Utilizing the History of Science to Enhance Student Understanding and Engagement: A Compilation of Earth Science Lesson Plans

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Utilizing the History of Science to Enhance Student Understanding and Engagement:

A Compilation of Earth Science Lesson Plans

By

Jennifer Boerner

Fall 2014

A culminating project submitted to the Department of Education and Human Development of The College at Brockport, State University of New York in partial fulfillment of the requirements for the degree of Master of Science in Education
Utilizing the History of Science to Enhance Student Understanding and Engagement:

A Compilation of Earth Science Lesson Plans

By

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Abstract

Classroom research has shown that the history of science can be used to enhance student understanding of scientific concepts and processes, as well as the context in which science is explored. Successful methods for incorporating the history of science into the classroom can also improve student understanding and use of scientific argumentation, as well as scientific literacy. Issues with incorporating history of science into the classroom include teachers’ lack of understanding and a dearth of available materials. The following project includes a review of relevant literature and Earth Science lessons incorporating the history of science into the topics of glaciers, weather maps, absolute dating, continental drift, and mineralogy. The lessons were designed to illustrate a sample of evidence based methods to incorporating the history of science, including the Monk and Osborne conceptual change approach, the story-line approach, the case study approach, argumentation, dialogues, and creative writing. All of these methods have been proven to improve student understanding of the nature of science and/or science concepts. The lessons were also designed to meet the content standards of the New York State Earth Science curriculum, as well as the Common Core State Standards for Language Arts and Literacy in History/Social Studies, Science, & Technical Subjects. Additionally, the lessons incorporate important scientific practices, such as: developing and using models, analyzing and interpreting data, using mathematics and computational thinking, engaging in argument from evidence, and obtaining, evaluating and communicating information. As such, the lessons are an example to teachers of how to incorporate history of science into the curriculum without compartmentalizing and sacrificing time in a busy school-year schedule.
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Chapter I: Introduction

While the history of science is often overlooked by educators, it provides meaningful perspective about scientific concepts, process and context. Science is not only a body of knowledge, but also a set of practices used to define that knowledge (National Research Council, 2012). Therefore science education needs to address both of these aspects. Unfortunately, there are many obstacles to integrating the history of science into the science classroom, including teacher perceptions of the history of science (Wang & Marsh, 2002). Many teachers have been found to be uncomfortable with teaching history of science because they are unsure of how to integrate it into an already crowded curriculum (Leite, 2002; Rutherford, 2001).

Moreover, the current curriculum for most science subjects includes a wide breadth of content knowledge requiring students to learn what they may see as a disconnected jumble of information. Consequently, students are not able to form a deeper understanding of science as a social enterprise, or to understand the importance of communication for scientists (National Research Council, 2012; Rutherford & Ahlgren, 1990). Instead, students develop misconceptions about science and scientists which lead to stereotypes and misunderstandings of the process of science (Solomon, Duveen, Scot, & McCarthy, 1992).

Using the history of science has been argued as a tool to illustrate not only the procedural understanding of science, but it can also be used to teach about scientific concepts and the context in which science occurs (Irwin, 2000; Wang & Marsh, 2002). Teaching using the history of science can help with developing conceptual problem-solving ability (Lin, Hung, & Hung, 2002). Historical elements help enrich students’ understanding of the process of thinking or thought experimentation, process of investigation, or process of concluding, applying, or reporting. Many naïve conceptions by students are similar to early philosophies of science. Thus,
students can trace these changes in scientific understanding and use the history of science as a tool for conceptual change (de Hosson & Kaminski, 2007; Jensen & Finley, 1995).

Several successful methods have been found to use history of science to improve understanding of both content and the nature of science, including narrative, debate, role-play, or simply as part of procedural instruction (Appelget, Matthews, Hildreth, Daniel, & Downing, 2002; Clary & Wandersee, 2013; de Hosson & Kaminski, 2007; Giunta, 1998; Monk & Osborne, 1997). Concrete historical examples also can be used to illustrate the nature of science. True stories which show scientists as more fallible and human are easier for students to identify with (Leite, 2002).

Overall, integrating the history of science into the curriculum has shown learning benefits over a wide range of areas, including understanding of content, procedure, and context, developing conceptual problem-solving ability, and achieving conceptual change. Teachers should consider how it is best to integrate history of science when teaching the key ideas of their content area.

Studies indicate that few science teachers are integrating history of science into their science curriculum (Hôtecke, Henke, & Riess, 2012; Wang & Marsh, 2002). One of the most common reasons for teachers not to include history of science into their curriculum is that they are unfamiliar with the topic, or with how to integrate it effectively. Another is the lack of resources available in the form of textbooks or other materials. Therefore, the design of this project is to create a set of units which integrate the history of science into the New York State Regents Earth Science Curriculum using research based strategies.
**Significance of Project**

The *Framework for K-12 Science Education* (National Research Council, 2012), identified the essential features of Science and Engineering Practices to be constructing scientific explanations and engaging in arguments from evidence. These skills are critical for making informed decisions about science and engineering issues which impact our everyday lives. As proved by many studies, using the history of science in science teaching helps students to improve these skills. The lesson plans in chapter 3 are designed to be a useful starting-point for teachers. They will provide a needed resource of researched methods for utilizing the history of science in science education.

**Overview of the Following Chapters**

Chapter II contains a review of the current literature about the history of science in the science classroom: the importance of including the history of science, a conceptual framework for incorporating the history of science into the science curriculum, methodologies, and issues.

Chapter III contains a compilation of five lesson plans and associated materials. These lesson plans use research-approved methodologies to incorporate the history of science into the New York State Earth Science curriculum, and cover the topics of: glaciation, weather maps, absolute dating, continental drift, and mineralogy.

Chapter IV is a short summary and discussion of the importance of including the history of science in the science classroom and the significance of the project.
Definition of Key Terms

ARGUMENTATION: The action or process of reasoning systematically in support of an idea, action, or theory. It includes debate, dialogue, conversation, and persuasion.

DEDUCTIVE THINKING: When reasoning flows from general concept to specific examples; testing general laws or principles.

HISTORY OF SCIENCE: The study of the historical development of science and scientific knowledge; can be used to promote: conceptual understanding, procedural understanding, and contextual understanding.

INDUCTIVE THINKING: When reasoning flows from specific instances to general principles; making observations and drawing conclusions from the data.

MISCONCEPTION: A belief that is incorrect because it is based on faulty thinking or understanding of how the world works. Often erroneous conclusions based on observations.

PSEUDOHISTORY/PSEUDOSCIENCE: Purported history which treats myths and legends as literal truth. Something presented as science but which does not meet the norms of science.

NATURE OF SCIENCE: The means used to develop ideas about the world around us and how it works are particular ways of observing, thinking, experimenting, and validating.
Chapter II: Review of Literature

Introduction

Learning about the history of science will provide students with a conceptual, procedural, and contextual understanding of science as a body of knowledge and as a process for discovering that knowledge (Wang & Marsh, 2002). Several research-based learning methods have been used to successfully engage students using the history of science.

Issues with adopting the history of science in the science curriculum include (a) the culture of teaching science, or how teachers and administrators believed science should be taught, (b) teachers’ skills, attitudes, and beliefs, (c) the institutional framework of teaching science, and (d) a lack of history of science in textbooks. Some of these issues can be countered through professional development and the development of classroom resources to use in teaching the history of science. This project will contribute to that pool of resources by providing lesson plans which integrate history of science into key themes of the New York State Earth Science Curriculum.

Using History of Science in the Science Curriculum

Proponents of including the history of science in the school science curriculum argue that it provides meaningful perspective about scientific concepts, processes, and context, and would provide a more scientifically literate citizenry (Irwin, 2000; Leite, 2002; Lin et al., 2002; Wang & Marsh, 2002). This is particularly important at the present because of the demands of the modern workplace and the many scientific issues which affect us (National Research Council, 1996).
Learning about the history of science will provide students with a conceptual, procedural, and contextual understanding of science as a body of knowledge and as a process for discovering that knowledge (Wang & Marsh, 2002). Researchers have undertaken various approaches to introducing the history of science into the curriculum to see what (if any) affect it has on students’ understanding of the nature of science and content knowledge (Irwin, 2000; Klopfer & Cooley, 1963; Solomon et al., 1992), as well as conceptual problem-solving ability (Lin et al., 2002) and conceptual change (Jensen & Finley, 1995; Solomon et al., 1992). Overall results of these studies have shown that so long as there is also an explicit element of guided teaching (Abd-El-Khalick & Lederman, 2000), students’ science knowledge benefits from learning about the history of science.

Student-based learning methods which have been used successfully to engage students include a “Story-line” approach (which includes vignettes, case-studies, argumentation, dialogues, dramatization, and thematic narratives), as well as creative writing, replications of historical apparatus, and explicit reflections on the nature of science (Clary & Wandersee, 2013; de Hosson & Kaminski, 2007; Giunta, 1998; Höttecke et al., 2012; Stinner, McMillan, Metz, Jilek, & Klassen, 2003).

There are difficulties to integrating the history of science into the science classroom, including the culture of teaching, teacher’s skills, attitudes, and beliefs, the institutional framework of teaching science, a lack of history of science in science textbooks, the introduction of pseudohistory, and students’ views (Allchin, 2004; Höttecke & Silva, 2011; Leite, 2002; Stinner et al., 2003; Wang & Marsh, 2002). However, professional development for teachers, clarifying the purpose of the teaching method with students, and scaffolding using a Facilitator
Model, and creating a body of reliable history of science resources are all steps which can be taken to combat these obstacles (Hôtecke et al., 2012; Şeker, 2011; Stinner et al., 2003).

The Importance of the History of Science

Using the history of science can help students to develop a healthy skepticism regarding scientific issues and theories (Irwin, 2000). This skill is vitally important in a citizenry which takes an active role in decision-making impacting the scientific community and all of humanity. This is particularly true in many issues related to earth science such as global climate change, rising sea levels, diminishing nonrenewable natural resources, and funding for NASA research.

The importance of historical science in practice is addressed in A Framework for K-12 Science Education, where the authors note the necessity of showing science as a set of practices. These practices show that theory development, reasoning, and testing are part of the larger process of science (National Research Council, 2012). Without these concrete examples, the propositions which we teach students about the nature of science (such as that new ideas are often built slowly from the contributions of multiple scientists) would simply be “empty slogans.” In this way, students can make connections between content knowledge and the process and characteristics of science through learning about the history of science. Without the context of history, students may come to “view science as an established body of knowledge and techniques that require minimal justification” (Stinner et al., 2003, p. 618). The history of science is a tool to illustrate the procedural understanding of science, and to teach about scientific concepts and the context in which science occurs.
Using the history of science will also help students to improve their ability to communicate and construct arguments based on evidence. There is a focus in the recent *Common Core State Standards* on writing and speaking to communicate, and these are skills which are closely tied to the processes of debating and reporting scientific investigations (National Governors Association Center for Best Practices & Council of Chief State School Officers, 2010). Indeed, these skills and scientific practices are necessary components of inquiry science education, which requires students to question and problem solve. The ability to analyze a claim based on evidence is a life skill that can be honed through scientific argumentation, and studies on the impact of teaching history of science have demonstrated an improvement in students’ ability to argue scientifically (Clary & Wandersee, 2013; Irwin, 2000).

Using the history of science in the curriculum aids student understanding of the nature of science. To prepare students for their futures, we must explicitly teach them about the nature of science. One effective method of increasing student understanding of the nature of science is to teach both science content and history of science together (Irwin, 2000; Solomon et al., 1992).

**A Conceptual Framework for the History of Science**

The conceptual framework by Wang and Marsh (2002) structures the various components of the history of science—as it affects learning—into three realms (figure 1). Using this framework allows us to better understand why so many researchers and teachers have differing views on what the “history of science” means, and what it means to incorporate it into the classroom.
In this framework, the history of science has been divided into three realms: 1) conceptual understanding, 2) procedural understanding, and 3) contextual understanding. Each realm is described in detail in the following sections.

![Figure 1. History of science conceptual framework. (Reprinted from Wang & Marsh, 2002, p. 180.)](#)

<table>
<thead>
<tr>
<th>Realm</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Conceptual understanding</td>
<td>Historical elements provide the description presentation, comparison, or contraction of scientific (a) thoughts, ideas, concepts, notions, plans, schemes; (b) definition, explanations, models, illustrations, graphics, instrumentation; (c) findings, standards, laws, theories to 1.1. Enrich the presentation of scientific knowledge 1.2. Emphasize the tentative nature of scientific knowledge</td>
</tr>
<tr>
<td>2. Procedural understanding</td>
<td>Historical elements provide the description of: 2.1. Process of thinking or thought experiment 2.2. Process of investigation 2.3. Process of concluding, inferring, elaboration, reporting, and application</td>
</tr>
<tr>
<td>3. Contextual understanding</td>
<td>Historical elements provide the description of: 3.1. Psychological factors involved in the science making (e.g., motivation, incentives, purposes) 3.2. Social factors (e.g., peer influences, public attitudes, social needs, or political factors that effect on the scientists action to communicate, confirm, confront, or contribute) 3.3. Cultural factors associated to the science research (e.g., personalities, culture of family, organization, social, or ethics, etc.)</td>
</tr>
</tbody>
</table>

**Contextual understanding.** Currently, many teachers in the classroom focus on using the history of science to enhance contextual understanding (Wang & Marsh, 2002). This often occurs as a result of how the history of science is presented in textbooks and teaching materials.
(Leite, 2002; Rodríguez & Niaz, 2004; Rutherford, 2001), and how pressured many teachers feel to cover a wide breadth of content. When teachers focus on the realm of contextual understanding, they are focusing on the psychological, social, and cultural factors that influenced the nature of science during a specific period of history. This may take the form of learning more about a particular scientist and his life, which allows students to develop a more realistic understanding of what a scientist is and can improve students’ attitudes towards scientists (Irwin, 2000; Solomon et al., 1992; Stinner et al., 2003).

However, teachers must be careful to avoid pseudohistory and pseudoscience. Anecdotal stories which teachers believe to be true, such as Newton and the apple tree, are often simply not true. Instead, the true stories which show the scientists as more fallible and human are easier for students to identify with (Leite, 2002). In the same vein, although it is much simpler to present science as a linear progression towards some great and absolute truth, the true nature of science can provide more opportunities for learning.

**Conceptual understanding.** The second most common use of history of science in the classroom falls into the realm of conceptual understanding, where historical elements are used to enrich understanding of a scientific concept through presentations of early experiments, or to illustrate the tentative nature of scientific knowledge as it changes over time. Researchers have noted that many naïve conceptions by students are similar to early philosophies of science. For example, many students have misconceptions of evolution similar to Lamarkian evolution (Jensen & Finley, 1995), or believe that vision operates because we emit something from our eyes which reaches the object we are viewing (de Hosson & Kaminski, 2007). Thus, students can trace these changes in scientific understanding and use the history of science as a tool for conceptual change.
**Procedural understanding.** Science teachers have difficulty incorporating procedural understanding into their current curriculum because of time constraints and because they have difficulty conceptualizing how to do so (Rutherford, 2001). In the realm of procedural understanding, historical elements help enrich students’ understanding of the process of thinking or thought experimentation, process of investigation, or process of concluding, applying, or reporting. While currently the least-applied realm of history of science in the classroom (Wang & Marsh, 2002), a procedural understanding of science is important to create what we would consider a scientifically literate citizen.

