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Inquiry learning in the earth science classroom

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INQUIRY LEARNING IN THE EARTH SCIENCE CLASSROOM

A Project

Presented to the

Faculty of

California State University,

San Bernardino

In Partial Fulfillment

of the Requirements for the Degree

Master of Arts

in

Education:

Curriculum and Instruction

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by

Jeni Kimberly Williams

December 2004

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ABSTRACT

This project includes research about inquiry learning and a handbook of Earth Science inquiry activities. The research describes the definition of inquiry learning, explores the history of this method of learning, and discusses the benefits and criticisms of inquiry learning. The handbook of Earth Science inquiry activities is designed for use in high school Earth Science classes. This handbook is a compilation from various sources of a variety of inquiry activities that focus on Earth Science concepts. The activities are correlated to the California State Science Standards for Earth Science and are appropriate for students in ninth grade Earth science classes.

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CHAPTER ONE

INQUIRY LEARNING IN EARTH SCIENCE

General Introductory Remarks

Currently, there exists a greater push than ever in science to increase student achievement in understanding of the State Standards. Academic achievement in science is not growing as expected (Helgeson, 1988; Martin et al, 2000). The current emphasis on science achievement results from the inclusion of the state test scores in science in the calculation of a school's 2003-2004 Academic Performance Index (API)(California Department of Education, 2004) as well as the recent political impetus to increase America's achievement in science and technology (California Department of Education, 2004). The influence of the No Child Left Behind Act can be seen in every school district. Teachers and students are pushed to greater academic achievement, especially on required testing (California Department of Education, 2004).

Students in the science classrooms are required to master a large number of science concepts in order to be successful. Many methods are used in science to teach the required concepts. Teachers use direct instruction, guided reading and practice, demonstrations, and hands-on inquiry learning. The traditional method for teaching science has been direct instruction (AbuSharbain, 2003). However, studies have shown that this method is not producing the academic growth expected in science education (Blosser, 1984; Helgeson, 1988; Martin et al, 2000).

Inquiry activities have always had a place in science education and are most effective in achieving true understanding or mastery of a concept (Exline, 2004; Haury, 1993; Hinrichsen, 1999; Ibe, 2003; Klentschy, 2001). Inquiry learning is an instructional method that is student centered and promotes critical thinking through the use of hands-on or authentic activities (Bonstetter, 1998; Dewey, 1897; Exline, 2004; Haury, 1993; Hinrichsen, 1999; Perkins, 1993). Many science teachers only use a few inquiry activities in their curriculum due to the difficulty of implementing and managing the activity (Hinrichsen, 1998; Ibe, 2003; Ruby, 2001). These teachers are doing the students a disservice (Ibe, 2003). Students who do not regularly practice inquiry activities in science may actually regress in their understanding of the processes of science (Ibe, 2003).

Inquiry activities that are easier to implement and manage are more likely to be used the classroom and can increase student success in science (Haury, 1993; Klentschy, 2001).

Significance of the Project

The ninth grade students in California School Districts are required to take and be tested by the state in Earth Science. These students' scores will be included in the school's API score beginning in the 2003-2004 school year (California Department of Education, 2004). Since these students currently are not exposed to many inquiry activities the science scores on the State tests are below the expected level. Therefore, there is an increased demand to increase student achievement in science. Research has shown that the regular use of inquiry activities in the science classroom can increase student understanding of science concepts (Hake, 1998; Haury, 1993; Hinrichsen, 1999; Ibe, 2003; Klentschy, 2001; Lord, 1997; Pandya, 2002; Paulson, 1999; Ruby, 2001; Udovic, 2002). These students will need to have access to inquiry activities in Earth Science Standards. A regular exposure to inquiry activities will likely increase student understanding, motivation, and achievement both in class and on required tests (Hake, 1998; Haury, 1993; Hinrichsen, 1999; Ibe, 2003; Klentschy, 2001; Lord, 1997; Pandya, 2002; Paulson, 1999; Ruby, 2001; Udovic, 2002).

A need exists in most Earth Science classes for an increase in the amount of inquiry activities in the curriculum. These activities need to be aligned with the State Standards and be easily implemented so that they will be used. Teachers must use inquiry activities on a consistent basis to be effective (Ibe, 2003; Klentschy, 2001). However, many teachers do not use inquiry activities due to the difficulties inherent with large class size and the management of such classes during the inquiry activities (Hinrichsen, 1999; Ruby, 2001). Also, many people believe that there is core body of knowledge that should be learned in a sequenced curriculum and that it is more efficient to just give the students this knowledge instead of letting the students learn through their own investigations (Exline, 2004; Hinrichsen, 1999). However, the benefits of using inquiry activities outweigh the efficiency of direct instruction. Most students who are exposed to inquiry learning demonstrate greater academic achievement (Hake, 1998; Hinrichsen, 1999; Klentschy, 2001; Lord, 1997; Paulson, 1999; Ruby, 2001; Udovic, 2002). Many students also show increased motivation for school (Haury, 1993). Students who experience a continued and consistent usage of inquiry learning show better retention of knowledge as well as an increased ability to extend their knowledge to other processes (Ibe, 2003; Pandya, 2002).

Inquiry activities need to be easy to implement and manage for increased teacher usage. A need exists for a variety or pool of inquiry activities in the Earth Science curriculum that teachers will be able to choose from and use effectively. As teachers regularly incorporate inquiry activities into the Earth science curriculum, students will be able to achieve greater success in the science classes, on standardized tests and with applications to their lives. This will benefit the schools as their API scores should increase with the increased student scores in science.

Purpose of the Project

The purpose of the project was to develop a handbook of inquiry activities that can be used in high school Earth science classes. Many teachers know that inquiry learning is beneficial but many teachers do not regularly engage their students in activities that involve inquiry. The availability of ready-to-use, low cost, inquiry activities will make it easier to implement this type of activity in the classroom. The activities in the handbook are correlated to the California State Science standards. They are grouped by major topics that occur in the Earth Science standards. The procedures are presented in the 5 E lesson plan format in order to support inquiry learning. This handbook will be useful to any Earth science teacher who wants to include more inquiry activities in the curriculum.

Scope of the Project

This project is a handbook of inquiry activities for the Earth Science high school classroom. The activities are designed to make it easier for Earth science teachers to implement inquiry activities in the classroom. The activities are grouped by major Earth science topics so that it is easy for the teacher to determine which activity would be appropriate for a particular unit. Each activity is correlated to the California State Standards for Earth

Science in grades nine through twelve. The activities are low cost and easy to implement.

Each activity begins with a description. The description lists the California State Earth Science Standard that it addresses, a list of materials needed, amount of time needed, the specific objective for that activity and a suggested procedure. The procedure is presented in the 5 E lesson plan format that supports inquiry learning. An evaluation rubric and teacher response form are also presented at the beginning of the project. Teachers are requested to evaluate the activities with regards to the effectiveness and usefulness of the activity. This form is requested to be returned to the author. The contact information is included on the evaluation form. The teacher evaluation forms will be used to make improvements in the Handbook of Earth Science Activities.

