work. Scientific inquiry also refers to the activities through which students develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world."[11] It is essential for students to not only learn how to ask important relevant questions, but how to locate evidence to answer those questions. The National Science Teachers Association suggests that teachers can encourage development of inquiry skills by helping students learn how to draw conclusions and think critically to create explanations based on the evidence discovered.[12] Facilitating the ability to clearly state an explanation using evidence based reasoning is an important skill in scientific inquiry.

To generate excitement within our unit on Plate Tectonics and Geothermal energy, students will view video clips from You Tube on Iceland and Geothermal Energy. We will discuss questions such as: How does convection within Earth's mantle fuel the convection current? How did continental drift begin and what will our world look like in the future? How can we capture thermal energy from Earth and use it to power our world? How does plate movement change Earth's surface over time? Is Earth the only planet with plate movement and if so, why? Students will complete a KWL chart explaining what they KNOW, what they WOULD like to know and what they have LEARNED. The creation of this chart allows students to establish personal learning goals for the unit. Throughout the unit students will be encouraged to refer to their KWL chart and fill in any concepts that they have learned through instruction or research. As stated previously my students come to me with varying degrees of science background knowledge. By articulating at the beginning of the unit what they WOULD LIKE to know about the concept, students will establish a set of personal leaning goals and thus increase student accountability for learning.

An additional instructional strategy that I will incorporate this year in my classroom is the Claim, Evidence, Reason framework when completing all explanation analysis of lab and hands-on activities. National Science Education Standards[13] and education researchers recognize the need for students to create evidence-based scientific explanations during hands-on inquiry investigations. The English Language Arts Common Core standards in writing also offer support for the use of the Claim, Evidence, Reason framework. Common core Standard CCSS.ELA-Literacy.W6.1a states that students will introduce a claim and organize the reasons and evidence clearly. Additionally, Common Core Standard CCSS.ELA-Literacy.W.6.1b states that students will be expected to support claims with clear reasons and relevant evidence, using credible sources and demonstrating an understanding of the topic or text. The integration of common core language arts standards into the science classroom supports the reinforcement of cross-curricular objectives.

The CER structure is adapted from Toulmin's model of argumentation and was presented during a Sixth Grade Science Curriculum Study Professional Development in August 2013. The presenter referenced the book Supporting Grade 5-8 Students in Constructing Explanations in Science: The Claim, Evidence, and Reasoning Framework for Talk and Writing by McNeill and Krajcik[14] as the source for the Claim, Evidence, Reason framework adaptation. The reference book offers further explanation of the rationale behind the framework. This synthesis of information provides students with a concrete framework to follow when constructing an explanation analysis. This encourages an analysis based in fact and conceptual observations and reinforces writing practices. Students are required to write a complete sentence making a **Claim** about the lab they performed. Students will write this claim as a statement or conclusion addressing the original question or problem. Students will then compose two or three sentences stating the **Evidence** from the lab. The evidence will be based on accurate data and observations from the activity. The evidence explanation will require students to reference data and observations from the lab activity. Students may also cite relevant information discovered during research or refer to alternate sources of factual information. This evidence will be used to directly support the stated claim. The final step in the framework is to state the **Reason** behind the claim. The reason should draw upon the evidence for support and relate directly to the claim. The reason should address why the student thinks the claim is true. This explanation analysis requires students to move beyond simply a literal explanation and encourages them to synthesize the observations and data into a detailed analysis of the activity. The CER framework is different from a hypothesis or prediction made before the inquiry lab in that students are offering an explanation for what occurred within the lab experience. Additionally, students are required to offer data as evidence and synthesize this information into a reason for the results observed.