Irwin (2000) studied the impact of the history of science on his 14 year old students and argued that the experimental group was better prepared to give a critical appraisal of any scientific field they encountered than his control group. Students who study history of science in the realm of procedural understanding can also develop higher-level thinking skills. Lin et al. (2002) found benefits to their 8th grade students’ chemistry conceptual problem-solving abilities after a year of the history of science in their curriculum. They also found that the more exposure the students had, the greater the gains.

**Alternate Conceptual Framework: A Facilitator Model**

An alternate conceptual framework for using history of science in the science classroom has been proposed by Şeker (2011), who organized his “facilitator model” along the principles of increasing complexity and higher-order thinking skills. It was developed so that science teachers could teach history of science at their own competency level, with overlap between levels as
necessary or appropriate. The author was also concerned with creating a pragmatic approach which could be integrated into current curriculum.

At the Interest Level, the lessons are focused on the lives of the scientists, with tentative connections to science procedure or content. The Sociocultural Level examines sociocultural and technological connections between scientists, science content, and technology. The Epistemological Level includes information about the scientific process or methods that scientists followed. The highest-order level, the Conceptual Level, analyzes how a concept was developed throughout history, as well as controversies and opposing ideas.

<table>
<thead>
<tr>
<th>Levels</th>
<th>Sub-Levels</th>
<th>History of Science</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interest Level</td>
<td>Lives of scientists</td>
<td>Scientists’ personal lives affecting their studies directly or indirectly</td>
</tr>
<tr>
<td></td>
<td>Scientists as human beings</td>
<td>Scientists’ lives besides their scientific studies</td>
</tr>
<tr>
<td>Sociocultural Level</td>
<td>Scientific society</td>
<td>The relationship between scientist and the scientific community</td>
</tr>
<tr>
<td></td>
<td>Science and People</td>
<td>How scientists and their discoveries interact with people</td>
</tr>
<tr>
<td></td>
<td>History of Technology</td>
<td>Technological outcomes of the scientific discoveries</td>
</tr>
<tr>
<td>Epistemological Level</td>
<td>Scientific Methods</td>
<td>Information about the scientific methods scientists followed in their research</td>
</tr>
<tr>
<td>Conceptual Level</td>
<td>Historical development of concepts</td>
<td>How a concept was developed throughout history</td>
</tr>
<tr>
<td></td>
<td>Discovery of concepts</td>
<td>How a specific concept was discovered</td>
</tr>
<tr>
<td></td>
<td>Controversies and opposing ideas</td>
<td>Controversies between scientists with opposing theories or paradigms</td>
</tr>
</tbody>
</table>

*Figure 2. Facilitator model. (Adapted from Şeker, 2011, p. 63.)*
Methods for Incorporating History of Science into the Science Classroom

Due to the nature of the history of science, it can be integrated into the science curriculum through a wide variety of methodologies. Through several years of research, the science educators and researchers in Germany working to implement the history and philosophy of science in science teaching have found that simply having students read more material related to history of science is ineffective (Höttecke et al., 2012). Instead, the integration should be based on student-centered activities like experimentation, discussion, and role-play which are motivating and promote cognitive and affective growth (Appelget et al., 2002; Höttecke et al., 2012).

Monk and Osborne Model. Monk and Osborne (1997) developed a model for including history of science in the curriculum that is based on constructivist theory. They argue that if a student’s knowledge is constructed, rather than absorbed, then this aligns neatly with a curriculum based on nature and history of science. In their pedagogical model, students’ ideas are considered alongside historical ideas related to the phenomenon under study. Students must puzzle out how to prove or disprove these ideas as part of their learning before the current understanding or theory of the phenomenon is taught. Their model includes six phases: (a) presentation of the phenomenon by the teacher, (b) elicitation of children’s ideas, (c) historical study, where a historical idea is presented or researched, (d) devising possible experimental tests of these ideas, (e) teacher presentation of the current scientific idea and empirical tests of that idea, and (f) review and evaluation where the class evaluates and discusses the evidence.

“Story-line” approach. One of the most versatile methods of incorporating the history of science into the science classroom is the “story-line” approach (Höttecke et al., 2012; Stinner
et al., 2003). Stories are a powerful tool of engagement, and properly choosing a narrative can aid memory and learning. In addition, Stinner et al. (2003) found that embedding a concept in a well-developed context, such as a story-line, encourages student engagement.

**Vignette.** One of the simplest story-line approaches, which would fall in Wang and Marsh’s (2002) realm of contextual understanding, or Şeker’s (2011) Interest Level, is the historical vignette. These vignettes, or extremely short stories, are useful because they are brief and can be crafted to connect the concepts being studied to the interests of the students.

**Case-study.** A case-study or case-history approach is another method for incorporating history of science into the classroom, and has been used successfully at the secondary and collegiate levels (Giunta, 1998; Irwin, 2000). Case studies give historical context to one unifying idea (Stinner et al., 2003). Through case studies, it is possible to show students the part that creativity and conjectures play in science (Irwin, 2000), and it is also possible to illustrate how later scientists are not necessarily smarter than earlier scientists, but instead how the work of successive scientists builds upon what came before and depends a great deal on context, such as what technology was available at the time (Giunta, 1998).

**Argumentation.** Argumentation, or confrontation, is a story-line approach which helps students to understand that scientific issues can be controversial, and that even modern science has not solved every issue. A *Framework for K-12 Science Education* notes that critique and argumentation are central to the scientific and engineering sphere of evaluating (National Research Council, 2012). Argumentation is particularly well suited to history of science, because historical controversies do not carry the same baggage which current controversies do (Clary & Wandersee, 2013). Historical controversies tend to be free of modern politics, and students will
not have been subjected to media coverage of the issues which may contain non-scientific information.

**Dialogues.** Dialogues can be used to dramatize science and explain the thinking process of scientists, as well as to better understand two rival theories (Stinner et al., 2003). Dialogues and role-play are excellent tools for integrating history of science into the classroom because the nature of science itself is often a dialogue within the scientific community as new theories are put forth and scrutinized. Drama also avoids presenting science as a final product without considering its developmental nature (Clary & Wandersee, 2013). De Hosson and Kaminski (2007) conducted research on using historical controversy to teach middle school students how vision operates. They introduced the historical idea through the use of a dialogue that included argumentation. Students read the dialogue in sections, then responded to questions designed to scaffold their thinking and discussion surrounding each step of the historical controversy surrounding how vision operates. Students found the lesson engaging, and through the scaffolded conversations after each dialogue engaged in metacognition and were able to analyze what elements of the dialogue convinced them to change their pre-conceptions regarding how we see.

**Role-play.** Role-play of dramas surrounding the life of a scientist, or re-enacting a famous science moment are another excellent way to engage students and increase their sympathy and understanding of the emotional and social aspects of science (Höttecke et al., 2012; Stinner et al., 2003). Students can work with already prepared dramas, or write their own. Science educators and researchers in Germany working to implement the history and philosophy of science (HPS) in science teaching have had success with what they refer to as the “metaphorical use of role-play” (Höttecke et al., 2012). After students have thoroughly analyzed a historical situation, a student builds a monument or human sculpture of a snapshot of time from
that situation, recreating the setting, controversy, or event by acting as the director and posing their classmates and instructing them on feelings and attitudes to express. Sometimes the student assigns a short line to the other students to summarize the thinking of the historical figures of the time. At the end, all students discuss the monument or freeze sculpture and contribute how they agree or disagree with it.

**Thematic narrative.** A broader, multi-disciplinary approach is a thematic narrative, which looks at important general themes, such as atoms or evolution. This approach may require several smaller case studies to thoroughly appreciate how the theme transcends particular historical moments (Stinner et al., 2003).

**Creative writing.** There are several methodologies outside of the “story-line” approach which have improved students’ understanding of the nature of science and scientists. One such method is through creative writing, where students are asked to write (letters, journal entries, short biographies, etc.) from the perspective of a historical or fictitious character (Höttecke et al., 2012). In particular, writing in character helps students to empathize with the scientist and writing creatively gives them an opportunity to analyze their own beliefs and understandings of the nature of science and the science content being studied. Teachers can embed higher-order questions into the writing assignments to aid student direction and help them to analyze the context at a deeper level.

**Replications of historical apparatus.** Research has found that replicas of historical apparatus are a viable learning tool in the science classroom, and that they have the added benefits of being highly authentic and aiding in contextualization for students (Höttecke et al., 2012). Unlike modern scientific instruments, historical apparati were often flawed and provided
as much noise as sound data. Having the opportunity to experiment with these historical apparati allowed students to reflect on how to analyze data for viable evidence, and how important an understanding of the theories and technology were to that analysis.

**Procedural instruction.** Teachers can also use procedural instruction to integrate the history of science into the content, such as why and how scientists designed and carried out experiments. In developing a general-science college course for non-majors, Giunta (1998) interwove aspects of the historical case-study of the discovery of argon with the content for each successive lesson, and used the case-study to teach important aspects of the nature of science, such as the social nature of the scientific endeavor, and the importance of the technology available at the time each scientist was working. She used heavily-annotated original text to present the case histories to her students.

**Issues with Incorporating History of Science into the Science Classroom**

Common issues that limit the implementation of the history of science in current curriculum include: (a) the culture of teaching science, or how teachers and administrators believed science should be taught, (b) teachers’ skills, attitudes, and beliefs, (c) the institutional framework of teaching science, and (d) a lack of history of science in textbooks (Höttecke & Silva, 2011; Wang & Marsh, 2002).

Many science teachers believe that science should be taught as facts and figures of absolute truth, without need for justification, and without room for student discourse or negotiation (Höttecke & Silva, 2011; Stinner et al., 2003). In general, “teacher views about the value of history of science [are] related to their practice in using it in their classrooms” (Wang &
Marsh, 2002, p. 181). Teachers who feel unsure of their understanding of the history of science or the pedagogy of how to include it in their lessons are reluctant to teach it extensively (Höttecke & Silva, 2011; Rutherford, 2001; Wang & Marsh, 2002). Although the New York State Earth Science Curriculum, the Framework for K-12 Science Education, and the National Science Education Standards all refer to the importance of science literacy and an understanding of the nature and history of science, the standardized assessments given to students do not match these recommendations. Höttecke and Silva (2011) found a similar situation in Germany and Brazil, and teachers in all three countries reported finding it difficult to include history of science into what they already considered an over-packed curriculum. Finally, several international surveys of science textbooks have found either cursory or misleading accounts of the history of science, and a tendency to focus on dates, names, and timelines (Allchin, 2004; Höttecke & Silva, 2011; Leite, 2002; Monk & Osborne, 1997). As most classrooms today continue to rely heavily on the content of their textbooks, and as there are few published materials available for teaching the history of science, this remains a large obstacle to including history of science in the science classroom.

As mentioned above, many teachers lack the knowledge or skills to teach history of science. Additionally, many teachers may believe that what they are teaching is history of science, but they may instead be propagating pseudohistory. In the realm of history of science, pseudohistory includes “stories that romanticize scientists, inflate the drama of their discoveries, and oversimplify the process of science” (Allchin, 2004, p. 179). The danger here is of giving students a misleading view of what the nature of science is about. In addition, there is a tendency to view past events in the light of current understanding and opinion (“whiggish” history), rather
than in the context of views and opinions of the time. This can lead to losing sight of science as a creative endeavor (Allchin, 2004; Irwin, 2000).

Höttecke et al. (2012) critique the model put forth by Monk and Osborne (1997) which elicits students’ ideas about the phenomenon being studied and later constructs experiments to test both the students’ ideas and historical hypotheses regarding the phenomenon. In practice, the authors believe that this method will not be successful because students’ science experience has relied on the teacher and the textbook as the final authority, and students will regard any deviation from the established pattern as a waste of time.

Implications for Including History of Science in the Curriculum

The issues of the culture of teaching science and teachers’ skills, attitudes and beliefs, while not simple and straightforward, can be countered through training and professional development (Höttecke et al., 2012; Höttecke & Silva, 2011). Teacher skills can also be scaffolded through the use of a model such as Şeker’s (2011) Facilitator Model which allows teachers to adjust their teaching to their skill level.

The development of dependable resources for teaching history of science, such as the work currently being done by the International History, Philosophy and Science Teaching Group (IHPST) will also aid in both scaffolding teachers who may not yet have the skills to teach history of science, and will combat the lack of history of science in textbooks (Höttecke et al., 2012).
This project will contribute to that pool of resources by providing lesson plans which integrate history of science into key themes of the New York State Earth Science Curriculum. In addition to implementing the researched methodologies above, these lesson plans will avoid propagating pseudohistory. Finally, the lesson plans will include explicit instruction regarding both the history of science and the nature of science. This explicit instruction has proven beneficial to learning about the nature of science (Abd-El-Khalick & Lederman, 2000; Höttecke et al., 2012). By clearly justifying the approach to the students, and clarifying that the process of doing science is just as important as content knowledge acquisition, the teacher may avoid student frustration regarding what they may see as a “waste of time.” Explicit reflections on the aspects of the nature of science as they are encountered increases metacognition and raises the students’ awareness for distinguishing different types of cognitive activity (Höttinge et al., 2012).

The history of science is a powerful tool for instructing students about science as a body of knowledge and as a tool for acquiring that knowledge. It can be used to improve their conceptual, procedural, and contextual understandings. These understandings are vital to create scientifically literate citizens prepared for the workforce and for participating in public debates regarding scientific issues which may affect them. Students learning about the history of science through student-based methods such as a “story-line” approach, creative writing, or replications of historical apparatus will increase engagement and motivation as well as understanding of the nature of science and science content. Professional development for teachers to aid their understanding of the history of science and how to teach it will help to overcome some of the major obstacles to including history of science in the science classroom. Developing a dependable pool of resources for teaching history of science will help to overcome the lack of history of science in most commonly used science textbooks.
Chapter III: The Project Design

Overview

Chapter III contains five lesson plans exemplifying research-based methods for including the history of science. Each lesson plan includes a rationale, possible issues, content standards and learning objectives, an outline, and relevant materials. The rationale explains the methodologies chosen for each lesson. Including the possible issues, as well as the content standards and learning objectives, will make the goals of the lesson clearer to the teacher and allow them to modify the lesson as necessary for their own purposes. Because the lessons are meant as an example of methodologies and are meant to be adjusted or modified according to teacher and student needs, the outline of instructional strategies and learning tasks (teacher and student actions) is kept as short and concise as possible. Materials are included as a resource to teachers interested in utilizing the lessons. Overall, it is hoped that the lessons compiled here will provide an example to teachers on how the history of science can be incorporated without detracting from curriculum content or science practices.
### Project Outline

#### Lesson 1: Glaciers (3 day lesson)

**Summary:** This lesson uses the Monk and Osborne (1997) pedagogical model to introduce the history of science into the science classroom. The model is focused on a conceptual change and constructivist approach. Students make observations of evidence left behind by the glacial process (modeled in this lesson) and use that evidence to make their own explanations of the phenomenon. Their explanations are then weighed against historical explanations (introduced by the teacher) and all are tested when students build their own models and are shown images of actual glacial landforms.