The Handbook of Earth Science Activities is designed to provide a selection of inquiry activities from which teachers can choose to implement in the classroom. The idea is if teachers have a supply of ready-to-go inquiry activities at their disposal, then they will be more likely to use the inquiry activities as part of the curriculum. As a result, the students are more likely to achieve better understanding of the science concepts and be more motivated in science class (Hake, 1998; Haury, 1993; Hinrichsen, 1999; Ibe, 2003; Klentschy, 2001; Lord, 1997; Pandya, 2002; Paulson, 1999; Ruby, 2001; Udovic, 2002).

Definition of Terms

The following terms are defined as they apply to the project.

- Inquiry learning = any type of learning that promotes critical thinking on the students part through the use of hands-on type and minds-on types of activities that are student centered (Dewey, 1897).
- Inquiry activity = an activity that requires critical thinking on the part of the student. This includes hands-on activities where the students are examining or experimenting with different materials, using authentic data that the students analyze as well as creative efforts on the part of the student where they must understand and then

creatively demonstrate their understanding (Exline, 2004).

CHAPTER TWO

LITERATURE REVIEW

Introduction

Science education reform has been the focus of a variety of organizations who are seeking to improve the overall education of American children (Blosser, 1984; Martin et al, 2000; Ruby, 2001). Teachers are encouraged to push students harder with more classwork, homework and higher standards for achievement (Blosser, 1984). Achievement in science still is not growing as expected (Helgeson, 1988; Martin et al, 2000). In spite of the evidence showing the traditional direct instruction method of teaching to be nonproductive, direct instruction continues to be the method of choice in many academic atmospheres (AbuSharbain, 2003). The burden of student achievement falls upon science educators.

The traditional methods are not working and a change is needed to increase student achievement (Blosser, 1984). Several suggested activities for improving the science curriculum are described as follows. First, interactive science learning, where the students are encouraged to work cooperatively to learn about science concepts (Blosser, 1990). Second, the use of a thematic approach to science, where the major strands of science are connected across the curriculum (Blosser, 1990). Third, conceptual change, where the central goal is to make science meaningful to students by connecting the content to the real world (Blosser, 1990; National Research Council, 1996). Fourth, science in technology and society, where the emphasis in science is to create citizens who understand and can benefit from the scientific advances in society (Blosser, 1990; National Research Council, 1996). Finally, inquiry teaching, where the students will develop better understanding of the nature of science and will be more interested in science by being active participants (Blosser, 1990; National Research Council, 1996).

Inquiry teaching and learning has been shown to increase student achievement in the classroom, student motivation, and student achievement on standardized tests and writing tests (AbuSharbain, 2003; Hake, 1998; Ibe, 2003; Klentschy, 2001; Lord, 1997; Mbajiorgu, 2002; Pandya, 2002; Paulson, 1999; Udovic, 2002). Inquiry learning is strongly encouraged for use in the classroom by the National Science Standards (National Research Council, 1996), the California State

Standards (California Department of Education, 1999) and the California Science Framework (California Department of Education, 2003). The increased usage of inquiry teaching and learning is an important step to increasing student achievement and motivation in science (Haury, 1993).

Definition: What is Inquiry Learning?

Inquiry learning is learning through hands-on activities that promote critical thinking (Hinrichsen, 1999; Ruby, 2001). Learning by inquiry allows students to connect the concepts being studied with their personal life and experiences (Haury, 1993). The students are able to make the connections that are needed to fully understand a concept by actively participating in the learning (Perkins, 1993). Inquiry learning emphasizes using the content to develop problem-solving skills that students can use in any situation (Exline, 2004).

In science education, the inquiry process engages students in the investigative nature of science (Haury, 1993). The focus for learning science is on the active search for knowledge and understanding. Students must be actively engaged in order to truly learn (Dewey, 1897).

Inquiry learning can be used in group work, laboratory work or in selected readings and lectures that cause students to think (Exline, 2004). Lessons that generate innovative thought and promote critical thinking and analysis in the student's mind are usually inquiry based.

Inquiry learning differs from the traditional approach to learning in that it is focused on acquisition of content in addition to the development of skills and abilities (Exline, 2004). This approach is student-centered with the teacher serving as a facilitator rather than the supreme source information (Bonstetter, 1998). Inquiry learning does have some varying levels of student-centeredness. Bonstetter (1998) describes an evolution of inquiry that begins with the teacher centered hands-on activities. These are entirely directed by the teacher. The next level is Structured Inquiry where the students are given a laboratory activity with explicit procedures and are instructed to find their own conclusions. The third level is Guided Inquiry where the students are given a problem and must create their own design or procedures as well as generate their own conclusions. The fourth level is Student Directed Inquiry where the teacher assigns a topic and the student is responsible for the rest of the investigation (Bonstetter, 1998). This is the level of inquiry that the National Science Standards suggests that students work at in learning science (National Research Council, 1996). The final level of inquiry is student research where the student is responsible for every aspect of the investigation using the teacher only for support and guidance (Bonstetter, 1998).

Inquiry learning can occur in a variety of levels and educational situations with varying degrees of teacher support. When students are actively engaged in asking questions and solving problems, they are using inquiry learning. The learning is mostly student directed with the teacher acting as facilitator. In summary, inquiry learning is a type of learning that uses the active participation of the student to promote critical thinking and problem-solving skills through hands-on activities.

History

The traditional method of science teaching is teacher-directed instruction where the students are passively receiving the required information that they will need to pass the next exam (Dewey, 1897; Exline, 2004; Perkins, 1993;

Yore, 2001). For over one hundred years most science students have been instructed in this traditional manner despite the findings in research that this method of instruction does not produce the desired achievement in student mastery of science concepts (AbuSharbain, 2003).

During the past one hundred years educators have been exposed to the idea that students need hands-on practice in order to truly understand science concepts. John Dewey, whose work was published and circulated during the early 1900's, began speaking of his philosophy about education in 1897 when his *Pedagogic Creed* was first published in The School Journal. Dewey was a strong advocate for the use of active learning in schools (Dewey, 1897). He also advocated the use of the scientific method as a guide for thinking through and solving a variety of problems (Rudolph, 2001). The purpose of the science classes, according to Dewey, was to teach the students how to think and reason logically so that they would be able to apply this reasoning and logic to a variety of situations (Rudolph, 2001). In spite of Dewey's strong philosophical points and many publications, most students were still instructed in the traditional manner.

In the mid 1900's another advocate for inquiry learning, Joseph Schwab, began publishing his work. Joseph Schwab believed, like Dewey, that science should be an active learning process (Rudolph, 2001). The point where he differed from Dewey was in the use of the scientific method. Schwab did not believe in the oversimplified application of the scientific method to all problems in all disciplines (Rudolph, 2001). He maintained that the scientific methods were discipline specific and could not be applied to everything (Rudolph, 2001). Schwab also believed that the science curriculum should not be presented as a complete and unchanging body of facts as the traditional method of teaching science implies (Rudolph, 2001). The science curriculum that should be presented needs to show that science is constantly changing and being updated (Rudolph, 2001). It is a dynamic body of knowledge. Schwab claimed that educating the public about this dynamic nature of science will bring more support for science in the community and is one of the primary functions of secondary school science (Rudolph, 2001).