In my classroom, we will participate in an extensive use of interactive technology. Diagrams, animations, and models of plate tectonics, geothermal energy and convection will allow students a visual perspective when learning new concepts. The movement of lithospheric plates under Earth's crust which we cannot feel nor see is an abstract concept for the sophisticated learner to accept. Providing my students with visual cues and hands-on experiences provides instructional differentiation and process. The use of hands-on materials, both web and research based, encourages students to delve into the science first hand and establishes a personal experience with the science concept. While investigating Wegener's evidence for continental drift, students will manipulate puzzle pieces with maps of fossils found throughout Earth's history. Students will color code and then cut out and align these fossils to create the Pangaea. Using manipulative materials provides a concrete reference for a very abstract concept. The puzzle pieces and accompanying background information can be found at http://volcanoes.usgs.gov/about/edu/dynamicplanet/wegener/[15]. Students will access various websites during our investigation of plate tectonics and geothermal energy. The United Nations University channel on You Tube, http://www.youtube.com/user/UNUChannel?feature=watch, is an excellent source of video clips for explanation of Geothermal Energy. This channel also provides in-depth look at Iceland and how this country uses Geothermal Energy to supply its nation with power. Students will investigate these video clips and refer to them during our introduction on Geothermal Energy. Students may also choose to reference this material when planning their culminating project. Within the classroom setting, students will engage students with interactive technology during all stages of content mastery. Students will use individual devices to participate in research and web-based instruction as well as produce alternative assignments throughout the unit. Students will participate in an increased focus on interactive technology during the creation of lab reports, explanation analysis, instructional videos and classroom presentations. I look forward to allowing my students to experience science through hands-on inquiry labs and watching them use technology to create methods of sharing their new knowledge with their classmates. The use of technology allows us to further explore the abstract concepts of Plate Tectonics, Convection and Geothermal Energy as well as the continuing effects on Earth's surface.

Classroom Activities

Density and Earth's Layers

It is necessary for students to investigate and understand the property of density and how it affects the formation of Earth's layers. Students will begin this investigation with a mini-lab using two beakers of warm fresh water. To one beaker students will add several spoonfuls of salt. Students will stir and dissolve the salt into the water. They will then add several drops of food coloring to the salt water. As students very slowly pour the salt water into the fresh water beaker they will see the salt water sink to the bottom of the beaker thus leaving a rim of clear water at the top of the beaker. Students will respond to this mini lab using the Claim, Evidence, Reason explanation analysis described in the strategies section of this unit. Students will state their claim regarding dense materials, cite the evidence from this lab that supports that claim, and provide a reason for this observation.

Another activity which requires students to consider density as a property and examine how it affects Earth's structure and application of the convection current, is the Earth's Edible Layers Model. Following our classroom exploration of Earth's structure and formation, students will be given a marshmallow, chocolate malt ball, pink frosting, and a graham cracker to create a model of Earth's layers. Students will also illustrate, color, and label a diagram of Earth's layers at the beginning of the lab activity. Students will reference text and web based resources as they illustrate Earth's layers. After initial instructions are provided, students will be given the materials and the lab sheet found at the end of this unit as *Appendix Two*.

Plate Boundary Investigation

This investigation will begin with a discussion of the convection current. Students will view a demonstration of the convection current. For this demonstration I will place a large pan of water on a hot plate. I will place Styrofoam cut-outs in the shapes of the continents on the water. As the water begins to boil and the "Plates" move students may infer how this model represents plate movement on Earth's asthenosphere. This demonstration may also be done using an aquarium pump. While not showing true convection, it might be easier to perform depending on materials available. To make this a hands-on activity for individual or small groups of students, provide each group with a small pie plate or bowl with water and Styrofoam or sponge cut-outs. To create the "convection current" students will be given a straw and instructed to blow air into the water. This is not true convection, but allows students to participate in the activity. Following this class instruction on the convection current, I will share the iPad application *Earthviewer* to demonstrate continental drift over time. Students will then view a teacher created multimedia presentation on plate movement and plate boundaries. Students will access multiple text and web based resources to investigate, illustrate, and describe plate boundaries on a graphic organizer. Students will access the websites cited in this unit to explore plate boundaries and the landforms that result from this plate movement. Scaffolded text resources will provide students with differentiated instructional materials. An image of this activity sheet is labeled as *Appendix Three*.

Following our introductory discussion on plate tectonics and plate boundaries, students will complete an Edible Tectonics Lab Activity. I was introduced to the idea of using a candy bar to model plate movement several years ago by a colleague. I have created a new set of questions and steps encouraging students to synthesize this information with a model representing plate movement. The incorporation of hands-on activities coincides with the inquiry model suggested by the National Science Teachers Association.[16] Steps to follow and question set for students are located under *Appendix Four*. Students may work through this investigation with their learning team and then discuss as a group. A whole class discussion will be held to ensure that all students have made appropriate inferences and conclusions based on the activity.