**Primary Learning Target:** I will be able to analyze evidence left behind by glacial processes and use that evidence to explain how the landforms were created.

**2 Learning Objectives:**
1. Students will construct a written argument regarding what kind of process has occurred on the teacher’s model using at least three pieces of physical evidence to support their claim.
2. Students will design a model to replicate the erosional and depositional forces of a glacier.

#### Lesson 2: Weather Maps (1 day)

**Summary:** There are three main activities to this lesson. The first is a lesson in the technology and knowledge that contributed to the construction of modern weather maps. The second is a story-line and case-study approach to reading historical weather maps and their importance during naval battles during WWII. The third allows students to use their skills and knowledge of modern meteorological technology to investigate and predict the weather.

**Primary Learning Target:** I will be able to identify weather variables and patterns on a weather map for use in justifying a weather forecast.

**2 Learning Objectives:**
1. Students will use their knowledge of weather, weather patterns, and weather map symbols to correctly answer accompanying questions about historical use of weather maps.
2. Students will analyze recent surface observations of weather in a particular region and construct a written prediction of local weather patterns in the immediate future.

#### Lesson 3: Absolute Dating (1 day)

**Summary:** This lesson uses both a case-study and story-line approach to history of science. Students are introduced to the story of Clair Patterson and use data from his published study on the Pb-Pb dating of meteorites to calculate the age of the earth.

**Primary Learning Target:** I will be able to measure the age of a rock using my knowledge of radioactive decay.

**2 Learning Objectives:**
1. Students will use content-specific vocabulary correctly in written and spoken form to discuss absolute dating and compare it to relative dating.
2. Students will complete a worksheet of calculations regarding the half-life of radioactive elements given either the data in word problem format or in a graph.
### Lesson 4: Continental Drift (1 day)

**Summary:** Through a dialogue and story-line approach, students will evaluate the various 19th and 20th century scientific explanations for the evidence that the continents were at one time connected in some way. Students will develop their skills at arguing from evidence, and write their own argument for the theory of continental drift.

**Primary Learning Target:** I will be able to develop a clear argument for the theory of continental drift, including evidence and a mechanism.

**2 Learning Objectives:**
1. Students will assess the reasoning and evidence behind 19th and 20th century theories of the continents by reading a dialogue and answering questions.
2. Students will synthesize information about plate tectonics and continental drift to create their own dialogue, including historical claims and opposing claims.

### Lesson 5: Asbestos Mineralogy (1 day)

**Summary:** This lesson considers both the historical and modern controversies surrounding asbestos use, with a story-line approach to the history of the use and understanding of asbestos. The importance of technology on our ability to research asbestos and asbestos-caused health problems will be considered as students research evidence for both sides of the debate of asbestos use and construct their own claim for or against.

**Primary Learning Target:** I will be able to synthesize evidence from a variety of resources to construct a claim about the safety or danger of asbestos.

**2 Learning Objectives:**
1. Students will synthesize data from a variety of online resources to construct a well-organized argument about the safety or danger of asbestos.
2. Students will present their claim to a group of peers in a well-organized, 3-5 minute oral argument.
Collection of Lessons Integrating the History of Science

Lesson 1: Glaciers

Rationale

This lesson plan is modified from Monk and Osborne’s pedagogical model (1997) for including history of science in the curriculum. This is a constructivist model, where the concept is introduced by considering first the students’ explanations of a phenomenon. The teacher includes historical explanations of the phenomenon, and then both the students’ and teacher’s explanations are tested, allowing the students to prove or disprove their prior conceptions.

Model-building is used in this lesson to allow students to conceptualize and test their theories, and to allow practice in engineering concepts.

Possible Problems

Problems which may be encountered when using this lesson plan include the time required to build and test models, as well as the cost or difficulty acquiring required materials. In addition, if students have not had experience with building physical models they may need more scaffolding and guidance from the teacher to keep them productive and on-track.

<table>
<thead>
<tr>
<th>Lesson: Glaciers</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Central Focus</strong></td>
</tr>
<tr>
<td><strong>Primary learning target</strong></td>
</tr>
</tbody>
</table>
| **Content Standard(s)** | NYS Earth Science Core Curriculum Standard 4  
*Key Idea 2* –  
2.1p Landforms are the result of the interaction of tectonic forces and the processes of weathering, erosion, and deposition.  
2.1u The natural agents of erosion include: |
Glaciers (moving ice): Glacial erosional processes include the formation of U-shaped valleys, parallel scratches, and grooves in bedrock. Glacial features include moraines, drumlins, kettle lakes, finger lakes, and outwash plains.

2.1v Patterns of deposition result from a loss of energy within the transporting system and are influenced by the size, shape, and density of the transported particles. Sediment deposits may be sorted or unsorted.

**Common Core State Standards**  
CCSS.ELA-Literacy.WHST.9-10.1.a  
Introduce precise claim(s), distinguish the claim(s) from alternate or opposing claims, and create an organization that establishes clear relationships among the claim(s), counterclaims, reasons, and evidence.

| 2 Learning objectives  
with measurable criteria, associated with the content standards. | 1. Students will construct a written argument regarding what kind of process has occurred on the model using at least three pieces of physical evidence to support their claim.  
2. Students will design a model to replicate the erosional and depositional forces of a glacier. |
|---|---|

**Instructional resources and materials**  
Include materials for teachers & students

**Teacher**  
- Completed model with evidence of “glacial” processes, worksheets

**Students**  
- Plastic tubs, wooden slats, rocks, pebbles, gravel, sand, clay, water, pencil, notebooks

**Assessments & data collection**  

**Formal**  
- Written argument regarding what process they think has occurred to create the teacher’s model.
- Glacier Model: Completed with clear written explanation by students about why they constructed it as they did and what they hypothesize will happen to the model over time.
- Deep reading assignment.

**Informal**  
- Participation in designing model with group. Teacher observations of student contributions and behavior.
- Ticket out the door questions: Questions about the lesson’s material answered independently by the students and collected before they leave the classroom.
<table>
<thead>
<tr>
<th>Time</th>
<th>Teacher Actions</th>
<th>Student Actions</th>
</tr>
</thead>
<tbody>
<tr>
<td>0:00-15:00</td>
<td>Teacher introduction of the model and requirements of the written explanation of the phenomenon.</td>
<td>Students write argument (in notebooks) regarding what process they think has occurred to create the teacher’s model.</td>
</tr>
<tr>
<td>15:00-30:00</td>
<td>Introduce ideas of catastrophism (the Great Flood) and uniformitarianism. [The story of Charpentier, Agassiz, and other geologists of the 1830s. How they made connections by observing current glacial processes in the Alps and then observed similar landforms in Scotland.]</td>
<td>Students take notes.</td>
</tr>
<tr>
<td>30:00-45:00</td>
<td>Monitor group discussions.</td>
<td>Share students’ ideas in table groups.</td>
</tr>
<tr>
<td></td>
<td>Get summary of group ideas in short full-class discussion.</td>
<td>Table groups discuss ideas put forth, including pros and cons.</td>
</tr>
<tr>
<td>45:00-60:00</td>
<td>Hand out worksheet on landforms created by glacial processes. Show pictures.</td>
<td>Compare landforms to model features.</td>
</tr>
<tr>
<td></td>
<td>Explain model-building activity.</td>
<td>List ideas of how glaciers might have formed the features.</td>
</tr>
<tr>
<td>60:00-85:00</td>
<td>Monitors group work and provides feedback.</td>
<td>Groups brainstorm how they can recreate glacially formed landforms using model materials. Write which materials they will use and why. Sketch model to be built. Write expected outcome.</td>
</tr>
<tr>
<td></td>
<td>Checks and approves models.</td>
<td>Groups construct models.</td>
</tr>
<tr>
<td>85:00-90:00</td>
<td>Provides ticket-out-the-door question.</td>
<td>Students complete ticket-out-the-door</td>
</tr>
</tbody>
</table>
Q: Glacial landforms such as cirques and erratics have been found in hot and arid Australia. Do you think this is evidence to support creationism or uniformitarianism? Why?

<table>
<thead>
<tr>
<th>Time</th>
<th>Teacher Actions</th>
<th>Student Actions</th>
</tr>
</thead>
<tbody>
<tr>
<td>0:00-5:00</td>
<td>Class review of ticket-out-the-door. Teacher returns assignments and reviews the purpose of the models being built and students’ written explanation of the phenomenon (“landforms”) from the previous lesson. [Review key points to a well-written argument.]</td>
<td>Students correct answers as appropriate. 1-2 student volunteers read to the class their individual or group explanations from the day before.</td>
</tr>
<tr>
<td>5:00-40:00</td>
<td>Teacher explains Guides and expectations of groups as they “tour” the models.</td>
<td>2 students from each group are chosen as Guides to explain how their model will work, and what kind of “landforms” they hope to create. Students circulate (5 minutes at each table) and listen to the guides’ explanations.</td>
</tr>
<tr>
<td></td>
<td>Teacher runs timer, and circulates, encouraging students to ask questions of the Guides and to share ideas for improvements.</td>
<td>Students complete models and make changes based on feedback from other groups.</td>
</tr>
<tr>
<td>40:00-55:00</td>
<td>Monitors group work and provides feedback.</td>
<td>Students set up models to begin running and monitor.</td>
</tr>
<tr>
<td>55:00-60:00</td>
<td>Sets up camera to record completed models.</td>
<td>Students contribute ideas.</td>
</tr>
<tr>
<td>60:00 – 65:00</td>
<td>While models are running, the teacher leads a group discussion on what may inhibit the models from working properly.</td>
<td></td>
</tr>
<tr>
<td>65:00-85:00</td>
<td>Introduces reading activity. Monitors</td>
<td></td>
</tr>
</tbody>
</table>

Day 2: Instructional strategies and learning tasks
Students complete close-reading activity and continue to check the progress of their models.

Students complete ticket-out-the-door question.

Turn in: group model write-up, reading assignment

### Day 3: Instructional strategies and learning tasks

<table>
<thead>
<tr>
<th>Time</th>
<th>Teacher Actions</th>
<th>Student Actions</th>
</tr>
</thead>
<tbody>
<tr>
<td>0:00-5:00</td>
<td>Class review of ticket-out-the-door.</td>
<td>Students correct answers as appropriate.</td>
</tr>
<tr>
<td></td>
<td>Teacher returns assignments.</td>
<td></td>
</tr>
<tr>
<td>5:00-15:00</td>
<td>Teacher monitors group work and provides feedback.</td>
<td>Students watch hi-speed video of their model. They make observations about the video and about the current state of the model. Group discussion about the results and what was or was not surprising. Construct explanations for observations.</td>
</tr>
<tr>
<td>15:00-20:00</td>
<td>Facilitates class discussion of results.</td>
<td>Class discussion.</td>
</tr>
<tr>
<td>20:00-35:00</td>
<td>Facilitates final notes on glacial processes.</td>
<td>Students take notes.</td>
</tr>
</tbody>
</table>
Notes to be used for longer lecture/reading to be used with Catastrophism vs Uniformitarianism worksheet

People saw several things in Europe and North America which puzzled them, and came up with alternative explanations for how they had occurred.

- Erratic boulders
- striated rocks
- loose gravel and clay deposits containing erratics which covered most of the bedrock of northern Europe

**Catastrophism**

Based on creation myths and stories in the Bible, there was an expectation that the world had been flooded in the past. So, one explanation was based on the idea of everything being flood (or fluvial) deposits. Since there was no evidence of flooding building mountains in the present day, people proposed that the flooding in the past was catastrophic unlike anything seen in the present.

**Uniformitarianism**

A second theory grew out of the research of those who were observing the glaciers in the Alps. They saw similar erratics and other evidence near the glaciers themselves. decade-long observations and measurements allowed them to show that the glaciers did grow and retreat. They proposed that the same processes we observe on the earth today were also responsible for the formations of the past.

Q: So what were some differences between the two theories? What were some similarities?

**Why scientists argue/d for Catastrophism or Uniformitarianism:**

- **Georges Cuvier** (1790s) studied the fossil record. He saw the many extinct species in the fossil record as evidence of multiple catastrophes throughout the history of the earth.
  - Local catastrophes
- **Buckland** (18\textsuperscript{th}/19\textsuperscript{th})
  - flooding / glacial theories of catastrophism w/biblical theology
- **James Hutton** (1785)
  - Deep time -> uniformitarianism
  - Natural cycle
At Glen Tilt in the Cairngorm mountains he found granite penetrating metamorphic schists.

- **Charles Lyell** (1830s)
  - *Principles of Geology* (subtitled "An attempt to explain the former changes of the Earth's surface by reference to causes now in operation")
  - Field studies used as evidence (specifics?)

- **William K. Hartmann and Donald R. Davis** (1975)
  - Near-miss by a large planetesimal early in Earth's formation approximately 4.5 billion years ago blew out rocky debris, remelted Earth and formed the Moon, thus explaining the Moon's lesser density and lack of an iron core.

- **Walter and Luis Alvarez** in 1980
  - 10 km asteroid struck near Mexico in Cretaceous Period
    - 70% of species extinct
    - Extinction of dinosaurs

*Q: So which scientists had theories which supported Catastrophism? What was their evidence? Which had ideas which supported uniformitarianism? What was their evidence?*

*Q: What do you think of the two theories?*

**More specifics on two glacial geologists:**

In 1817, Gietro Glacier in Switzerland grew across part of a valley, creating a dam and building a lake high in the Alps. By the spring of 1818, the water level was rising. Engineers were called to the area to try to drill through the ice to allow the water to escape gradually, but after a month worth of punishing work, they were unsuccessful. Instead, the ice dam burst, pouring the lake down into the inhabited villages in the valleys below. In the wake of the many deaths, a German-Swiss mining engineer named Jean de Charpentier came to the area to study the glacier. Charpentier spent many years studying this area of the Alps and discovered large boulders both next to the glaciers and in areas where there were no glaciers. He hypothesized that the boulders had been brought there by glaciers in the past, and that they were evidence that the glaciers had once covered a larger area than they did in the 19th century.