Recent publications have also illustrated the need for science education to shift away from the traditional method towards an inquiry method in science instruction (AbuSharbain, 2003). The publication of The Benchmarks for Science Literacy by the American Association for the Advancement of Science in 1993, the National Science Education Standards by the National Research Council in 1996 and the California State Standards in 1999 by the California Department of Education each call for an emphasis on inquiry learning in science. In spite of the publications produced by Dewey and Schwab throughout the early to mid 1900's and the current publications in circulation most science students are still taught science in the traditional teacher-directed manner (AbuSharbain, 2003).

Benefits of Inquiry Learning

Inquiry learning in the classroom has a variety of benefits. This method of learning can increase student achievement both in the classroom and on standardized tests, increase students' flexibility with using new information for a variety of different problems, increase students' long term retention of concepts and may increase student motivation and enjoyment in school (Hake, 1998; Haury, 1993; Hinrichsen, 1999; Ibe, 2003; Klentschy, 2001; Lord, 1997; Pandya, 2002;

Paulson, 1999; Ruby, 2001; Udovic, 2002). Inquiry learning enhances student performance in laboratory skills, graphing and analysis of data (Haury, 1993).

A study conducted by Rajul Pandya of the Digital Library for Earth System Education Program Center in Colorado compared two groups of similar university students taking geoscience classes. One group was instructed using the traditional direct instruction method only. The other group used primarily inquiry learning with a small amount of direct instruction. At the end of the class, students learning through inquiry showed improvement in reasoning and analysis (Pandya, 2002). These students also demonstrated that the reasoning and analysis skills gained in one inquiry activity are used over again in other situations (Pandya, 2002).

Inquiry learning also increases the students' understanding of content vocabulary and the related concepts (Haury, 1993; Sutman, 1993). As such it is a valuable tool to use with underserved populations such as English language learners (Haury, 1993; Sutman, 1993). Successful instructional techniques in teaching science to English language learners include inquiry, hands-on activities in cooperative learning groups where students of varying levels of English language proficiency work together (Sutman, 1993). Several studies have shown that inquiry learning has increased scientific skills in thinking and communicating among language minority students (Haury, 1993; Sutman, 1993). The inquiry approach is especially successful with language minority students when it is used to connect the science content with real world applications or problems (Sutman, 1993).

Another group that specifically benefits from using the inquiry approach to learning is the high ability or gifted learners at all levels of education (VanTassel-Baska, 1998). The use of inquiry activities increases motivation in both the teachers and students and can be used to achieve higher levels of understanding with increasingly complex topics (VanTassel-Baska, 1998). Studies in high school biology, chemistry and physics classes have shown significant improvement in student achievement and levels of scientific literacy when inquiry activities were employed (Hake, 1998; Lord, 1997; Mbajiorgu, 2002; Paulson, 1999; Udovic, 2002).

Inquiry learning has also been shown to increase student achievement in science at the elementary school level. The Valle Imperial Project in Science, headed by Michael

Klentschy in Imperial Valley, California, implemented a kit based inquiry science curriculum for the elementary schools. Students in grades one through six were exposed to this method of science instruction. Also, teachers were given professional development workshops and support in order to learn how to implement this science curriculum. To assess student achievement, students in fourth and sixth grades were required to take the science portion of the Stanford Achievement Test (SAT 9). The sixth graders were also required to take the Imperial County District Writing Proficiency Test.

The students who participated in the Valle Imperial Science Project scored significantly higher that those students who did not participate. The students who participated in the Valle Imperial Project in Science also showed significant increase in their scores on the science section of the Stanford Achievement Test and in District Writing Proficiency Tests. Also, the longer the students were exposed to the inquiry science curriculum over the years at elementary school, the better their scores were both on the SAT 9 and the Writing Proficiency Test (Klentschy, 2001). Inquiry learning shows increased student achievement with consistent usage over several years (Ibe, 2003). However, if usage is discontinued students show regression in achievement (Ibe, 2003).

A study conducted by Mary Ibe and Rebecca Deutscher at the Lewis Center for Educational Research in Apple Valley, California in 2001-2002 revealed that students regress in their ability to apply inquiry when inquiry instruction is not consistent throughout their school career (Ibe, 2003). Students at the Lewis Center were given pre and post assessments to determine their level of proficiency in using scientific inquiry skills. The students who were instructed using inquiry methods over several years showed improvement in their inquiry skills. However, the students who did not use inquiry learning or only used inquiry at a low level over several years regressed in their proficiency levels (Ibe, 2003). Inquiry learning provides the greatest benefits with consistent usage over time (Ibe, 2003; Klentschy, 2001).

Criticisms of Inquiry Learning

In spite of the large amounts of research suggesting that inquiry learning is beneficial many people do not agree. One criticism of inquiry learning as described E.D. Hirsch and Howard Gardner (in Exline 2004) is that there exists a core body of knowledge which all people should learn and that there should be a sequenced curriculum in K-12 education that teaches this core knowledge (Exline, 2004). This type of curriculum has no room for inquiry learning. Proponents of the core knowledge approach believe that the students will not be able to make the connections and understandings that it took many generations of scientists to accomplish and still cover the prescribed curriculum within the given time (Exline, 2004). If the students spend too much time learning one concept, they will not have enough time to cover the rest of the concepts required for that year and will be out of sequence. Another criticism of using inquiry in the classroom put forth by many educators, parents and members of society is that it takes too much time and is too difficult to ensure that they are learning all they will need for the test (Exline, 2004). Proponents for the traditional, direct instruction method of teaching argue that students are taught more efficiently with direct instruction (Hinrichsen, 1999). Again, these proponents consider it very unlikely that students will be able to discover the ideas that took many centuries to be developed by using inquiry learning (Hinrichsen, 1999).

Among teachers that use inquiry learning in the classroom there are problems with creating an inquiry learning environment and with training the students to learn in this environment (Lorsbach, 1997). Students may be uncomfortable with the use of inquiry and actively resist. Some students may have difficulty adapting to the use of inquiry and taking responsibility for their own decisions and learning (Lorsbach, 1997). Teachers must persevere and continually give guidance and support as students are learning how to understand how inquiry learning works and what they must do. Inquiry learning does require a large amount of time and effort from both the teacher and the students (Ruby, 2001).

Many of these criticisms have valid points, on the surface. Teachers are required to cover a certain amount of material each year. It may be faster to cover more material with direct instruction. Many students are uncomfortable with inquiry. However, student academic achievement has not shown any significant increase since 1970 (Helgeson, 1988; Martin et al, 2000). This indicates that a change is needed in the methods of teaching (Blosser, 1984). Some studies have shown that a compromise between direct instruction and inquiry learning have also produced increases in student achievement (Haury, 1993; Hinrichsen, 1999). Educators that are reluctant to use inquiry learning may incorporate this method along with their traditional method and still have gains in student achievement (Haury, 1993).