Geothermal Energy Investigation

During this unit I want students to explore geothermal energy as a viable, clean alternative to fossil fuels and other nonrenewable sources of energy. Geothermal energy is basically steam used to either turn a turbine to generate electricity or as a direct use heat source. As a class demo I will use boiling water to represent geothermal energy and a burning candle to represent the use of fossil fuels. First light the candle and allow it to burn. Next, boil water on the hot plate and then hold a coffee filter 15 centimeters over the pot using tongs with rubber handles. I plan to move the filter over the steam for one minute. Students will then examine the coffee filter for signs of burning or residue. As steam is a clean energy source, there will be no residue. After this demo, I will hold a clean coffee filter over a candle 15 centimeters above the flame, again using tongs with rubber handles. I will move the filter around again so as to keep the filter from catching on fire. Hold the filter in place at times long enough for slight burning to occur and residue to accumulate. After one minute students will examine the filter for residue. I will do this several times so that each learning team will have a set of filters to examine. I will also show the activity under the document camera. Students will then respond to a variety of critical thinking questions about the demo. Students will also construct an explanation analysis using the Claim, Evidence, Reason framework. The set of questions can be found as *Appendix Five*. **Teacher's note:** I suggest that you try this activity beforehand to get a feel for how long to hold the filter over the flame. It may take some practice to accomplish the desired results.

Plate Tectonics and Geothermal Energy Project

Students will select a topic associated with Plate Tectonics or Geothermal Energy to culminate our unit of study. Students have the option to research and create a model of any of the following:

- Landform caused by plate movement (Rift Valley, Island Arc, etc.)
- Demonstration or diagram of the convection current
- Earthquake fault
- Plate Boundary (Convergent, Divergent, Transform)
- Geothermal energy system

Students will design and build a three dimensional representation of their topic and also create a technology based presentation. For the presentation, students may create a Prezi, iMovie, Photo Story, Voice Thread, Power Point or other student-selected presentation model. Students will synthesize information taught throughout the unit to respond to learning goals set at the beginning of instruction and determine a topic about which they would like to further research. Students will use the project description described in *Appendix Six* as an outline for their research. As students may choose to research a geologic occurrence or geothermal system, the explanation of the project will need to include both directions. Students will use the class Chrome Book to conduct research within the classroom setting, but the actual project model will be constructed at home. I plan to partner with my school's media specialist to instruct students as the correct process for research citations. Students will be assigned points for project completion based on the following rubric. Presentation, On-time completion, and Bibliography will earn 10 points each while the technology product and physical model will each earn a possible 35 points. Teachers may further refine each category as it suits his/her individual classroom.

I am so excited to teach this unit with my sixth grade students. Marrying the concepts of plate tectonics and geothermal energy will truly allow my students to recognize and experience how these phenomena are related. Often in science students learn content in isolation without understanding the relationships and interdependence of the many geologic events occurring beneath our feet. Incorporating a culminating project will encourage students to take ownership of their learning and allow them to further investigate topics in which they are most interested. Facilitating an interest in science and an understanding of the amazing changes taking place every day beneath Earth's surface is the ultimate goal in my science classroom. Our Earth is a fascinating planet and I look forward to taking this journey of discovery with my students.

Appendix One

Implementing Common Core and Essential Standards

Substandard 6.P.3.1
Students will illustrate the transfer of heat energy from warmer objects to cooler ones using examples of conduction, radiation, and convection. Students will recognize the effects of energy transfer.
Students will investigate and model convection in Earth's mantle and explore how it drives plate movement.

Overall Essential Standard 6.E.2
Students will understand the structure of the Earth and how interactions of constructive and destructive forces have resulted in changes in the surface of the Earth over time and the effects of the lithosphere on humans.
Students will use text and web based resources to investigate plate boundaries and plate movement. Students will explore digital and print diagrams, animations, and illustrations of plate tectonic concepts. Students will model plate movement using candy bars and kinesthetic movements.

Technology Substandard 6.TT.1.1 and Substandard 6.TT.1.3
Students will select appropriate technology tools to gather and present data and information.
Students will access a variety of web based research sites and online animations to research information about plate tectonics. Additionally students will use interactive technology to design and produce a class presentation as part of a culminating project.

Common Core Standard CCSS.ELA-Literacy.RST.6-8.7
Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., flowchart, diagram, model, graph, or table).

Common Core Standard CCSS.ELA-Literacy.RST.6-8.9
Compare and contrast the information gained from experiments, simulations, video or multimedia sources with that gained from reading a text on the same topic.
Students will synthesize information gathered from print and web based resources to identify, illustrate and explain movement at plate boundaries. Students will create a physical model and technology based presentation explaining a topic related to plate tectonics or geothermal energy.