[picture of erratic boulder]

*Q: So do you think Charpentier’s theory fits into Catastrophism or Uniformitarianism?*

**Other scientists in Europe at the time were proposing a similar idea (of glaciers covering more of Europe in the past) from similar evidence.**
- Louis Agassiz (1830s – 40s)
  - At first disbelieved Charpentier, but did his own observations and spent many years measuring the Alpine glaciers’ positions and movement.
  - Proposed idea of giant ice sheets (before the sheets in Antarctica or Greenland had been discovered)
    ✷ Causing catastrophic changes and extinctions
# Catastrophism vs Uniformitarianism

<table>
<thead>
<tr>
<th>Definition</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>4Ws (Who, What, Where, When)</td>
<td>4Ws (Who, What, Where, When)</td>
</tr>
<tr>
<td>Evidence For (Why)</td>
<td>Evidence For (Why)</td>
</tr>
</tbody>
</table>
Does the information on the front of this page change your explanation of how the marks on the model formed? List one of your ideas below as an example and give specific evidence of why the idea has changed, or why not.

____________________________________________________________

____________________________________________________________

____________________________________________________________

____________________________________________________________

Discuss your ideas with your group and record at least three of your group’s ideas below.

____________________________________________________________

____________________________________________________________

____________________________________________________________

____________________________________________________________

____________________________________________________________

____________________________________________________________
Building a Model

Your group will be building a scale model to try and recreate glacial features and landforms. Building a model helps us to visualize the processes which create the landforms. The process of building the model will also help us to learn about how to create a solution to a problem, and will require everyone’s input.

Stage 1: Brainstorming

1) What materials will you need to create your model? You can follow the basic design of the teacher’s example, or you can try something entirely new. Take a look around the room. What materials are available? If there’s something you would like to use but you don’t see, ask the teacher (hint: bars of gold are not available).
Stage 2: Planning

1) Take a look at your list of possible materials. Now list the materials and the reason for including them. (Example: We will use clay to help represent the rock surface which the glacier passes over, because our model isn’t large enough to scratch actual rock.)

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___________________________________________________________________
___________________________________________________________________
___________________________________________________________________
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___________________________________________________________________
___________________________________________________________________

2) **Sketch** the basic design of your model below, and **label** the materials in the design.
Stage 3 & 4: Observations and Conclusions

1) You will have some time to observe your model as it is running. You will also watch a hi-speed video of the model. Write down some observations about the model as it is running. What do you see occurring which you expected? What is unexpected?

_____________________________________________________________________
_____________________________________________________________________
_____________________________________________________________________
_____________________________________________________________________
_____________________________________________________________________

2) Why do you think the model might not be a 100% accurate representation of glacial processes? Is there anything that could be done to make it a better model in the future?
3) **Sketch** the final view of your model and **label** anything which resembles a glacial landform or feature.
Glaciers on Mars

The principles of the theory of uniformitarianism tell us that the same natural laws and processes that operate in the universe now have always operated in the universe in the past and apply everywhere in the universe. Scientists working together in Europe in the early 1800s collected data about the traces that active glaciers in the Alps were leaving behind. Once they had enough data to draw conclusions, scientists like Agassiz were then able to find similar landforms and features in places that no longer have glaciers, like Scotland or Australia, and extrapolate that there were once glaciers there.

Much of the earth’s surface has been mapped today, but scientists are still using the principles of uniformitarianism to explore whole new worlds... literally. Researchers have found what look like similar glacial landforms on places like the moon and mars. Studying the shape of the land (geomorphology) is one of the pieces of evidence they have used to identify these extraterrestrial glaciers.

Read the article and answer the questions below.

1) What glacial formations or landforms did the researchers use as evidence for past glaciers on mars?

2a) What evidence do the researchers believe points to multiple periods of glaciation?

2b) Consider the geological rules and laws that you have studied. Which one is necessary for this data to be used as evidence of multiple periods of glaciation?
3) What is the significance of the thickness of the glacial ice? How is that connected to the possibility of life on Mars?

____________________________________________________________________________________

____________________________________________________________________________________

____________________________________________________________________________________

____________________________________________________________________________________

4) Skim the original *Geology* research article and take a moment to look at the images there. What do you think of the evidence of glaciers on Mars? Is it convincing to you? Why or why not?

____________________________________________________________________________________

____________________________________________________________________________________

____________________________________________________________________________________

____________________________________________________________________________________

____________________________________________________________________________________
Lesson 2: Weather Maps

Rationale

This lesson is designed for the end of the weather unit, when students have an understanding of weather variables and what causes weather. The first two activities in this lesson were developed to help improve students’ conceptual and contextual understanding of the history of science, while the third and final activity allows them to apply their new understanding of weather maps in a personally relevant manner.

The first activity, the History of Weather Maps, is a small lesson on how the concept/tool of weather maps was developed over time. By teaching each other, students will have an opportunity to improve their contextual understanding of the cultural factors which affected the development of weather maps. They will also improve their conceptual understanding of the tentative nature of scientific knowledge: How scientific knowledge depends on available technology and how it is rarely the product of one scientist working in isolation.

The second activity, Meteorology and the Battle of Midway, combines two approaches to teaching the history of science: the story-line approach and the case-study approach. The vocabulary of weather “fronts” and their first visual representations on weather maps in 1942 are part of a larger sociocultural phenomenon. As with many scientific inventions, they are partially a product of war-time technology. The narrative approach will increase student engagement, while the case-study of how weather maps and weather knowledge were employed during World War II will increase student understanding of the nature of science.

The final activity, Weather Prediction, will allow students to use modern technological resources, together with their understanding of weather patterns and weather maps, to investigate and predict the weather.
Possible Problems

The flow of the lesson assumes that the teacher and students have used a jigsaw-type activity where the students teach each other the material. If the class has not done such an activity before, more time may be necessary for instruction.

The weather prediction activity as designed below is very open, without much teacher guidance. Depending on the level of the students, more structure or scaffolding may be necessary. For instance, the teacher may provide the maps that the students should find and use in their prediction. If there are not enough computers available for student use, the activity may need to be modified as paper-only, or structured so that students can share computers or stagger their computer-usage.

<table>
<thead>
<tr>
<th>Central Focus</th>
<th>How can weather maps be used to understand weather patterns and make weather forecasts?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary learning target</td>
<td>I will be able to identify weather variables and patterns on a weather map for use in justifying a weather forecast.</td>
</tr>
</tbody>
</table>
| Content Standard(s) | NYS Earth Science Core Curriculum Standard 4
Key Idea 2 –
2.1c Weather patterns become evident when weather variables are observed, measured, and recorded. These variables include air temperature, air pressure, moisture (relative humidity and dewpoint), precipitation (rain, snow, hail, sleet, etc.), wind speed and direction, and cloud cover.

2.1g Weather variables can be represented in a variety of formats including radar and satellite images, weather maps (including station models, isobars, and fronts), atmospheric cross-sections, and computer models.

Standard 6
Key Idea 5 –
Identifying patterns of change is necessary for making predictions about future behavior and conditions. |
### Common Core State Standards

**CCSS.ELA-Literacy.L.9-10.6**

Acquire and use accurately general academic and domain-specific words and phrases, sufficient for reading, writing, speaking, and listening at the college and career readiness level; demonstrate independence in gathering vocabulary knowledge when considering a word or phrase important to comprehension or expression.

### 2 Learning objectives with measurable criteria, associated with the content standards.

1. Students will use their knowledge of weather, weather patterns, and weather map symbols to correctly answer accompanying questions about historical use of weather maps.
2. Students will analyze recent surface observations of weather in a particular region and construct a written prediction of local weather patterns in the immediate future.

### Instructional resources and materials

**Teacher**

- Smartboard presentation/notes, colored pencils, worksheets, history of weather maps cards

**Students**

- Notebooks, textbooks

### Assessments & data collection

**Formal**

- Meteorology & the Battle of Midway activity
- Weather Prediction activity

**Informal**

- Teacher observations of group and individual work/participation
- Bellwork

### Instructional strategies and learning tasks

<table>
<thead>
<tr>
<th>Time</th>
<th>Teacher Actions</th>
<th>Student Actions</th>
</tr>
</thead>
<tbody>
<tr>
<td>0:00-10:00</td>
<td>Bell work (review)</td>
<td>Students complete bell work individually. In notebooks.</td>
</tr>
<tr>
<td></td>
<td>Q1: What is a weather front?</td>
<td>Turn-and-talk: Students share their answers with a partner.</td>
</tr>
<tr>
<td></td>
<td>Q2: Why does precipitation often occur along a weather front? (Hint: convection)</td>
<td>Students check answers as a class.</td>
</tr>
<tr>
<td></td>
<td>Teacher circulates and monitors work</td>
<td></td>
</tr>
</tbody>
</table>
and conversations.

10:00-17:00  
**History of Weather Maps Jigsaw**

- Explain that students will take turns teaching.
- Pass out short paragraph of weather map invention to each table group
- Monitor groups, keep time

17:00-30:00  
Monitor activity, provide prompts as necessary.

Final review of the information.

**Discussion Prompts:**
- *What are some similarities across these ideas/inventions?*
- *As we’ve learned, the weather maps that we have today utilize many different inventions and ideas from scientists and inventors around the world. Can you think of some other invention or scientific tool that we use today which is similar?*

30:00-37:00  
**Weather Map Symbols**

- Review/Introduce weather map symbols on board

Groups read the paragraph and discuss how to present the information to the class. Groups may use textbooks.

Groups divide so that one “specialist” of each topic is in each new group. The specialists present their information to their new group members, one at a time. Students draw a summary chart in their notebooks and summarize the information from each group in the “slices.”

Class discussion.

As a class, students verbally identify symbols and individually label on worksheet.
<table>
<thead>
<tr>
<th>Time</th>
<th>Activity</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>37:00-67:00</td>
<td><strong>Meteorology &amp; the Battle of Midway</strong></td>
<td>As a class, students brainstorm what they know about the Battle of Midway.</td>
</tr>
<tr>
<td></td>
<td>Introduce activity. Prompt students about the Battle of Midway.</td>
<td>Partner work on activity.</td>
</tr>
<tr>
<td></td>
<td>Hand out activity.</td>
<td>If finish early, check answers against the key.</td>
</tr>
<tr>
<td></td>
<td>“This is to be done with a partner, but do ask for help if you don’t understand a question. Read the information in sections. Pre-read the questions for each section, and use them to help guide your reading.”</td>
<td>Students use the computers and NOAA site [<a href="http://www.hpc.ncep.noaa.gov/html/sfc2.shtml">http://www.hpc.ncep.noaa.gov/html/sfc2.shtml</a>] to generate weather maps.</td>
</tr>
<tr>
<td></td>
<td>Circulate and observe students, help as needed. Check groups who are finished, and hand out the key.</td>
<td>Students analyze maps and use evidence from the maps and knowledge to write a weather prediction.</td>
</tr>
<tr>
<td>67:00-75:00</td>
<td><strong>Weather Prediction Activity</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Introduce activity part 1.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Monitor and aid students.</td>
<td></td>
</tr>
<tr>
<td>75:00-90:00</td>
<td>Introduce activity part 2.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Monitor and aid students</td>
<td></td>
</tr>
</tbody>
</table>
First justification of using a weather chart/map:

During the Crimean War (1853-1856) a storm devastated the French fleet at Balaklava, and the French scientist Urbain Le Verrier was able to show that if a chronological map of the storm had been issued, the path it would take could have been predicted and avoided by the fleet.

(Source: http://en.wikipedia.org/wiki/Weather_map)

(Retrieved October 15, 2014, from: http://understandinguncertainty.org/node/204)

The first weather map:

In England, the scientist Francis Galton gathered information from weather stations across the country for the month of October 1861. He plotted the data on a map using his own system of symbols, thereby creating the world’s first weather map. He used his map to prove that air circulated clockwise around areas of high pressure; he coined the term 'anticyclone' to describe the phenomenon. He was also instrumental in publishing the first weather map in a newspaper in 1875.

(Source: http://en.wikipedia.org/wiki/Weather_map)

An invention necessary to make weather maps:

(1) We needed a way to quickly get weather information from a large area. No telephones or satellites yet, but in 1832 the **telegraph** was invented. It became a primary means of communicating over long distances, and nation-wide systems of cables were set up. By 1847 the newspapers in England were using the telegraph system to ask for weather information from other counties.

(Source: http://en.wikipedia.org/wiki/Weather_map)

![Telegraph key](http://www.smithsonianmag.com/arts-culture/how-the-telegraph-went-from-semaphore-to-communication-game-changer-1403433/)

An invention necessary to make weather maps:

(2) It was important for time to be standardized across time zones so that the information on the map should accurately represent the weather at a given time. A **standardized time system** was first used to coordinate the British railway network in 1847, with the inauguration of Greenwich Mean Time (GMT).

The US didn’t fully adopt time zones until 1905. Before then, time zones were determined by time systems run in individual cities.

(Source: http://en.wikipedia.org/wiki/Weather_map)


Since 1960 we have used UTC, or Zulu Time, as the universal scientific standardized time system.
Fronts & Air Masses:

The use of **frontal zones** on weather maps began in the 1910s in Norway. Polar front theory is attributed to **Jacob Bjerknes**, derived from a coastal network of observation sites in Norway during World War I. Because of their resemblance to the military fronts of World War I, the term "front" came into use to represent these lines. The United States began to formally analyze fronts on surface analyses maps in late 1942.

The concept of **air masses** developed from the concept of fronts, but a 3D understanding of weather systems wasn’t developed until the 1940s.


---

**Upper air maps:**

In the 1940s, weather agencies began to analyze weather (wind speed, wind direction) at certain “constant [air] pressure” levels above the surface. From this information they were able to construct a 3-dimensional understanding of weather systems and large-area weather patterns.
Station models:

Station model plots use an internationally-accepted coding convention that has changed little since August 1, 1941. Surface maps in the United States primarily use Imperial units, such as inches, degrees Fahrenheit, and knots. Most of the world, however, uses metric measurements for everything but wind speed, which is shown in knots.


<table>
<thead>
<tr>
<th>Station Model</th>
<th>Station Model Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Present weather</td>
</tr>
<tr>
<td></td>
<td>Temperature (°F)</td>
</tr>
<tr>
<td>28</td>
<td>28</td>
</tr>
<tr>
<td>1/2 *</td>
<td>196</td>
</tr>
<tr>
<td>27</td>
<td>+19/</td>
</tr>
<tr>
<td>.25</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Amount of cloud cover</td>
</tr>
<tr>
<td></td>
<td>(approximately 75% covered)</td>
</tr>
<tr>
<td></td>
<td>Barometric pressure (1019.6 mb)</td>
</tr>
<tr>
<td>196</td>
<td>+19/</td>
</tr>
<tr>
<td>27</td>
<td>.25</td>
</tr>
<tr>
<td></td>
<td>Barometric trend</td>
</tr>
<tr>
<td></td>
<td>(a steady 1.9 mb rise in past 3 hours)</td>
</tr>
<tr>
<td></td>
<td>Precipitation</td>
</tr>
<tr>
<td></td>
<td>(0.25 inches in past 6 hours)</td>
</tr>
<tr>
<td></td>
<td>Wind direction</td>
</tr>
<tr>
<td></td>
<td>(from the southwest)</td>
</tr>
<tr>
<td>whole feather = 10 knots</td>
<td></td>
</tr>
<tr>
<td>half feather = 5 knots</td>
<td></td>
</tr>
<tr>
<td>total = 15 knots</td>
<td></td>
</tr>
<tr>
<td>1 knot = 1.15 mi/h</td>
<td></td>
</tr>
</tbody>
</table>

Computer Age weather mapping:

By 1999, computer systems and software had finally become sophisticated enough to allow several sets of data to be overlaid on the same workstation. These data sets include: satellite imagery, radar imagery, and model-derived fields such as atmospheric thickness and frontogenesis (mapped fronts).