CHAPTER THREE

PROJECT DESIGN AND METHODOLOGY

The goal of the project is to enable teachers to use more inquiry activities in the classroom. The Handbook of Earth Science Activities is designed as a tool for teachers. This handbook will provide teachers with a variety of inquiry activities to choose from that will enhance the Earth Science curriculum. These activities have been compiled from a large selection of resources and adapted for use in the high school classroom. Ideas from other teachers at the high school level have generated some of the activities. Ideas generated in education classes from other students gave rise to some activities. Extensive research on the Internet and in Earth science books provided the information and resources for many activities. These activities have been adapted for ease of use at the high school level. The handbook is formatted to allow teachers to easily find an activity that will support the content standard currently being taught. Teachers will be able to use the Handbook of Earth Science Activities as a tool to support their teaching.

The activities in the handbook were selected on the basis of their ability to enhance student understanding of Earth science concepts by using inquiry learning. Another criterion for selection was the ease of implementation into the high school classroom. The effectiveness of the handbook as a tool for motivating teachers to provide more inquiry activities in the classroom depends on the ease of implementation of inquiry activities that support or enhance the content standards.

The format of the handbook is designed for ease of use. The activities are grouped into several major Earth science topics in the table of contents. For each activity, a description is provided. The description includes the correlation to a California State Earth Science Standard, a specific objective for that activity, amount of time required, a list of materials needed and suggested procedures. The procedures are presented in the 5 E lesson plan format developed by Roger Bybee for the Biological Sciences Curriculum Study (Miami Museum of Science, 2001). This lesson plan format aids teachers in ensuring that inquiry learning is occurring. Associated with the activities is a teacher evaluation rubric and form. The intent of these forms is to provide feedback to the author that can be used to give information about the effectiveness and usefulness of activity and the handbook. This information can then be used to improve the activity or the handbook. This format is engineered to enable teachers to quickly locate an inquiry activity that will meet their needs.

The Handbook of Earth Science Activities is designed to be useful tool that will aid teachers in creating more opportunities for inquiry learning in the classroom. The compilation and design of this project focused on meeting the needs of high school Earth science teachers. The activities were carefully selected and adapted for use at the high school level. The criteria for selection included the use of inquiry to teach Earth science concepts and the ease of implementation of the activity in the classroom. The format of the handbook is designed for ease of use. Teachers will be able to easily find activities related to the concepts they are teaching.

CHAPTER FOUR

SUMMARY AND RECOMMENDATIONS

Summary

The recent emphasis on improving student achievement in science in today's schools is brought about by the state mandated inclusion of state science test scores in the calculation of a school's Academic Performance Index (API) (California Department of Education, 2004). Many methods of teaching science are used in classrooms today. The traditional method for teaching science, direct instruction, is the most commonly used even though research has shown that it is not very effective (AbuSharbain, 2004; Blosser, 1984; Helgeson, 1998). The most effective method for teaching science is inquiry (Exline, 2004; Haury, 1993; Hinrichsen, 1999; Ibe, 2003; Klentschy, 2001). Inquiry learning can increase student achievement and raise test scores (Haury, 1993; Ibe, 2003).

Many teachers do not use inquiry activities as a regular part of the curriculum (Hinrichsen, 1999; Ibe, 2003). Students in Earth science classes in high school are not required to do any laboratory activities as it is not considered a laboratory class in the requirements for college (UC Regents, 2004). Yet, the most effective way to learn science is by inquiry (Exline, 2004; Haury, 1993; Hinrichsen, 1999; Ibe, 2003; Klentschy, 2001). A need exists for a pool of easily implemented Earth science inquiry activities that teachers can choose from for use in the classroom. As teachers use more inquiry activities in the Earth science classes, student achievement and motivation should improve (Hake, 1998; Haury, 1993; Hinrichsen, 1999; Ibe, 2003; Klentschy, 2001; Lord, 1997; Pandya, 2002; Paulson, 1999; Ruby, 2001; Udovic, 2002). Students, teachers and schools will all benefit from the use of inquiry activities in the classroom.

Inquiry learning is defined as learning through hands-on activities that promote critical thinking (Hinrichsen, 1999). It is a student-centered approach that focuses on actively searching for knowledge and understanding (Dewey, 1897). Inquiry learning uses content to develop problem-solving skills (Exline, 2004). It engages students in the experimental and investigative nature of science (Haury, 1993).

Inquiry learning has been advocated for use in science instruction since the nineteenth century (Dewey, 1897). Research shows that learning by inquiry is the most effective method to achieve understanding of a concept (Exline, 2004; Haury, 1993; Hinrichsen, 1999; Ibe, 2003; Klentschy, 2001). However, most students are still taught science through direct instruction (AbuSharbain, 2003). Recent publications such as the Benchmarks for Science Literacy (American Association for the Advancement of Science, 1993), the National Science Education Standards (National Research Council, 1996) and the California State Standards (California Department of Education, 2004) emphasize the need for inquiry learning in the classroom. In spite of the many publications describing the benefits and advocating the use of inquiry learning, most students in today's schools are still not being exposed to many inquiry activities (AbuSharbain, 2003).

The students in high school Earth science classes need to experience more inquiry learning. Teachers need to be able to implement a variety of Earth science inquiry learning experiences throughout the school year. This project was developed to help Earth science teachers to use more inquiry activities in the classroom. The Handbook of Earth Science

Activities is a compilation of inquiry activities that have been carefully selected and adapted for use in high school Earth science classes. This handbook is designed as a tool for Earth science teachers to use in order to increase student achievement and motivation by implementing more inquiry activities in the classroom.

Recommendations

The recommendations for improving or extending this project are to develop or compile several different inquiry activities that teachers may choose from for each Earth science content standard. This would improve the handbook by increasing the pool of inquiry activities easily available for use. As teachers use more inquiry learning, student achievement in school and on standardized tests should increase (Hake, 1998; Haury, 1993; Hinrichsen, 1999; Ibe, 2003; Klentschy, 2001; Lord, 1997; Pandya, 2002; Paulson, 1999; Ruby, 2001; Udovic, 2002). This would help to satisfy the push for greater student achievement in science and increase schools' Academic Performance Index. A larger pool of inquiry activities would also increase the effectiveness of the handbook by making it more likely that a teacher will at least choose one of the inquiry activities to implement in the classroom. Another recommendation is to develop similar handbooks with inquiry activities for the sciences that are often included in Earth science classes, such as physics and chemistry.

APPENDIX

A HANDBOOK OF EARTH SCIENCE ACTIVITIES

A HANDBOOK OF EARTH SCIENCE ACTIVITIES

Compiled by Jeni Williams

Preface

The activities contained in this handbook are a compilation and have been adapted from various resources over several years of research and teaching. They are in no way intended to be considered as original work by the compiler. Ideas from other teachers at the high school level have generated some of the activities. Ideas generated in education classes from other students gave rise to some activities. Extensive research on the Internet and in Earth science textbooks provided the information and resources for many activities. These activities have been adapted for ease of use at the high school level. The activities in the handbook were carefully selected based on the criteria discussed in the methods portion of this project on the basis of their ability to enhance student understanding of Earth science concepts as well as their ease of implementation in the high school classroom.

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Biogeochemical Cycles

Maps

Plate Tectonics

Earth Materials

Earthquakes

Volcanoes

Universe and Space

Atmosphere and Weather

California's Resources

Please use the following planning guides to help plan and prepare for each inquiry lesson.