Appendix Two

Earth's Edible Layers

1. Use the available text and digital resources to...
   Illustrate, Color, and Label a diagram of Earth's layers on the back of this paper.
2. Create a model of Earth's layers using the materials given.

You will model:		Materials:
• Crust • Asthenosphere • Mantle • Core	Using……	• Marshmallow • Chocolate Maltball • Pink Frosting • Graham Cracker

3. List which material you used to demonstrate each layer. Write this beside the label for each layer. (For example: crust/graham cracker)
4. Answer the following questions about your model.

1. What characteristics of the layers and the materials did you consider when you created your model?
2. How is each material similar to/different from the layer it represents?
3. *Why do you think the layers are arranged in this manner? What affects Earth's structure?*
4. Write a description of each layer. **(You May Eat Your Earth Model Now!)**

*Crust:*____

*Lithosphere:*____

*Asthenosphere:*____

*Mantle:*____

*Outer Core:*____

*Inner Core:*____

Appendix Three

Boundary	**What is it?**	**What does it look like?**	**What does it do?**	**What forms as a result?**
Transform				
Divergent				
Convergent Continental-Continental Collision				
Convergent Oceanic-Continental Subduction				
Convergent Oceanic-Oceanic Subduction				

Synthesis:

Use the Claim, Evidence, Reason explanation analysis to describe why Earth's plates are moving:____

Appendix Four

Edible Tectonics Lab

Materials:

Snack Size Milky Way candy bar for each student　　　Paper towel for each student

Steps to Follow and Questions to Answer:

1. Use your thumbnail to make a small dent in the middle of the candy bar.
2. Pull the pieces away from each other slightly.
3. Name the layers of your candy bar and describe which of Earth's layers each would represent.
4. Pull the two "plates" away from each other, but do not separate them completely.
5. What type of boundary is formed when you pull the plates apart? What landform could result from this plate movement? Give a real-world example of this type of boundary.
6. Push the two "plates" back together to make the candy smaller than the original.
7. What type of boundary is formed when you push the plates together? What landforms could result from this type of plate movement between continental plates? What landforms could result if this movement occurred on the ocean's floor? Give real-world examples of these types of boundary.

8. Explain the type of boundary which occurs when plates move/slide past each other? What geologic events are common at this boundary?
9. How do scientists explain the energy forcing plate movement among Earth's tectonic plates?
10. Why are Earthquakes, Volcanoes, and other geologic events common at plate boundaries?

Appendix Five

Geothermal Energy Exploration

Materials: coffee filters, candle, lighter or matches, hot plate and pot with water

Questions to consider…

1. What did you observe on the filter that was held over the boiling water?
2. How does this demonstration represent geothermal energy use?
3. What can you infer about geothermal energy's effect on our environment based on this demonstration?
4. Explain what could be the advantages and disadvantages of geothermal energy.
5. Describe what you observed on the filter after the fossil fuel demonstration.
6. How does this model represent the effects of burning fossil fuels on our environment?
7. Discuss how this could be harmful to our environment. What are the advantages of using fossil fuels for energy?
8. Use the Claim, Evidence, Reason framework to write an explanation analysis about the use of geothermal energy.

Appendix Six

Plate Tectonics or Geothermal Energy Geologic Event Project

Objective:

To identify and describe a geologic event related to Plate Tectonics or Geothermal Energy.

To create a visual representation or model and technology based informative presentation of the chosen topic.

Products:

Original student-created visual representation and technology based informative presentation.

Assignment Value:

One formal test grade and one informal class assignment grade.

Project Description:

- <u>*Visual Representation*</u>
    - Student chosen method of presentation.
    - Possibilities include, but are not limited to: Photograph, diorama, 3-D model, poster or brochure, or illustration.
    - Student original design (pictures/illustrations from outside sources may be used within the overall design)

- *Technology based presentation*
- Part One: Detailed description of the event or system.
- Include an explanation of the topic and areas of the world affected.
- Part Two: Geologic events which occur as a result or are necessary for system.
- Part Three: Current Policy/Actions
- Include government and private agencies currently researching this topic.
- Part Four: Environmental Impact

Presentation:

Each student will share his/her visual and technology product with the class.

Bibliography:

Each student will cite at least three reference sources using MLA format.

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[3] (US Geological Service 2012)
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[7] (How Geothermal Energy Works)
[8] (Geothermal)
[9] (Geothermal)
[10] (Iceland: Photogalleries 2013)
[11] (Academy 1996, 23)
[12] (National Science Teachers Association Position Statement n.d.)
[13] (Academy 1996)
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