By 2001, the various surface analyses done within the National Weather Service were combined into the Unified Surface Analysis, which is issued every six hours and combines the analyses of four different centers: National Centers for Environmental Prediction (NCEP), Ocean Prediction Center (OPC), National Hurricane Center (NHC), and Honolulu Forecast Office (HFO).

Weather Map Symbols

Station Model

28
\[ \frac{1}{2} \star \]
27
+19/
.25

196

Station Model Explanation

28
\[ \frac{1}{2} \star \]
196
+19/
.25

whole feather = 10
half feather = 5
total = 15

Present Weather

\[ \cdot \]
\[ . \]
\[ \cdot \]
\[ \cdot \]
\[ \cdot \]
\[ \cdot \]

Fronts

\[ \cdot \]
\[ \cdot \]
\[ \cdot \]
\[ \cdot \]
\[ \cdot \]
\[ \cdot \]
Meteorology and the Battle of Midway

Introduction

The Battle of Midway was one of the most important naval battles of World War II. Between 3 and 7 June 1942, only six months after Japan's attack on Pearl Harbor, the United States Navy decisively defeated an attack by the Imperial Japanese Navy. It was Japan's first naval defeat since 1863.

Four Japanese aircraft carriers and a heavy cruiser were sunk at a cost of one American aircraft carrier and a destroyer. After Midway and the exhausting attrition of the Solomon Islands campaign, Japan's shipbuilding and pilot training programs were unable to keep pace in replacing their losses, while the U.S. steadily increased its output in both areas.

(Adapted from http://en.wikipedia.org/wiki/Battle_of_Midway)

The following text and images (weather maps and atmospheric profiles) are taken from a formerly classified study about the impact of meteorology on the Battle of Midway. Meteorology was used both by the Japanese in planning their attack and by the Americans in predicting the attack, as well as throughout the course of the four day battle.

Remember, the US had only begun officially analyzing fronts on surface maps in 1942, so this was cutting-edge science. At that time there were no weather satellites, so atmospheric observations over the Pacific Ocean were done by balloon and airplane. In the text they refer to this as aerology, which is a term that was used interchangeable with meteorology.
Instructions

The questions and instructions provided in this packet are to help guide your reading. Read them carefully before preceding to the next section.

Questions for Part 1: Introduction

(1) In May and June of 1942, the US forces were trying to predict which islands the Japanese would attack next. It was decided that stormy weather followed by clear weather would be most useful for an attack. Read that section of the text carefully. Consider what you know about weather. What kind of front do you think would be most useful for an attack like the one described? Why?

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

(2a) According to the text, in what direction do storms move across the Pacific?

________________________________________________________________________

(2b) Is this similar to or different from how large weather systems move across the United States?

________________________________________________________________________

(2c) What do you think is the driving force directing large storm systems across the surface of the earth?

________________________________________________________________________
The Battle of Midway

Introduction

Following the action in the Coral Sea, May 4-8, 1942, the Japanese were inactive in the Southwest Pacific; the lull apparently being employed to prepare for the launching of a major attack.

The location to be attacked was a matter of surmise though strategists eliminated Australia as the locale by virtue of the almost complete absence of Japanese men-of-war in the Australian area and by the decrease in the intensity of the bombing of Port Moresby and other allied bases.

With Australia eliminated as the probable striking point of the Japanese attack, the defense of other vulnerable bases and of Midway was immediately organized. To protect Midway, two task forces (identified as SUGAR and FOX) were dispatched to the area north of the island, and air and ground forces on the island itself were augmented.

Sequence of weather desirable for an attack on Midway

The weather sequence of greatest strategic and tactical advantage for the attack on Midway followed by a landing operation is given below.

(1) Since low ceilings and visibilities reduced by squalls and showers make adequate scouting difficult by the defending forces, "bad weather" during the approach and rendezvous increase the possibility of a surprise attack.

(2) For the softening up phase, with air and surface bombardment, it is highly desirable to have high ceilings and good visibility over the target area. At the same time, it is advantageous for the carriers to operate in a zone of low ceilings and reduced visibilities with favorable wind direction so that the launching and recovery of aircraft can be accomplished without constant advances and withdrawals.

(3) The actual landing - the final phase - requires clear skies in order to gain the greatest advantage from air superiority established earlier, and light winds to insure a low sea essential to a landing operation.

Weather conditions over the Pacific

The location of Midway and the Aleutian Islands makes it possible to schedule such a combined operation with a good chance of enjoying all the weather conditions favorable to simultaneous attack. The course of storms over the Pacific at this season of the year often results in an active disturbance to the west and northwest of Midway. Subsequently, these storms move northeastward, accompanied by a movement of related frontal systems toward the east, producing rain, clouds and low visibility ahead of the disturbance. Behind, there is usually rapidly improving weather. Furthermore, during the summer season, frontal systems tend to dissipate in a large percentage of cases in the vicinity of Midway. Thus, it is reasonable to expect favorable landing conditions during this period.
It is not certain at this point whether the Japanese chose the 4th of June as the date of attack for both Midway and Dutch Harbor expecting at that time the simultaneous occurrence in both localities of near-ideal weather conditions suitable to their purposes. There is a strong possibility that the date was selected on the basis of weather conditions known to be approaching Midway; and that the enemy task force commander of the Aleutian Islands operations was probably instructed to attack at a time as near that date as weather considerations permitted.

Due to the movement of storm areas eastward from Japanese controlled territory and waters, it was possible for the enemy aerologist aided by Japanese weather vessels to obtain an accurate "fix" on the orientation, speed, and direction of one such storm under the concealment of which the enemy force could advance to within striking range of Midway.

The enemy chose the time of attack. Our use of the weather was limited to a consideration of the weather situation the enemy might make use of to obtain maximum tactical advantage.

**Weather situation prior to the action**

During the latter part of May and early June, a large high pressure area centered northeast of Midway dominated the weather around Midway. This system, of moderate intensity (1027 millibars, 30.3 inches), was practically stationary and the circulation around it was sufficient to cause all fronts to the west and northwest to slow down and stagnate. Similarly, to the west and southwest of Midway, the deceleration caused the gradual disappearance of all fronts. Broken clouds, low and intermediate, and reduced visibilities were the only evidence of their former existence.
Questions for Part 2: June 3rd

(1) Trace the fronts on the maps of June 3rd: RED for *warm fronts*, BLUE for *cold fronts*, and PURPLE for *occluded fronts*.

(2) Find the weather station on Midway (28°12’N, 177°21’W) and mark it with ORANGE on both maps.

(3) Read the text descriptions of the weather in Area A and Area B. Look at the maps. Explain the different weather conditions in Area A and in Area B using your knowledge of air masses and fronts.

___________________________________________________________________
___________________________________________________________________
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___________________________________________________________________

June 3rd

The weather situation is shown on the 0230 map (Page 7). There was definite evidence that a weak storm center had developed some 650-700 miles to the northwest of Midway. From this center, a weak cold front extended to the south and southwest. The action of this storm as it moved northeastward was complicated by the presence of an old and "masked" warm front which extended in a north-south direction 200 miles west of Midway joining with a major system extending from the Aleutians.

The weather conditions in the Midway area are indicated on the map. In the eastern part of Area A, skies were broken but ceilings were unlimited and visibility good. In a westward direction, the weather became progressively worse: the broken skies developing into an overcast, ceilings lowering from unlimited to 1,000 feet and visibilities decreasing gradually to 6-12 miles and less. In Area B, skies were overcast with rain and showers. Low ceilings made flying undesirable.
Visibilities varied between 2 and 6 miles. To the west and southwest of Midway, Area C, although skies were partly cloudy, visibility was high and flying conditions ranged from average to good.

At Midway itself, skies were clear, ceilings unlimited, and visibilities were over 12 miles. Light easterly winds prevailed.

Japanese forces to the northwest, advancing under cover of the approaching storm area, remained securely hidden throughout the day. The troop and cargo ships to the west-southwest approaching Midway in the area between the warm and cold fronts were not so fortunate. These fronts were sufficiently weak that they offered no obstacle to scouting from Midway.

First contact with the Japanese force to the west-southwest was reported at 0904, bearing 247°, distance 470 miles. Two long range attacks were made on these ships by planes from Midway without diminishing the enemy's strength to any appreciable extent.

The first of these was a daylight attack by nine B-17's. The other was an "historic mission" - the first night torpedo attack by our patrol planes on surface ships. Four PBY's left Midway at 2115, 3 June, under clear weather conditions. Some hours later while flying toward the enemy (see cross section, Page 9) two of the planes became separated in the clouds outlining the intervening front. Although the darkness prevented them from reuniting with the remainder of the flight, one of these succeeded in finding the enemy alone. The other was forced by fuel shortage to return to base without making contact. The remainder of the flight succeeded in scoring several hits on the enemy ships.
WEATHER MAP FOR
0230 3 JUNE, 1942
+ 10 1/2 ZONE TIME
1300 GCT, 3 JUNE 1942

LOW
LOW
LOW
LOW

HIGH
HIGH

AREA A: PARTLY CLOUDY. CEILING UNLIMITED IN EASTERN PORTION LOWERING TO 1000 FEET NEAR WARM FRONT. VISIBILITY 6-12 MILES. WIND SE 12 KNOTS. AVERAGE FLYING CONDITIONS.

AREA B: OVERCAST WITH RAIN AND SHOWERS. CEILING 600-1000 FEET, VISIBILITY 2-6 MILES. MODERATE SW WINDS AHEAD OF FRONTS. GENTLE NW BEHIND COLD FRONT. UNDESIRABLE FLYING CONDITIONS.

AREA C: PARTLY CLOUDY. CEILING MOSTLY UNLIMITED. VISIBILITY 12-20 MILES. GENTLE EASTERLY WINDS. GOOD FLYING CONDITIONS.
WEATHER MAP FOR 1430, 3 JUNE, 1942
+ 10 1/2 ZONE TIME

AREA A
CLOUDY. UNLIMITED CEILING IN EASTERN PORTION LOWERING TO 1000 FEET AND LESS IN WARM FRONT AREA. VISIBILITY 6-12 MILES. WINDS GENTLE S AND SE. AVERAGE FLYING CONDITIONS IN EASTERN PORTION, UNDESIRABLE IN VICINITY OF FRONT.

AREA B
OVERCAST WITH RAIN AND SHOWERS. CEILING 600-1000 FEET, VISIBILITY 2-6 MILES. MODERATE SW WINDS AHEAD OF FRONT, FRESH NW BEHIND COLD FRONT. FLYING CONDITIONS UNDESIRABLE TO BAD.

AREA C
PARTLY CLOUDY. CEILING 2500 FEET EXCEPT NEAR WARM FRONT. VISIBILITY 12-20 MILES. GENTLE EASTERLY SURFACE WINDS. FLYING CONDITIONS AVERAGE TO GOOD.
The enemy task force was discovered in a relatively clear area southwest of Midway. At the time contact was made, and during subsequent high level bombing attacks, the enemy was in the "warm sector" behind a dying warm front.

During the night of 3 June, PBY's from Midway attempted a night torpedo attack. Two planes were lost from the formation while passing through the war front cloud system.
Questions for Part 3: June 4th

(1) Trace the fronts on the maps of June 3rd: RED for warm fronts, BLUE for cold fronts, and PURPLE for occluded fronts.

(2) Find the weather station on Midway (28°12’N, 177°21’W) and mark it with ORANGE on both maps.

(3a) In the text they mention the “circulation around the storm center.” Do storm centers form in areas of low pressure, or areas of high pressure? Why?

___________________________________________________________________
___________________________________________________________________

(3b) Surface winds blow in a _______________ direction and ______ around an area of high pressure. Surface winds blow in a _______________ direction and ______ around an area of low pressure.

(4a) Use your textbook and notes to compare and contrast the weather conditions along a warm front and along a cold front (i.e. – wind speeds, precipitation, types of cloud cover).

___________________________________________________________________
___________________________________________________________________
___________________________________________________________________
___________________________________________________________________
___________________________________________________________________
(4b) Consider how the Japanese and American forces used the weather patterns on June 4th. According to the text, what about the cold front and what about the warm front helped and hindered the two forces?

Weather on June 4th

During the evening of June 3rd and the early morning of June 4th, the storm area to the northwest of Midway intensified. As it moved toward the northeast at 30 knots, the increased circulation around the storm center sharpened the old and stagnant warm front. The increased intensity of the center and related frontal systems produced a large area of overcast skies and low visibility north of Midway. This weather situation is brought out by the maps for 1430, 3 June, (Page 8) and 0230, 4 June, (Page 13) as well as by the diagram of the cross section of the atmosphere lying between our forces and the approaching enemy for 0230 on 4 June (Page 14). Ahead of the fronts, in the region to the east where our task forces were cruising, there was an overcast typical of an approaching warm front system. (Area A on both Page 8 and Page 13). Going through the fronts, the weather became increasingly poor with the height of the ceiling and the visibility diminishing and scattered showers becoming more general over the whole area. Immediately behind the cold front, where the Japanese carrier force was concealed, there was a region of broken ceilings varying between 1,500 and 2,500 feet, scattered showers and good visibilities except within the shower areas (Area B, Page 13).

During the night of June 3-4, the cold front overtook the warm front forcing the warm air aloft and leaving an occluded front at the surface. Our naval forces approached this occluded front from the east, moving to a point about 200 miles north of Midway. At 0545 when reports were received of enemy planes approaching the island, task force SUGAR prepared to carry out an attack against the Japanese carrier force. Somewhat later, our forces steaming south-southwest passed through the front encountering by 1000, typical post-frontal weather. Broken to overcast skies with 1,000-2,300 foot ceiling, scattered showers, and good visibility insured average flying
conditions but the light southeasterly wind forced our carriers to turn away from the enemy while launching and recovering aircraft.

Although the enemy was not handicapped by the wind direction, the concealment provided by the storm no longer operated in his favor. His aircraft carriers were now in the relatively clear area to the rear of the front and thus exposed to observation and attack.

**Action on June 4th**

The enemy succeeded in launching planes for an assault on Midway before his carriers were discovered, but while Japanese planes fought through the Midway fighters to bomb the island installations, bombers and torpedo planes from Midway, along with our carrier-based aircraft, attacked the enemy carrier force.

The battle continued throughout the day of the 4th - planes against planes, and planes against ships. The enemy used cloud cover and shower areas for tactical concealment to great advantage during the action. The same cloud cover produced navigational errors by our own planes. In several cases these resulted in imperfect rendezvous and uncoordinated attacks.

Analysis of the 1430 map of June 4th, Page 9, showed little change in the weather situation. In most of the area to the northwest of Midway, where the enemy carrier force was deployed, scattered showers and thick cumulus clouds remained as evidence of the frontal passage during the early morning.