Teachers' 5-E Planning Guide

Lesson: ______________________ Grade Level: _________Date: _______

Objective: Include only the one or two direct or strong outcomes that this lesson actively pursues (write out the entire outcome).

Big Ideas/Standards: State the main concept(s) you will teach (Ex. Magnets have two repelling poles – north and south).

1.

2.

"5-E" Phase	Planned Activities/Events	*Guiding Questions*	**Notes: Materials, Safety, Graphic Organizers**
Engage ☐ Tap prior knowledge ☐ Focus learners' thinking ☐ Spark interest in the topic			
Explore ~ HANDS-ON! ☐ Provide learners with common, concrete, tactile experiences with skills and concepts ☐ Observe and listen to students ☐ Ask probing questions ☐ Act as a consultant			
Explain ~ MINDS-ON! ☐ Encourage students to explain concepts in their own words			

☐ Ask for justification ☐ Use students' previous experiences as the basis for explaining concepts ☐ Clarify and correct misconceptions			
Extend ~ HANDS-ON! ☐ Apply same concepts and skills in a new context resulting in deeper and broader understanding ☐ Encourage the students to apply the concepts/skills to new situations via new activities.			
Evaluate ☐ Observe the students as they apply new concepts and skills ☐ Assess, formally and/or informally, student progress toward achieving the learner outcomes (knowledge and/or skills) ☐ Allow students to assess their own learning and group-process skills			

Students' 5-E Planning Guide

Learner Outcomes/ Evidence of Learning: What will the students be able to do or know as a result of this experience (use measurable action verbs).

The Students will...

1. Students will
2. Students will

5 E Phase: Student Performance Indicators	**Describe the Learning Environment:** field trips/lab/research/cooperative learning, etc.	**Possible Questions Your Students May Ask**
Engage ☐ Shows interest ☐ Asks questions		
Explore ☐ Formulate questions ☐ Tests hypotheses ☐ Records observations and data ☐ Draws reasonable conclusions ☐ Proposes explanations		
Explain ☐ uses recorded observations in explanations ☐ Explains possible solutions ☐ Listens critically to others' findings ☐ Questions one another's explanations ☐ Listens and tries to comprehend the explanations that the teacher offers		
Extend ☐ Applies same		

concepts and skills in a new, but similar situation ☐ Uses previous information to ask questions, propose solutions, make decisions, and design experiments		
Evaluate ☐ Answers open-ended questions by using observations and evidence ☐ Demonstrates an understanding of the concept/skill ☐ Evaluated his/her own knowledge ☐ Asks related questions that would encourage future investigations		

Inquiry Lesson Evaluation Rubric

Use the following rubric to evaluate and provide feedback about the inquiry activities in this handbook. Please send your evaluations and comments to: Jeni Williams Rubidoux High School 4250 Opal St. Riverside, CA 92509

5 E Model	Beginning	Developed	Accomplished
Ideas & Indicators	Did not identify "big idea" (standard) and indicators appropriate for lesson.	Missing either "big idea" (standard) or indicators for lesson OR they do not match the lesson content.	Identifies "big idea" (standard) and indicators appropriate for lesson.
Engagement	Missing two or more of the following components: captures students' attention, accesses prior knowledge, and identifies appropriate activities.	Missing one of the following components: captures students' attention, accesses prior knowledge, and identifies appropriate activities.	Addresses all components of this stage: captures students' attention, accesses prior knowledge, and identifies appropriate activities.
Exploration	Missing 3 or more components of this stage: student centered, teacher as guide, interactive, inquiry based, direct concrete experiences with the concept.	Missing 2 components of this stage: student centered, teacher as guide, interactive, inquiry based, direct concrete experiences with the concept.	Addresses all components of this stage: student centered, teacher as guide, interactive, inquiry based, direct concrete experiences with the concept.

Explanation	Missing 3 or more components of this stage: teacher and students work together, analysis of info from exploration, teacher clarifies info and shares scientific terminology, concept is formed.	Missing 2 components of this stage: teacher and students work together, analysis of info from exploration, teacher clarifies info and shares scientific terminology, concept is formed.	Addresses all components of this stage: teacher and students work together, analysis of info from exploration, teacher clarifies info and shares scientific terminology, concept is formed.
Extension	Missing 2 components of this stage: student centered, active learning, activities to deepen understanding of concept OR apply to a real world situation.	Missing one component of this stage: student centered, active learning, activities to deepen understanding of concept OR apply to a real world situation.	Addresses all components of this stage: student centered, active learning, activities to deepen understanding of concept OR apply to a real world situation.
Evaluation	Lacking means to evaluate or inappropriate tool identified.	Evaluation conducted only at end of lesson.	Appropriate formal and informal evaluations are identified throughout lesson.

Adapted from
http://cte.jhu.edu/techacademy/fellows/Ullrich/webquest/mkuindex.html

INQUIRY ACTIVITY EVALUATIONS AND COMMENTS

Activity Name ____

Name of Class (Earth science, integrated science, etc.)

____

Grade Level ____

Overall Evaluation ____________________________________

____

____

Comments or Suggestions ________________________________

____

____

____

____

Please send completed evaluation form for each activity used in your classroom to:

Jeni Williams
Rubidoux High School
4250 Opal St.
Riverside, CA 92509

Or you may email evaluation and comments to: jeni_williams@jusd.k12.ca.us

Erosion, Transportation and Deposition

Objective: Students will observe and describe the processes of erosion, transportation, and deposition by creating a physical model.

CA State Science Standard: Standard Set 7 - Biogeochemical Cycles

7. Each element on Earth moves among reservoirs, which exist in the solid Earth, in oceans, in the atmosphere, and within and among organisms as part of the biogeochemical cycles.

Time Required: 2 – 3 55-minute class periods

Materials

paint tray (the kind used for a paint roller)
pieces of sod (enough for each group)
potting soil
heavy clay like soil
Rainmaker (paper cup with about ten tiny holes poked in the bottom)
Water

Procedure:

Engagement

Take students on a walk outside the school building and ask them to note where the soil is worn away or seems to have collected. Before going on the walk you may want the students to explain what they will look for or what are the signs that soil has worn away or built up? (Suggested answers may include: erosion - puddles, hollowed out areas, areas that dip or are lower that the surrounding area; deposition - mounds of dirt, collection of soil or other materials in a certain spot, etc.) Upon returning to the classroom make a list of the sites where soil was worn away or collected.

Examples:

end of splashguard by rainspout at entrance to door

path leading to the sports fields at the bottom of hill/slope

Do you notice anything different about these areas? (they are just dirt; no grass is growing here.)

What do you think caused these changes? (Students walking over them; water running through it.)

Exploration

Construct a model to investigate how these changes may have occurred. Provide materials so the students can construct their own model of a landscape. It should include a piece of sod, fine potting soil, and a heavy clay like soil. Have them use a paint roller tray as the base of the landscape. Do not put any landscape materials in the bottom well; it should remain empty.

Once students have constructed their models have them diagram and label their models and make a prediction as to what will happen if it "rains" on their landscape.

One student pours a cup of water all at once into the rainmaker. Hold the rainmaker about 4 inches above the upper end of the landscape and slowly move it back and forth so the water "rains" down on the model landscape. Observe what happens to the landscape. When it is finished raining have the students observe the final effects of the rain on their landscape. Have students go back to their predictions and record what actually happened.