This picture applies as well to the evening situation although scattered showers and squalls further reduced the visibility. It was this condition which prevented the detection of the enemy forces by a group of our planes leaving Midway at 1700. PT boats ordered to launch a torpedo attack later that evening were unable to locate the enemy and lost their chance to use what would otherwise have been ideal conditions for delivering an effective attack. Had there been more accurate reporting of earlier contacts, the course of the enemy during the night might have been followed, and a more disastrous defeat at smaller cost to our forces been possible. As it was, no contact was made with the enemy during the night.
WEATHER MAP FOR 0230, 4 JUNE, 1942
+ 10 1/2 ZONE TIME
1300 GCT, 4 JUNE 1942

AREA A
PARTLY CLOUDY IN EASTERN PORTION WITH INCREASING CLOUDINESS TO THE WEST. UNLIMITED CEILING IN EASTERN PORTION, LOWERING TO 800 FEET NEAR WARM FRONT. VISIBILITY 6-12 MILES. LIGHT SOUTHERLY WINDS. AVERAGE FLYING CONDITIONS EXCEPT AT WARM FRONT.

AREA B
PARTLY CLOUDY TO CLOUDY WITH SCATTERED SHOWERS. CEILING VARIABLE BETWEEN 1000 AND 2500 FEET. VISIBILITY 12-16 MILES EXCEPT IN SHOWER AREAS. MODERATE NW WINDS BECOMING LIGHT SE BY 0600. MOSTLY AVERAGE FLYING CONDITIONS.

AREA C
PARTLY CLOUDY. CEILING MOSTLY UNLIMITED AFTER 0700. VISIBILITY 12-30 MILES. MODERATE EASTERLY SURFACE WINDS. AVERAGE FLYING CONDITIONS BECOMING GOOD.

Weather map for 0230, 4 June, 1942
The enemy carrier force approached Midway from the northwest under cover of a moving cold front. Behind this front were lower broken clouds with scattered showers and a variable ceiling between 1000 and 2300 feet. At the front an area of overcast, towering cumulus clouds, heavy showers, and lowered visibility prevented effective scouting by the defending forces. Farther to the east, Task Force SUGAR was operating in an area under a dying warm front. The sky was cloudy, with high broken and lower scattered clouds. Ceilings were unlimited over the task force but lowered to 1000 feet in a westerly direction.
Weather Map for 1430, 4 June, 1942


Questions for Part 4: June 5th - June 6th

(1) Trace the fronts on the maps of June 3rd: RED for *warm fronts*, BLUE for *cold fronts*, and PURPLE for *occluded fronts*.

(2) Find the weather station on Midway (28°12′N, 177°21′W) and mark it with ORANGE on both maps.

(3) The text states that the weather on June 5th was “air mass weather.” What do they mean? How is this type of weather different from the weather on June 6th?

(4a) Despite being the “air mass weather,” there were still scattered showers on June 5th. Why?

(4b) Are there any geographical features around Rochester that might create the same effect? Why?
Weather on June 5th

The weather on 5 June typifies "air mass weather". A mass of modified polar air covered the whole Midway area. As the air mass was slightly colder than the water surface over which it flowed, local instability showers with small regions of reduced visibility were characteristic of the whole region. By 1000 these showers stopped with consequent improvement in visibility. By early afternoon, flying conditions became good with unlimited ceilings, scattered clouds, and a light southeast wind. At Midway the weather was clear. With scattered clouds at 8,000 feet and a gentle southeast wind, flying conditions remained good during the day.

Analysis of the 0230 map of 5 June (Page 19) indicated the probability of another storm development 900 miles to the northwest of Midway. No positive statement could be made of the specific structure of the system due to the complete lack of reports from this area. However, knowledge of the general circulation of air masses over the Pacific during that season indicated that the approaching storm would increase in intensity so that its effect would be felt in the northwest in 12-24 hours.

Action on June 5th

Aided by favorable flying conditions early in the day, planes made contact with several enemy cruisers, scoring a number of hits and near misses in their bombing attacks. In the direction of the storm area to the northwest, visibility deteriorated rapidly and cloudiness increased until at 1600 it was overcast at 12,000 feet in that region. Thus, all attempts to locate the surviving ships ended in failure.

On June 6th, patrol planes placed the approaching storm 540 miles northwest of Midway. South of the disturbance, there were low scattered clouds and a high overcast. With unlimited ceilings, good visibility, gentle southeast surface winds and fresh westerly winds aloft, flying conditions were good. Our own task forces, now west of the 180th meridian, were in this region. Several cruisers and destroyers, apparent stragglers from the landing task force, were discovered and attacked.

But to the northwest, in the probable direction of the enemy retirement, weather was increasingly bad. Lowered ceiling and visibility furnished good cover for the fleeing enemy.

The weather conditions can best be described by reference to the weather maps of June 6th and to the cross section on Page 15. On the 1430 map (Page 20) Area A is the region through which the landing force was steaming, while Area B is the region of the carrier task force retreat. The latter is further illustrated by the atmospheric cross section. Except for the position of our forces to the south and the heavy losses of the enemy, the picture of the Japanese advance on June 3rd and that of the retreat of June 6th are sensibly the same. None of our aircraft ventured into the
immediate area of probable enemy retreat, but is indicated that flying conditions there were so poor that air search of that region would have been useless as well as ill-advised.

The pursuit ended in the early evening of the 6th when our forces retired to the northeast.
Weather Map for 0230, 5 June, 1942

AREA A

AREA B
WEATHER MAP FOR
1430, 6 JUNE, 1942
+ 10 1/2 ZONE TIME

WEATHER MAP FOR 1430, 6 JUNE, 1942
+ 10 1/2 ZONE TIME

73

Weather Map for 1430, 6 June, 1942
Cross Section of the Atmosphere, 0230, June 6,
Showing the Weather Conditions in the Area Northwest of Midway

[Text from image] After his carrier force was destroyed, the enemy withdrew the main body of accompanying ships into an area of extremely bad weather. This excellent tactical use of weather helped to save the surviving force from destruction.

Conclusion Questions

The author of this 1944 pamphlet was arguing for the importance of studying meteorology. World War II was still continuing at that time, two years after the Battle of Midway. It is easy to imagine that most of the government money and funding was going toward the war effort, so scientists would need to show how their work would help during battle.

(1) Do you think the author made a convincing argument that understanding meteorology can influence a battle? What evidence does he use? List three examples.

___________________________________________________________________
___________________________________________________________________
___________________________________________________________________
___________________________________________________________________

(2) Consider what you learned today about the history of weather maps. What influence did war have on how they evolved? List at least two examples.

___________________________________________________________________
___________________________________________________________________
___________________________________________________________________

(3) Scientific inventions and understandings evolve and are influenced by the technology that is available at the time. List one invention from the 19th century and one invention from the 20th century that have influenced weather mapping.

___________________________________________________________________
___________________________________________________________________
___________________________________________________________________
Weather Prediction

For this activity, you will be using up-to-date surface weather maps (and your knowledge of weather patterns!) to predict the weather for tonight and tomorrow.

First, you will generate 6 weather maps. Go to the North American Surface Analysis web site [http://www.hpc.ncep.noaa.gov/html/sfc2.shtml] and spend a few minutes trying out the different ways to generate maps. Think carefully about what kind of maps you want for your prediction: regional, continental, spaced out across the day, or the most recent. Then generate 6 maps.

Hint: remember that Z (zulu) is an international time. We are 4 hours behind zulu time, so 03Z on October 14th = 11 p.m. on October 13th in Rochester.

(1) List the 6 weather maps you chose and explain why you think they will be the most helpful to you:

___________________________________________________________________
___________________________________________________________________
___________________________________________________________________
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(2) Describe the weather features which you can see represented on your maps and how they have changed or moved over the past 24 hours.

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(3) Use the weather station data to help you describe the weather conditions at your city over the past 24 hours. Have they changed or remained steady?

___________________________________________________________________

___________________________________________________________________

___________________________________________________________________

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___________________________________________________________________

___________________________________________________________________
(4) Use your knowledge of weather patterns and the information provided by the maps to predict how the weather will change in your city over the next 24 hours or so. Provide at least 5 specific pieces of data from the maps as evidence to support your claim. *If it will rain all day, why? If it will be hot, why? If it will be windy for a few hours, why?*
Lesson 3: Absolute Dating (Radiometric)

Rationale

This lesson was designed to improve students’ conceptual understanding of absolute dating, as well as their procedural and contextual understanding of science as a process. They explore all of these aspects through the story of Clair Patterson’s struggle to master measuring trace amounts of lead. This is a case-story and story-line approach to teaching history of science, where students will explicitly consider the collaborative nature of science, as well as the repetitive, problem-solving nature of experimentation. Finally, students will have an opportunity to work with some of Patterson’s data themselves to recreate part of his investigative process.

Possible Problems

Students will need basic graphing skills and some understanding of exponential functions to complete sections of this lab. The mathematical and graphing portion of the lab may need to be adjusted for the students’ math level, or may need more scaffolding from the instructor.

<table>
<thead>
<tr>
<th>Lesson: Absolute Dating</th>
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</thead>
<tbody>
<tr>
<td>Central Focus</td>
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<tr>
<td>Primary learning target</td>
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<tr>
<td>Content Standard(s)</td>
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1.2j Geologic history can be reconstructed by observing sequences of rock types and fossils to correlate bedrock at various locations.

- The regular rate of nuclear decay (half-life time period) of radioactive isotopes allows geologists to determine the absolute age of materials found in some rocks.

Common Core State Standards
CCSS ELA-Literacy.RST.9-10.7
Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words.

2 Learning objectives
with measurable criteria, associated with the content standards.

1. Students will use content-specific vocabulary correctly in written and spoken form to discuss absolute dating and compare it to relative dating.
2. Students will complete a worksheet of calculations regarding the half-life of radioactive elements given either the data in word problem format or in a graph.

Instructional resources and materials
Include materials for teachers & students

Teacher
- Worksheets, puzzle set for each group, notes, smartboard, Cosmos ep 7.

Students
- Notebooks, graphing calculator

Assessments & data collection

<table>
<thead>
<tr>
<th>Formal</th>
<th>Video discussion worksheets</th>
</tr>
</thead>
<tbody>
<tr>
<td>Informal</td>
<td>Teacher observations of student discussions</td>
</tr>
<tr>
<td></td>
<td>Ticket-out-the-door</td>
</tr>
</tbody>
</table>

Day 1: Instructional strategies and learning tasks

<table>
<thead>
<tr>
<th>Time</th>
<th>Teacher Actions</th>
<th>Student Actions</th>
</tr>
</thead>
<tbody>
<tr>
<td>0:00-10:00</td>
<td>Introduction Qs:</td>
<td>Students answer questions and contribute ideas to T-chart as a class.</td>
</tr>
<tr>
<td></td>
<td><em>What is relative dating?</em></td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>What is absolute dating?</em></td>
<td></td>
</tr>
<tr>
<td>10:00-45:00</td>
<td>T-chart on board to compare two methods.</td>
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</table>

**Warm-up: Vocabulary Triangle**

This vocabulary activity is designed to check prior knowledge students may have about radioactivity and absolute dating.

Note: Make certain students understand that they have not yet learned this material in class, but should try and complete as much as they can.

Teacher circulates to see what information students know or do not know.

Qs: Were there any puzzle pieces that gave you trouble?

Is there anything you would add to the T-chart now? Looking at the charts, what are the main differences between the two methods? Give an example of when we would use relative dating. Give an example of when we would use absolute dating. What kinds of professions would use these dating methods?

**Viewing-With-a-Purpose: Cosmos ep 7 (3:00-23:00)**

Explain purpose of watching the video.

Show 3:00-9:00. Pause video so students can work on worksheet.

Show 9:00-13:30. Pause video so students work in groups to complete the vocabulary triangle.

Students answer Qs in class discussion.

Students pre-read questions for section one. Watch section one. Discuss and answer questions with a partner.
<table>
<thead>
<tr>
<th>Time</th>
<th>Activity</th>
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</table>
| 45:00-50:00 | students can work on worksheet.  
Show 14:30-19:40. Pause video so students can work on worksheet.  
Show 19:40-23:00. Pause video so students can work on worksheet.  
Lead class discussion of major points.  
Show image of Geochron.  
**Q:** *Do you think the data on this graph have a strong or weak association? Why?*  
Explain strong association and how that led to the building of isochrons.  
Show exponential graph representing half-life of K-40.  
**Q:** *What kind of graph does this represent? Explain in your own words why we use an exponential graph to represent radioactive decay. What are the dependent and independent variables on this graph?* |
| 50:00-60:00 | Notes on radioactivity.  
Put up two sample questions on the board.  
Radioactive Dating Worksheet, part 1 |
| 60:00-75:00 | Students discuss and self-check answers.  
Students help fill-in notes and complete notes in their notebooks.  
Students complete and self-check answers.  
Students complete worksheet |
| 75:00-85:00 | Circulate and help students as necessary.  
   Radioactive Dating Worksheet, part 2  
   Simplified explanation of Patterson’s Geochron and how it was developed.  
   Circulate and help students as necessary.  

| Ticket-Out-the-Door  
   Q1: List two things you learned about the process of science today.  
   Q2: List two things you learned about absolute dating today.  
   Q3: List one question you have about absolute dating. | individually.  

| 85:00-90:00 | Students listen and ask questions.  
   Students plot Pb-Pb points for known meteorite fragments. Then overlay with an overhead sheet with the growth curve and determine the age of the meteorites.  
   Students answer Ticket-Out-the-Door. |
**Absolute Dating**
A chemical substance consisting of a single type of atom.

**Proton**
A subatomic particle with a positive charge.

**Carbon**
A subatomic particle with no charge.

**Element**
Any of two or more forms of a chemical element with the same number of protons but different numbers of neutrons.

**Parent Isotope**
An element used to date organic material (e.g., bones, wood).

**Half-life**
Radioactive uranium isotopes decay into...
The atoms of unstable isotopes break apart.

**Daughter Isotope**
The time required for a given amount of radioactive substance to disappear.

**Electron**
The unstable isotope which decays.

**Isotope**
The atoms of a given element which the radioactive substance decays into.

**Neutron**
The stable isotope which the radioactive isotope decays into.

**Isotope**
Radioactive carbon isotopes decay into...
absolute age

lead

... very young objects.
... very old objects.

relative age

radioactive decay

A comparative age (ex: older than, younger than)

nitrogen

A calculated, numerical age.

A large half-life is good for dating...

The chemical symbol for lead.
A small half-life is good for dating...

The chemical symbol for carbon.
Dating Stardust

Use your knowledge of earth science and the information in the video (episode 7 of the 2014 Cosmos series) to answer the following questions. Pre-read the questions with your partner before watching the video to help guide your viewing. Answer in complete sentences.

**Part 1: Early attempts to calculate the age of the earth**

1. Neil deGrasse Tyson narrates the birth of our solar system. First came our sun. What force affected the dust surrounding the sun? ________________

2. In your own words, how does the video show the planets being created? ____________________________________________________________

3. In 1650, Archbishop James Usher of Ireland calculated the age of the earth. What method did he use? ____________________________________________________________

4. What are some problems with Usher’s method? ____________________________________________________________

5. How did the layers in the Grand Canyon form? [hint: deposition? erosion?] ____________________________________________________________
6. The layers at the bottom of the Grand Canyon are the oldest, and the layers at the top of the Grand Canyon are the youngest. This is called the **Law of** ________________.

7. What are some problems with using rock layers to calculate the age of the earth?

________________________________________________________________

________________________________________________________________

________________________________________________________________

**Part 2: A radioactive clock**

8. 50,000 years ago, an iron asteroid was pushed out of its orbit around the sun and struck earth as a meteorite. Some fragments of the meteorite remain on the earth’s surface. Neil deGrasse Tyson tells us: *If we can measure the age of the meteorite fragments, we know the age of the earth.* Why? [hint: Think about what you learned about how the solar system formed.]

________________________________________________________________

________________________________________________________________

________________________________________________________________

9. Uranium is a radioactive isotope in many rocks. What is the final, stable element that uranium decays into? ________________________________

10. In the 20th century, many scientists worked for decades to measure how long it takes radioactive elements to decay. They discovered that radioactive elements decay at a ____________ rate. Compare this to the erosion and deposition of rock layers in the Grand Canyon. Why do you think this makes radioactive elements a better “clock” better for measuring time?
Part 3: Patterson’s “easy” assignment

11. Dr. Brown gave Clair Patterson an assignment to measure the amount of the radioactive isotope uranium and the decay product lead in tiny crystal zircon crystals. This was the first test of a new dating technique. They could check the new technique because they already knew what about the zircon crystals?

12. Patterson’s measurements of lead from the same grain were wildly different every time. What did he decide was the problem? How did he try to solve it?

13. How many years did it take Patterson to actually measure the amount of lead in the zircons?

Part 4: The age of the earth

14. What does a mass spectrometer do?

15. After successfully testing the dating technique on the zircons, what material did Patterson measure in the mass spectrometer to calculate the age of the earth?
16. What was the age of the earth that Patterson calculated? ________________

17. Why do you think Patterson thanked so many people?

________________________________________________________________________

________________________________________________________________________

18. Consider the entire video and your own knowledge. What kinds of technology needed to be invented and knowledge understood before Patterson could do his work?

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________
Radioactive Dating: Part 1

During radioactive decay, the atoms of unstable isotopes break apart, releasing energy and protons and neutrons from the nucleus. Eventually they form a stable isotope of a new element. Radioactive isotopes decay at a steady exponential rate, known as their half-life. The half-life of a radioactive isotope is the time it takes for one half of the unstable isotope to change into the stable decay product. If we know the half-life of a radioactive isotope, and can measure the amounts of the isotope and its decay product, then we can calculate the age of the rock or material.

Ex: A piece of shell is found inside an old fire pit at an archaeological site. Shell contains the radioactive isotope carbon-14, which decays into nitrogen-14. The half-life of carbon-14 is 5,730 years. The shell contains 5 grams of carbon-14 and 5 grams of nitrogen-14. How old is the shell?

Assuming the original shell was composed of the radioactive isotope, with no decay product, then the shell originally contained 10 grams of carbon-14. Thus, one-half of the original radioactive isotope has decayed, and so one half-life has passed. The shell is approximately 5,730 years old.

1. A rock contains 25 grams of potassium-40 and 75 grams of its decay product calcium-40. The half-life of potassium-40 is 1.3 billion years. How many half-lives of potassium-40 have passed since the rock was formed? How old is the rock?
2. The trunk of a fallen tree contains 7.5 kilograms of radioisotope carbon-14 and 52.5 kilograms of nitrogen-14. The half-life of carbon-14 is 5,730 years. How many years ago did the tree fall?

3. We know the age of a rock is 9 billion years old. If there are 15 grams of decay product lead-206 in the rock, how many grams of radioactive isotope uranium-238 remain in the rock? (The half-life of uranium-238 is 4.5 billion years.)

4. The half-life of an isotope can also be represented graphically. The graph below show the decay rate of a radioactive isotope. The original amount of the radioactive isotope is 10 grams.

![Decay Rate of a Radioactive Isotope](image)

According to the graph, what is the half-life of the isotope?
5. Base your answer to the question on the graph below.

Analysis of a rock sample shows that 25% of its radioactive uranium-232 remains undecayed. How old is the rock sample?

6. We can graph the decay rate of a radioactive isotope using the following formula: \[ y = a(1-r)^x \]

\[
a = \text{initial amount of the radioactive isotope} \\
r = \text{decay rate} = 0.693/\text{half-life}
\]

Write the formula below for the decay rate of a radioactive isotope with a half-life of 3 years and the initial amount of 20 grams.

Use your graphing calculator to graph the formula, then raise your hand to have an instructor check your results.

Instructor’s initials: _____________
Radioactive Dating: Part 2

We have gained a basic understanding of the mechanics of radioactive dating, but the real universe is always more complicated than simple theory. When Clair Patterson was dating the meteorite samples, he found that the most accurate dates could be obtained by using different decay products of the uranium-lead system.

Based on research done by other scientists, Patterson used modified formulas to calculate time by substituting ratios of different lead isotopes. He then plotted the ratios on a graph. The trend-line of the data points of both meteorites and deep-sea sediments on the earth allowed him to calculate an age.

Using Patterson’s lead isotope data, you will be recreating his graph.

<table>
<thead>
<tr>
<th>Meteorite</th>
<th>Pb Composition</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>206/204</td>
</tr>
<tr>
<td>Nuevo Laredo, Mexico</td>
<td>50.28</td>
</tr>
<tr>
<td>Forest City, Iowa</td>
<td>19.27</td>
</tr>
<tr>
<td>Mudoc, Kansas</td>
<td>19.48</td>
</tr>
<tr>
<td>Henbury, Australia</td>
<td>9.55</td>
</tr>
<tr>
<td>Canyon Diablo, Arizona</td>
<td>9.46</td>
</tr>
</tbody>
</table>

Directions

1. Plot the meteorite data from table 1 onto the graph below. Use a dot with a circle around it to show possible error.

2. Draw a best-fit line through the data points you have plotted on the graph. This is your isochron line.
Questions

1. How does your isochron compare with the others already plotted on the graph (1.0 Byr, 2.0 Byr, etc.)? Does it fall between any of them? If so, what would you estimate is the age of your isochron?

2. When Patterson published his paper in 1956, he published information on his lead-lead dating method and his isochron, but he also published information on other dating methods which had been used by scientists to date meteorites. These included argon-40/potassium-40 and strontium-87/rubidium-87. Why do you think he would include this information in his paper?
Lesson 4: Continental Drift

Rationale

This lesson was designed to improve students’ understanding of science as a process, as well as their conceptual understanding of continental drift and plate tectonics. Dialogues have been found to improve student engagement, and the format can also include scientific argumentation. The discussion questions are written so that students consider the claims and counterclaims which take place within scientific argumentation. Students will consider how scientific theories are developed, as well as how they can be strengthened over time by new technology and ideas (i.e. – sonar, seafloor spreading, mantle convection).

Writing the closing section of the dialogue allows students to use earlier portions as a template if necessary. Depending on their level of conceptual understanding and argumentation and writing skills, the activity can be modified to allow students’ focus to be more or less on claims and counter-claims.

Possible Problems

Part C is not meant as a self-contained lesson on plate tectonics, but an introduction. The focus is on the process of how scientific theories develop, with the intention that the next lesson in the unit will contain a more structured explanation of plate tectonics. Students who have not encountered plate tectonics in earlier grades, or who have not retained any knowledge on the subject, will need more scaffolding and teacher or peer help to complete Part C.

<table>
<thead>
<tr>
<th>Lesson: Continental Drift</th>
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<tbody>
<tr>
<td><strong>Central Focus</strong></td>
</tr>
<tr>
<td><strong>Primary learning target</strong></td>
</tr>
</tbody>
</table>
| **Content Standard(s)** | NYS Earth Science Core Curriculum  
Standard 1: Scientific Inquiry  
Key Idea 1:  
The central purpose of scientific inquiry is to develop explanations of natural phenomena in a continuing, creative process.  
Standard 4 |
Key Idea 2:

2.1k The outward transfer of Earth’s internal heat drives convective circulation in the mantle that moves the lithospheric plates comprising Earth’s surface.

2.1l The lithosphere consists of separate plates that ride on the more fluid asthenosphere and move slowly in relationship to one another, creating convergent, divergent, and transform plate boundaries. These motions indicate Earth is a dynamic geologic system.

2.1n Many of Earth’s surface features such as mid-ocean ridges/rifts, trenches/subduction zones/island arcs, mountain ranges (folded, faulted, and volcanic), hot spots, and the magnetic and age patterns in surface bedrock are a consequence of forces associated with plate motion and interaction.

Common Core State Standards
CCSS.ELA-Literacy.RST.9-10.8
Assess the extent to which the reasoning and evidence in a text support the author's claim or a recommendation for solving a scientific or technical problem. (e.g., in an equation) into words.
CCSS.ELA-Literacy.W.9-10.1.a
Introduce precise claim(s), distinguish the claim(s) from alternate or opposing claims, and create an organization that establishes clear relationships among claim(s), counterclaims, reasons, and evidence.

2 Learning objectives
with measurable criteria, associated with the content standards.

1. Students will assess the reasoning and evidence behind 19th and 20th century theories of the continents by reading a dialogue and answering questions.
2. Students will synthesize information about plate tectonics and continental drift to create their own dialogue, including historical claims and opposing claims.

Instructional resources and materials
Include materials for teachers & students

Teacher

Students
- textbooks

Assessments & data collection

Formal
- dialogue packet discussion questions, construction of dialogue Part C

Informal
- group and class discussion participation, participation in group research and writing, ticket-out-the-door
<table>
<thead>
<tr>
<th>Time</th>
<th>Teacher Actions</th>
<th>Student Actions</th>
</tr>
</thead>
<tbody>
<tr>
<td>0:00 – 8:00</td>
<td>Show music video “Continental Drift: Alfred Wegener” [<a href="http://youtu.be/T1-cES1Ekt0">http://youtu.be/T1-cES1Ekt0</a>]</td>
<td>Students watch video.</td>
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<td></td>
<td>Qs for class discussion: “Why did Alfred Wegener’s peers laugh at him?”</td>
<td>Students answer questions.</td>
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<tr>
<td></td>
<td>“Why is evidence so important?”</td>
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<td></td>
<td>“What else is an important part of science?”</td>
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<td></td>
<td>“Can you think of any other examples of scientists whose ideas were not accepted in their own time?”</td>
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</tr>
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<td></td>
<td>“What changed to make their ideas more accepted?”</td>
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<tr>
<td>8:00 – 10:00</td>
<td>Introduce dialogue and the purpose of the dialogue and discussion questions.</td>
<td>In groups of four, students are each given a role from the dialogue.</td>
</tr>
<tr>
<td>10:00 – 22:00</td>
<td>Observe groups and redirect where necessary.</td>
<td>Groups read Part A and answer the questions.</td>
</tr>
<tr>
<td>22:00 – 27:00</td>
<td>Lead whole class discussion to check group understanding.</td>
<td>Participate in class discussion.</td>
</tr>
<tr>
<td>27:00 – 39:00</td>
<td>Observe groups and redirect where necessary.</td>
<td>Groups read Part B and answer the questions.</td>
</tr>
<tr>
<td>39:00 – 44:00</td>
<td>Lead whole class discussion to check group understanding.</td>
<td>Participate in class discussion.</td>
</tr>
<tr>
<td>44:00 – 46:00</td>
<td>Explain goals and expectations of Part C.</td>
<td>Listen and ask questions for clarification.</td>
</tr>
<tr>
<td>46:00 – 61:00</td>
<td>Observe groups and redirect where necessary. If necessary, assign roles within the groups to help focus their research. Encourage students to go beyond the questions if they are able.</td>
<td>Groups use textbooks, classroom resources, and appropriate internet resources to answer the questions in Part C. Students may move ahead to the dialogue writing if they complete their research.</td>
</tr>
<tr>
<td>61:00 – 76:00</td>
<td>Observe groups and redirect where necessary. If necessary, assign roles within the groups to help focus their writing. Encourage students to use claims and opposing claims to strengthen their arguments.</td>
<td>Groups write dialogue, clearly explaining the theory, evidence, and mechanisms.</td>
</tr>
<tr>
<td>76:00 – 85:00</td>
<td>Observe presentations.</td>
<td>Selected groups present their dialogues.</td>
</tr>
</tbody>
</table>
| 85:00 – 90:00 | **Ticket-Out-the-Door**  
Q: *The modern Theory of Continental Drift was developed from many earlier theories, and the work of many scientists and naturalists. Consider the dialogue and discussion questions you have answered today. Why are argumentation and evidence so important to the process of science?* | Students answer question. |
A Dialogue About the Continents

Three bewildered young men and women have been gathered around a small table in a strange room. They don’t seem to have anything in common, other than their age. Even their clothing is a strange mix of fashions across the centuries. They all have similar stories about being approached by a mysterious man in a black suit. They remember feeling sleepy, and then waking up in a strange place.

Now the mysterious man, Mr. Smith, calls them to order.

MR. SMITH: You have been gathered here today to explain why the continents are like they are. Let’s start with Ruth. Ruth, tell us the date, and then tell us about the continents.

RUTH: Is this an examination? Because it’s really strange…. Well, today is November 10th, 1904. About the continents, well, we were studying the land-bridges across the oceans the other day. There aren’t really any of them left across the Pacific or the Atlantic, but they were there in the past. I thought they were interesting because we learned about the bridge between Africa and South America that the monkeys crossed.
JON: Land-bridges between Africa and South America? I’ve never heard about those before. And, by the way, it’s 2014, not 1904!

RUTH: What? But—

MR. SMITH: Don’t worry about the dates. I think you’ll find that you all disagree. Explain more about the land-bridges, Ruth. What evidence do we have for them?

RUTH: Oh, there’s quite a lot! The same families of trees and animals can be found in North America, Europe, and Asia. They can’t travel across the water, so they must have crossed on land. Paleontologists have found the same patterns in fossils along the coasts as well. Oh, and marsupials in South America and Australia.

These land-bridges would have cut off the waters at the North Pole from the rest of the oceans, so the cold currents couldn’t travel all around the oceans. The climate would have been warmer even in northern places like the United States. There are tropical fossils there that support that theory.

MR. SMITH: Interesting evidence. But where did they come from? What caused the land-bridges to form and then disappear?

RUTH: Different parts of land lift up at different times. We know this because scientists have found rocks at high elevations that originally formed under salt-water. And some places, like the narrow part of the Atlantic Ocean, still have archipelagos and islands.
Discussion Questions for Part A:

*Discuss these questions with your group. We will also be discussing as a class, so take notes to help you remember what you discussed.*

1. Ruth is from 1904. At the time, scientists and naturalists believed strongly in the land-bridge theory. What types of observations were they trying to explain with the theory of land bridges?