Explanation

Tell me what some of your predictions were before it rained on your landscape. (Record on board.)

What actually happened to your landscape when it rained on it? (record so you can make comparisons.)

How is your landscape different after the rain than before it rained on it? What happened to the soil? Where did it go? Why did this happen?

As students share their ideas and understandings, record key phrases on the board. Some phases that may be valuable to your later discussion may include:

dirt and soil washed away

the soil collected at the bottom of the slope

the water hollowed out the soil

the rain carried the soil down the hill

when the water washed away the soil it formed a hole

Relate their observations to the processes scientists observe over an extended period of time. Use student models to identify and label erosion and deposition. Have students work to create definitions for these terms. When you are sure students have a real understanding of the terms, formulate a final definition and post on board or chart in the classroom for future reference. Demonstrate the process of transportation and lead students to understand that it is the movement of soil particles from one place to another. Refer to the list generated during the engagement and have students make connections; they should use the new terms to discuss and explain what they saw. Help them to understand that they just used water to simulate erosion, transportation, and deposition, but it can also be caused by wind, people, animals, etc.

Extensions

1. Using the same paint roller tray as the base for their landscape, have the groups of students plan a method to decrease or eliminate erosion. Students should draw a diagram of the model planned and label the materials used in their landscape. They should write a short explanation explaining why they think this would work to curb erosion. (Tell students that you will provide the same materials that they used today and they are responsible for supplying the rest of the materials to build their new landscape tomorrow.)

2. Have students use a variety of resources and references to research various landmarks that are the result of these processes (e.g. Grand Canyon, Mississippi River Banks, etc.). You can then lead a class discussion on the topic: Erosion and Deposition - Help or Hindrance?

Evaluation

1. Have photographs representing each process and have students identify and explain why they identified it as such.

2. Have students take a walk in their own neighborhood to find examples of each process. They should draw and write one paragraph telling what they observed.

3. Have students write their own definition and list an example for each process in their science journals.

Reading Topographic Maps

Objective: To learn to read and understand a topographic map.

California State Science Standard:

Investigation and Experimentation

1h. Read and interpret topographic and geologic maps.

Time Required: Two 55-minute class periods.

Materials: Ruler

Topographic Maps

Procedure:

Engagement: Present them with a scenario, such as you are at home (give coordinates) and you need to get to the best party of the year located at (give coordinates). You do not have any access to cars, buses, taxi's, etc. You must either walk or ride a bicycle. Your friend has a topographic map of the area. What is the best way to get to the party?

Exploration: Students look at topographic maps of familiar places, such as the area where their school and neighborhood are located. Have them examine the keys/legends. Instruct students to go outside and compare the topographic maps to what they can see. Have the students make a reference sheet or notes page about what they think the different things on the map might be or mean.

Explanation: When the students come in from comparing the topographic map to the outside world, ask them about their reference or note sheet. What do they think the symbols mean? What are the wavy lines on the map? What do they show? Discuss how they know what location they are at and how to describe it with latitude and longitude. Go over some of the vocabulary related to topographic maps and compare it to their notes. They can learn the correct terms for what they saw on the map. Show examples of different maps and discuss the types of terrain each map is showing. Be sure to ask them to explain and justify how they know. Go over examples of how find location, direction and elevation on topographic maps.

Extension: Students use the maps of their general area and plan a scavenger hunt using coordinates and elevations. Have students trade scavenger hunts and follow each other's clues.

Evaluation: Give students a topographic map of an unknown area, give them their initial coordinates and have them find the best route to a specified destination. Make sure they either show you the route on the map or write down specific directions.

Wandering Continents Activity

Objective: To explore evidence supporting the theory of continental drift.

California State Science Standard:

Earth Science Standard Set 3 - Dynamic Earth Processes

3. Plate tectonics operating over geologic time has changed the patterns of land, sea and mountains on Earth's surface.

Time Required: Two-three 55-minute class periods.

Materials: Scissors

Glue

Construction paper

Colored pencils

Access to the geologic data about glaciers, fossils and rock formations from 200 million years ago (Internet, textbooks, reference books, etc).

Fossils or pictures of different fossils of animals that lived 200 million years ago from each continent.

Procedure:

Engagement: Show students 200 million year old fossils or pictures of fossils and the types of animals they were from each of the major continents.

Discuss the type of environment those animals might need to live. Compare that to the current environment on each continent. How could those environments have changed?

Exploration: Give students outline maps of the continents that they may cut out and move. Give students access to the geologic data about rock formations, locations of glaciers and fossils on the continents dated at 200 million years ago. Let the students work with the continents and data to figure out how environments may have changed from 200 million years ago. Give the students enough time to consider all the evidence: "fit" of coastline, fossils, glaciers and rock formations. Student may work in pairs or alone while exploring the movement of the continents. Have students discuss what they think might have happened that would change the environments.

Explanation: After students have generated several possibilities for what happened to the continents, they will be ready to learn about Alfred Wegener and his theory about continental movement 200 million years ago and Pangaea. Have the students describe what they think about the movement of the continents. List their descriptions on the board and discuss each of the possibilities. Supply students with the relevant vocabulary and introduce then to the ideas of Alfred Wegner. Revisit the students' descriptions and discuss and make modifications to them as a class.

<u>Extension:</u> Ask students if the continents are still moving or did only move to from Pangaea to their current locations? Students can research and find the evidence for the movements of the continents since they were formed. Students can use several sets of continent outlines and the geologic evidence used to support those claims to show and, therefore, better visualize the different positions of the continents at various times in geologic history.

<u>Evaluation:</u> Observations of students during activity. Listen to the student discussions and pay attention to their logic in their use of the evidence and placement of the continents. This is the essence of the evaluation for this activity. Students will turn in their completed map of Pangaea and questions. They will also turn in their illustrations of how the continents have moved over time.

Wandering Continents Activity

Background: When Alfred Wegener first proposed the theory of continental drift in 1915, it was almost an idea ahead of its time. It did not gain popular acceptance until the 1950's, when plate tectonics began to emerge as a relevant new science. Wegener proposed that the present continents were once joined together about 200 million years ago into a huge super-continent he called Pangaea. As Pangaea broke apart, the continents slowly drifted into their present positions. The theory of plate tectonics now suggests that entire plates of the Earth's crust, including the ocean floor, have migrated to new positions. Some were lost, turned under, in the process and some are still moving. There is strong evidence to support this theory, which is still referred to as continental drift.

Purpose: This activity will help us explore some of the current evidence supporting continental drift.