2. Based on those observations/evidence, what different fields of scientific study do you think contributed to the land-bridge theory? Why would that make it stronger?

3. Have you ever heard of the theory of land-bridges? In what context?

4. Using your 21st century knowledge, what are some strengths and weaknesses to the theory of land-bridges as explained by Ruth?

[B]

**MR. SMITH:** Very interesting. Tim, tell us the date and what you’ve heard about the expanding earth theory.

**TIM:** It’s 1910, and naturalists and scientists have been discussing the expanding earth theory for a decade or two. It’s not as popular as the land-bridges, but it makes more sense to me. When
people talk about land bridges, they don’t have a mechanism to drive the process of how the land goes up and down. I think that’s what you were trying to get from Ruth earlier.

**RUTH:** Oh, I see. I never thought of that. There really isn’t a reason for the land to move up and down, is there?

**TIM:** Right! Have you ever seen a motion picture of a volcano in Hawaii? Those are the shield volcanoes, with the lava that flows very slowly. Because it flows so slowly, the air actually cools the top of the flowing lava and it forms a stiff crust. But sometimes the lava below is forced upwards or the speed changes, and that thick crust is split and moves apart.

That’s the theory of the expanding earth. Roberto Mantovani, of Italy, first published it in 1989. Thermal expansion and volcanic activity caused the land to split apart and drift apart. Some scientists agree that this theory is useful, because it also explains how mountains form. In the same way cooling lava folds as it is pushed along, the mountains formed from volcanic activity and expansion.

**JON:** Wait a minute, but Ruth mentioned rocks that formed under sea water at high elevations. You mean the sedimentary rocks like the ones they’ve found at the top of the Himalayas, right? How could there be sedimentary rocks at the top if all the mountains were formed by volcanoes?

**TIM:** That’s a good point….
Discussion Questions for Part B:

Discuss these questions with your group. We will also be discussing as a class, so take notes to help you remember what you discussed.

1. What is the theory of the expanding earth?

2. Which pieces of evidence discussed in Part A does the theory of the expanding earth address? Which doesn’t it?

3. Compare the theory of the expanding earth to the theory of the land bridges. If you lived 100 years ago, which do you think you would have supported? Why?

Instructions for Part C:

Using your textbook, classroom resources, and reliable internet resources (hint: Remember what makes an internet resource reliable for research), find information on Wegener’s (1910) theory of continental drift and Arthur Holmes’s (1929) explanation of mantle convection.

Answer the questions below in complete sentences.

1. What was Wegener’s theory of continental drift?
2. What evidence did he propose to support his theory?

__________________________________________________________________________________________________________________________________

__________________________________________________________________________________________________________________________________

__________________________________________________________________________________________________________________________________

3. Why did the scientists and naturalists of his time discredit his ideas?

__________________________________________________________________________________________________________________________________

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4. What are some explanations that Wegener proposed to explain the mechanism behind continental drift?

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5. What is the theory of plate tectonics?

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6. Why is mantle convection important to plate tectonics?

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__________________________________________________________________________________________________________________________________

7. How are the mid-ocean ridges related to mantle convection and plate tectonics?

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__________________________________________________________________________________________________________________________________
8. The theory of plate tectonics did not become popular until the 1960s. Some of the reasons for this were SONAR mapping of the ocean floors and the discovery of seafloor spreading. Why would these have been important?

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Using the information that you have gathered, you will write the final part of the dialogue between Mr. Smith Jon, from 2014, and the other students. Be certain to have Jon explain the theory of continental drift and how it developed. Include why it was unpopular when it was first proposed, evidence for the theory, and the mechanism of mantle circulation and plate tectonics.

Once you are certain you have addressed the science focus above, you can write a fun, school-appropriate ending for the dialogue if you would like. Why has the mysterious Mr. Smith brought the students together from different times?

[C]

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Lesson 5: Asbestos Mineralogy

Rationale

Research has shown that historical controversies can be a useful tool for teaching argumentation, in some cases because they do not carry the baggage of modern controversies. In the case of this lesson’s topic, asbestos regulation is still an active topic in the United States, but not one that many everyday people are aware is still an issue. The approach here was to use a wide range of resources (some more modern), but to make students explicitly aware of how continuing research can add new dimensions and evidence to ongoing controversies, even nearly 100 years later.

Possible Problems

Students with learning disabilities related to reading and writing may find this a challenging lesson and may need more scaffolding and guidance when writing their letters. IF students have never given peer feedback before they may need more explicit instruction on what is or is not acceptable. Finally, the research portion relies heavily on internet access, which may not be available in all classrooms.

<table>
<thead>
<tr>
<th>Lesson: Asbestos Mineralogy</th>
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</thead>
<tbody>
<tr>
<td><strong>Central Focus</strong></td>
</tr>
<tr>
<td><strong>Primary learning target</strong></td>
</tr>
</tbody>
</table>
| **Content Standard(s)** | **NYS Earth Science Core Curriculum Standard 4**  
Key Idea 3:  
3.1a Minerals have physical properties determined by their chemical composition and crystal structure.  
● Minerals can be identified by well-defined physical and chemical properties, such as cleavage, fracture, color, density, hardness, streak, luster, crystal shape, and reaction with acid.  
● Chemical composition and physical properties determine how minerals are used by humans. |

**Common Core State Standards**  
CCSS.ELA-Literacy.SL.9-10.4  
Present information, findings, and supporting evidence clearly,
concisely, and logically such that listeners can follow the line of reasoning and the organization, development, substance, and style are appropriate to purpose, audience, and task.

2 Learning objectives
with measurable criteria, associated with the content standards.

1. Students will synthesize data from a variety of online resources to construct a well-organized argument about the safety or danger of asbestos.
2. Students will present their claim to a group of peers in a well-organized, 3-5 minute oral argument.

Instructional resources and materials
Include materials for teachers & students

Teacher

Students
- notebooks, textbooks

Assessments & data collection

Formal
- written letter, peer oral argument assessments

Informal
- teacher observations of students’ ability to stay on task, answering questions in class discussions, teacher observations of presentations

Instructional strategies and learning tasks

<table>
<thead>
<tr>
<th>Time</th>
<th>Teacher Actions</th>
<th>Student Actions</th>
</tr>
</thead>
<tbody>
<tr>
<td>0:00 – 5:00</td>
<td>Question students on previous lesson on minerals.</td>
<td>Students answer questions.</td>
</tr>
<tr>
<td></td>
<td>Qs: “What is a mineral?” “What are the defining characteristics of a mineral?”</td>
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<tr>
<td></td>
<td>“How do we identify minerals?” “What are some minerals that you use every day?”</td>
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<tr>
<td>5:00 – 10:00</td>
<td>Ask students what they know about asbestos.</td>
<td>Students brainstorm.</td>
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<td></td>
<td>Pass out packet and go over introduction information about asbestos.</td>
<td>Students read information aloud.</td>
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<tr>
<td>10:00 – 20:00</td>
<td>Have students read the printed article and the relevant section on the</td>
<td>Students read and complete questions</td>
</tr>
<tr>
<td>Time</td>
<td>Activity</td>
<td></td>
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<tr>
<td>20:00 – 50:00</td>
<td>Wikipedia page about the health risks of asbestos and early research into those health risks. Class discussion about students’ answers. Prompt them to think about technology such as electron microscopes, x-ray machines, etc.</td>
<td></td>
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<tr>
<td>50:00 – 60:00</td>
<td>Explain the task of the letter. Circulate and answer student questions. Help students focus on task. Check students’ letters. Explain the task of the argument presentation. Circulate and answer student questions. Help students focus on task.</td>
<td></td>
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<tr>
<td>60:00 – 80:00</td>
<td>Circulate and observe presentations. Help students focus on task.</td>
<td></td>
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<tr>
<td>80:00 – 90:00</td>
<td>Ticket-Out-the-Door Qs: 1. <em>The physical properties of minerals are determined by their chemical composition and crystal structure.</em> In your own words: Why is asbestos a fibrous mineral? 2. <em>What are some properties of asbestos that make it a useful material?</em> 3. <em>Why is asbestos harmful to humans?</em> 4. <em>Considering all of the information that you have read and heard discussed today, why do you think that asbestos is still legal to use in the United States today?</em> Students work on completing part 1 research and part 2 letter-writing. Students analyze their letter to decide how they would like to present it orally. Students present their arguments and evaluate each other. Students complete Ticket-Out-the-Door in their notebooks.</td>
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</tbody>
</table>
Asbestos

Asbestos is a silicate mineral. **Silicates** are one of the major mineral groups. These mineral groups are determined by their chemical compositions. In silicates, one ion of silicon is joined by four ions of oxygen to form a tetrahedron. These tetrahedra are held together by strong covalent bonds. There are two types of asbestos: **chrysotile (serpentine) asbestos**, and **amphibole asbestos**. Based on their chemical structure, the minerals form into sheets or double-chains. Chrysotile asbestos forms into sheets or layers (they are the same family of silicates as mica). Amphibole asbestos forms into double-chains.

The tetrahedra in silicates all share oxygen atoms, which makes their bonds strong. However, the chains or sheets are only held together by ionic bonds between the metal atoms. This forms a plane of weakness, where the bonds can be more easily broken. This is why mica breaks into long, thin sheets. In chrysotile asbestos, although it is a sheet and not a chain, the spacing between oxygen atoms in the sheets is a little different, which causes the sheets to roll into long scrolls, like a sheet of paper can be rolled into a tube. These form asbestos fibers.

Asbestos has many useful properties, including an ability to withstand high heat without burning. It has been used for many thousands of years, including manufacturing in the late 19th and 20th centuries. However, it soon became apparent that asbestos fibers posed a serious health risk under certain circumstances.

You will be using several provided internet resources to research information on asbestos. (Hint: When taking notes, don’t forget to credit which resource you got the information from!) Evaluate the information and the sources, and choose whether you would argue for or against continuing to use asbestos in the United States. You should have 3-5 main points, and some evidence or data for each of them. Organize your information into an outline. You will be using the outline to present your argument to a group of your peers, so make sure you write enough so that you can remember the full point.
Part 1: Research & Claim

For the purpose of this activity, you are a researcher in the 1920s. Use your textbook and the web sites below to find out information on asbestos. First, skim through the following sections of the Wikipedia article:

http://en.wikipedia.org/wiki/Asbestos#Discovery_of_toxicity

and the attached article:

Think about questions like: Where and how is/was asbestos used? What are some health problems associated with asbestos? When did researchers and doctors begin to suspect asbestos caused health problems? Why and how did companies continue to use asbestos for so long after the health risks were recognized?

Resources:
http://en.wikipedia.org/wiki/Asbestos
http://www.csa.com/discoveryguides/asbestos/review.php
http://www.asbestos.com/asbestos/
Questions

What kind of information do we have available today that would not have been available in the 1920s?

What technology do we have available today that helps us to better understand minerals like asbestos?

Challenge

You are a researcher in the 1920s. Choose a side.

➢ Are you a doctor working in a mining town? If so, using the information available to you (such as Dr. Cooke’s research), write a letter to Congress urging them to ban using asbestos in the United States.

➢ Are you a researcher for an asbestos company? If so, write a letter to Congress arguing that asbestos is not so bad of a health risk.

Now that you have made your claim, read the article and web sites more carefully and choose 3-5 important points. Try to limit yourself to information which could have been available in the 1920s. Record your points and evidence or data to support them in your class notebooks. Make sure you have at least one piece of evidence or data for each point.
Part 2: Write a Letter to Congress

Once you have enough evidence and data to support your claim, you need to organize it. Remember the structure of an argument, with an introduction, your main points and evidence to support them, and a conclusion. Then, write your letter to Congress.

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Part 3: Oral Argument

Congratulations! Your letter impressed your representative so much he asked you to come to D.C. to present your argument to Congress.

Re-read the information in your letter. Consider how you will present the information in a short speech. Are there any key points you have forgotten? Any evidence or quotes you think are especially important? You can annotate or highlight your letter if you find it will help you to keep your thoughts organized.

You will present your argument to a group of your peers. Each person’s argument should last 3-5 minutes.

You will be evaluating your peer’s oral arguments below. The scoring system is on a scale of 1 to 3, with 1 needing the most improvement, and 3 being the strongest.

<table>
<thead>
<tr>
<th><strong>Student Name:</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Was the argument organized? Was there an introduction, main points, and a conclusion? Could you follow their reasoning?</strong></td>
</tr>
<tr>
<td><strong>Was there evidence or data from a credible source for each of the main points?</strong></td>
</tr>
<tr>
<td><strong>Did the student speak clearly and make eye contact with their audience?</strong></td>
</tr>
<tr>
<td><strong>Did the speaker use Earth Science vocabulary where appropriate?</strong></td>
</tr>
<tr>
<td><strong>Was there anything that the speaker said or did that you found especially positive? Or anything that wasn’t covered above that you think the speaker could improve next time?</strong></td>
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Chapter IV: Summary and Discussion

Currently, the focus of education is on preparing students for college and career readiness, and the emphasis in science education is on not only science concepts, but on teaching students about the nature of science as well. Given that atmosphere, it is more important than ever to incorporate the history of science into the science curriculum. This is because the history of science improves student understanding of the context in which science takes place and the process of not only scientific experimentation, but the entire process from conceptualization to publication and debate.

A glance through the literature shows that several methodologies have been successful at incorporating history of science into the classroom. Some of these methods, such as case-studies, allow students an opportunity to independently evaluate historical data and draw their own conclusions. Others, such as the Monk and Osborne Model, asks students to develop their own theories to explain historical observations or results, allowing misconceptions and pre-conceptions to be rigorously questioned before presenting the historical or current explanation. Still others, such as vignettes or a story-line approach, provide opportunities for deepening student understanding of how the context of society or technology impact the process of science. Historical case-studies can also be used to help students develop their understanding and use of scientific argumentation, as they make and support a claim with evidence.

An issue that many science teachers reported was that they felt that teaching history of science took too much time and diverted attention from the concepts that needed to be taught. However, research has shown that when incorporated into the classroom correctly, students continue to learn the conceptual material in conjunction with other important aspects of science, such as the process or nature of science. In addition, many of the methods listed above also
incorporate scientific literacy, which is important not only for future scientists but for all citizens. Thus it appears that the main issue is in fact to educate science teachers about what it really means to teach the history of science, and about the broad range of ways that the history of science can be incorporated into the curriculum.

The lesson plans in this project were a first step in demonstrating the broad range of topics and approaches that can be used to incorporate the history of science into the New York State Earth Science curriculum. The lesson plans addressed the content, context, and process of science through case-studies, story-lines, and dialogues. Students employed creative thinking, mathematics, argumentation, using and creating models, and other skills to complete the lessons. It is hoped that these lessons will be a useful resource for Earth Science teachers looking for ideas on how to incorporate history of science into their classrooms.
References