Materials: pen or pencil, colored pencils or crayons, instructions, continent handout, scissors, construction paper, glue, Earth science reference materials

Procedure:

1. Cut around each continent. Then, using the geologic evidence about the locations of glaciers, rock formations and fossils you will place them together for a close fit. This will count as one form of evidence for continental drift. **Wegener saw the continents as pieces of a puzzle.**

2. Geological features, such as the same type and age of rock formations have been found on various continents. Use the reference materials to determine which continents have the same rocks. This is another form of evidence for the theory of continental drift. Use a black pen or pencil to shade in the areas on each continent that have the same rock formations.
3. By 1900, scientists had established the existence of an Ice Age, over 200 million years ago, which left glacial markings in the form of rows of parallel grooves on several continents. Use your reference materials to determine which continents had glaciers 200 million years ago. This is another form of evidence for continental drift. Use a blue pencil to make parallel lines on these continents.
4. Identical plant and animal fossils have been found on different continents that are now vastly separated and have widely different climates. A fern-like plant called Glossopteris was found on various continents. Use your reference materials to find out where this plant lived. This is another form of evidence for continental drift. Draw a green fern leaf in these areas.

5. Fossils of a small alligator-like reptile called Mesosaurus were found on various continents. Since it was only 18 inches long, it could not have traveled by swimming any great distances. Use your reference material to find out where this animal lived. This is another form of evidence for continental drift. Draw a small red alligator in these areas.
6. When your continents look 'believable' glue them to your construction paper. Make a key or legend just below your map of Pangaea showing the symbols you have drawn and naming the type of evidence that each one represents.

WANDERING CONTINENTS ACTIVITY QUESTIONS

Answer the following questions on a separate paper and turn in with your map.

1. List all the forms of evidence for continental drift that are shown on your map of Pangaea.

2. On most widely separated continents, very different forms of plants and animals developed. When identical fossils are found on two distant continents, what other explanations could be given?

3. THE IDEA OF CONTINENTAL DRIFT IS STILL CALLED A THEORY. DO YOU THINK THE EVIDENCE AVAILABLE IS STRONG ENOUGH TO CALL IT A FACT INSTEAD? EXPLAIN WHY OR WHY NOT?

SEA FLOOR SPREADING MODEL

Objective: The purpose of this activity is to make a simple model that shows the evolution of oceanic crust through sea-floor spreading and subduction.

California State Science Standard:

Earth Science Standard Set 3 – Dynamic Earth Processes

3. Plate tectonics operating over geologic time has changed the patterns of land, sea and mountains on Earth's surface.

Time Required: One 55-minute class period.

Materials: Cardstock or other heavyweight paper

Scissors

Colored pencils

Masking tape

Clear tape

Student Handout

Procedure:

Engagement: Alfred Wegener's ideas were ahead of his time. His was laughed at and ridiculed. The major flaw in his theory of continental drift was that he could not explain *how* the continents moved. So, no one believed him. In the previous activity, we explored evidence that showed that continents have indeed changed their locations several times in the past. The climates and animals on the continents were different than they are today. So, how did it happen? Students discuss different mechanisms for continental movement. Encourage students to explore the magnetic patterns of the rocks on the sea floor. Students discuss what made those patterns. Ask if the patterns on the sea floor have anything to do with the continents moving.

Exploration: Students can make a working paper model that simulates sea floor spreading to help understand the process. After the students finish making the model, they need to use the model to examine how the motion is making the patterns on the sea floor.

Explanation: Guide students in a discussion about the magnetic bands in the sea floor. What type of motion is occurring? Why is the motion occurring? Why does it make the same patterns on both sides of the rift? Will this move the sea floor? Will this move the continents? Why? When do you think it started? Will it ever stop?

Extension: Students use their knowledge about sea floor spreading to give support to the theory of continental drift. Divide the class into teams and assign one team to defend Alfred Wegener's and his views about continental drift. They can be the attorneys for the defendant. Assign the other team to attack Alfred Wegener's views. They will be the plaintiffs. Students can have a court hearing that decides the fate of Alfred Wegener and his theory.

Evaluation: Students turn in completed answers to model questions. Make observations of students during activity, especially the discussion and court hearing.

Notes: This activity was adapted from an activity found on the USGS Learning Web.

A MODEL OF SEA-FLOOR SPREADING

INTRODUCTION: The creation of new sea floor at mid-ocean spreading centers and its destruction in subduction zones is one of the many cycles that causes the Earth to experience constant change.

PURPOSE: The purpose of this activity is to make a simple model that shows the evolution of oceanic crust through sea-floor spreading and subduction.

MATERIALS:

-- paper #1 - Sea Floor Spreading

-- paper #2 - Magnetic Bands

— colored pencils or crayons

— scissors

— transparent tape

— masking tape

PROCEDURES:

1. With a pair of scissors, cut the vertical lines on the Sea Floor Spreading paper so there will be three slits on the paper all the same height and parallel to each other. To reinforce the slits you have made,

place masking tape over each one and re-cut the slit though the tape.

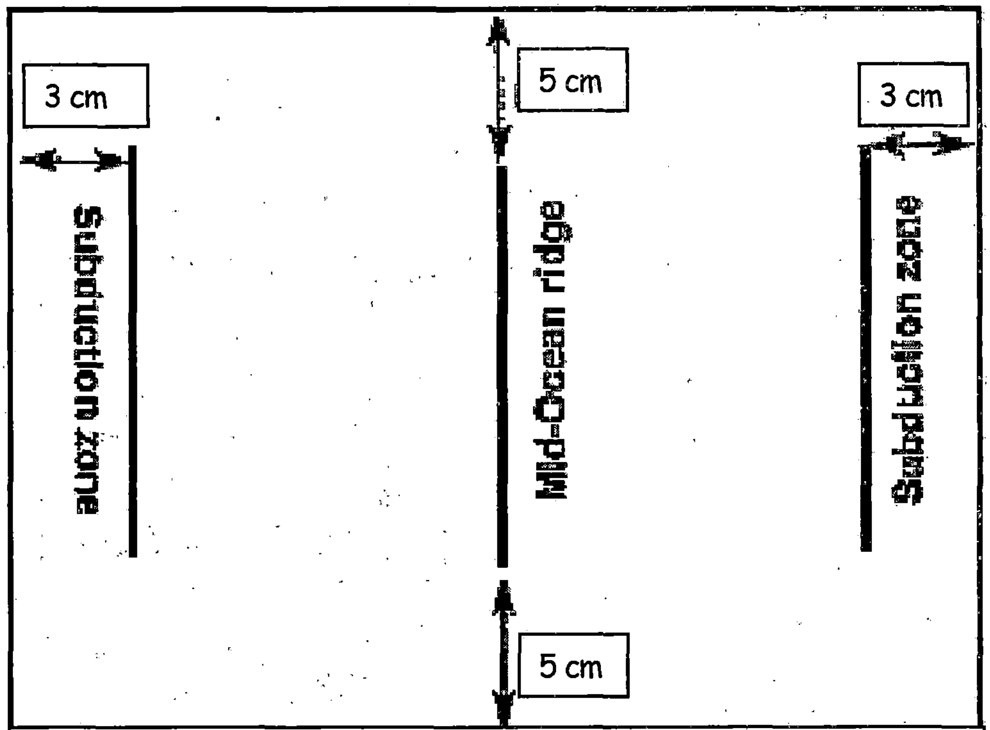


Figure 1: Cut along Heavy lines.

2) On the Magnetic bands paper, color the bands. Choose one color to represent normal polarity and a second to represent reversed polarity. Color alternate bands to represent periods of normal and reversed polarity. Color the band on the far left as reversed polarity.

3) Cut the paper in half parallel to the long edge to get two strips of paper as shown in Figure 2. Mark the bands on each strip with arrows to indicate alternating periods of normal (up arrow) and reversed (down arrow) polarity.

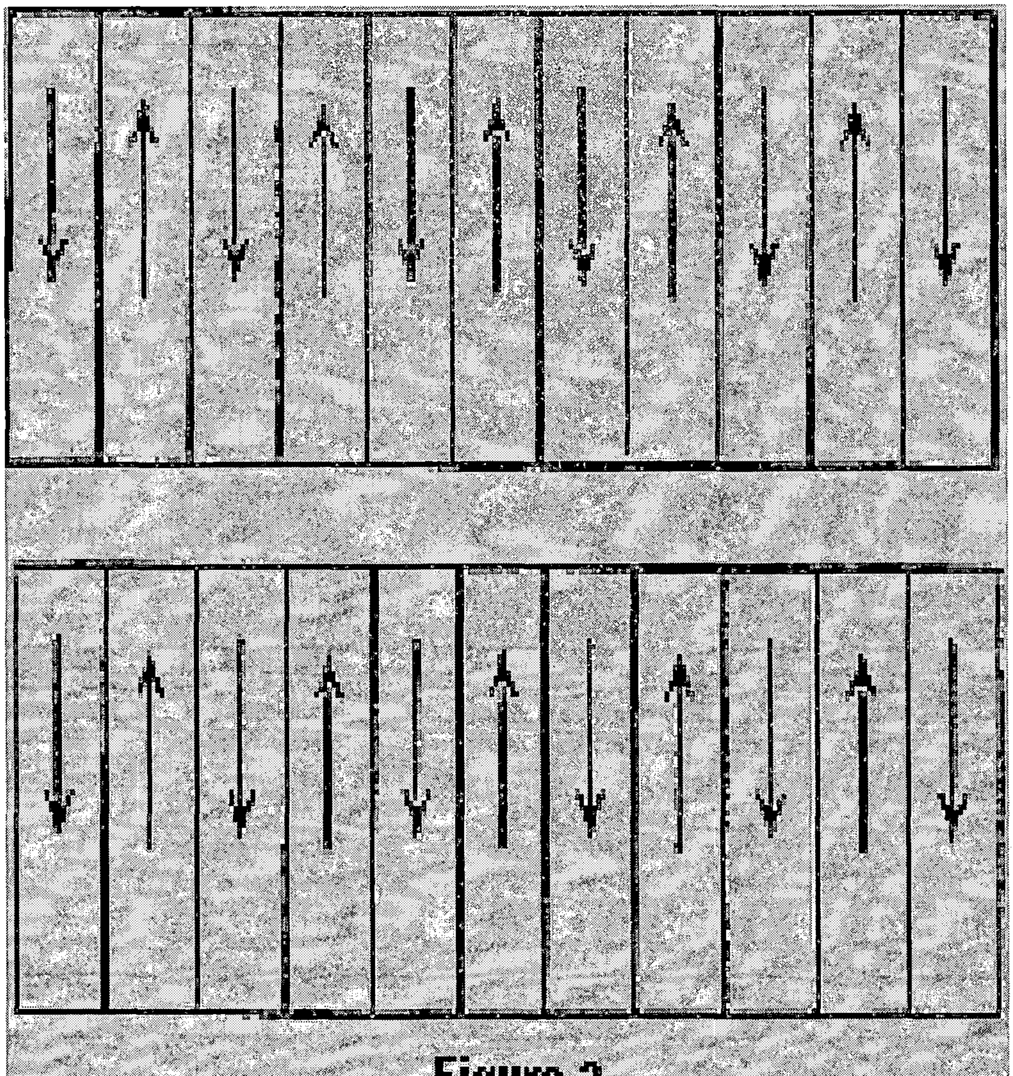


Figure 2.

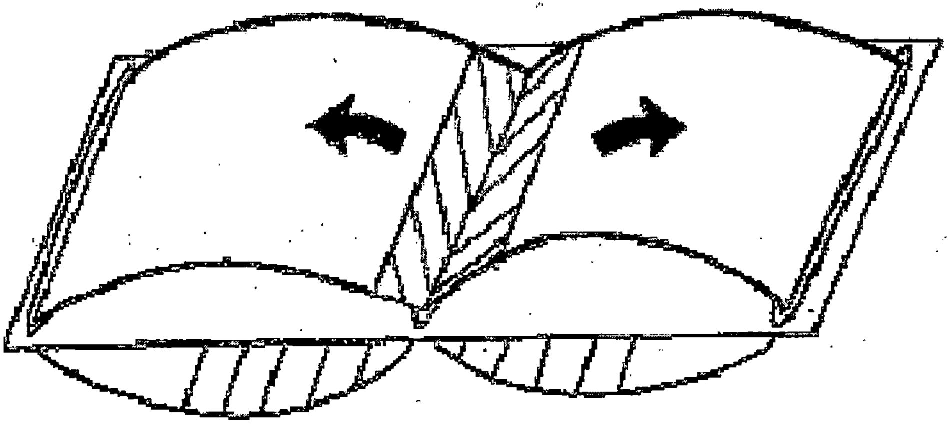


Figure 3.

4) Insert one end of each strip of paper through the spreading center line on your first piece of paper (see Figure 3).

5) Pull each strip of paper towards the slits nearest the margins of the paper (the subduction zones). Tape each strip to make a loop as shown in Figure 3.

6) Circulate the ribbons of paper (which represent oceanic crust) to simulate the movement of ocean floor from the mid-ocean spreading center to the subduction zone. Start the movement of the ribbons with bands representing normal polarity.

<u>**QUESTIONS:**</u> *Answer each question using complete sentences on a separate piece of paper.*

1) Describe the process of sea-floor spreading and how it supports the theory of continental drift.

2) The Earth is about 4.6 billion years old. Based on observations of your sea-floor spreading model, why do you think that the oldest ocean floor is only about 200 million years old?

3) On the real ocean floor, alternating stripes of normal and reversed polarity are not all of equal width. What does this tell you about the lengths of time represented by normal and reversed polarity?

Rock Lab

Objective: To learn to identify rocks based on their physical properties.

California State Science Standard:

Earth Science Standard Set 3 - Dynamic Earth Processes

3c. Students know how to explain the properties of rocks based on the physical and chemical conditions in which they formed, including plate tectonic processes.

Time Required: One-two 55-minute class periods.

Materials: Set of sample rocks for each group: shale, sandstone, conglomerate, granite, obsidian, pumice, basalt, slate, schist and gneiss.

Worksheet Masters: Rock Key

Procedure: Instruct to students use the rock key to identify the rocks. Have the students show you that they can correctly identify each rock. Observe and guide students as needed throughout the activity.

Engagement: Take students on a short "field trip" to search for rocks or have each student find at least one kind of rock from their local area and bring to class. When students bring in their rocks they need to bring a written paragraph that describes where their rock was found. The students should be ready to share their rock and paragraph with the class.

Exploration: Have students place all the rocks on one central table. Students should create categories based on observations of the rocks. They need to briefly write and explain what each category includes and how they came up with it.

Explanation: Be sure to show students many samples of all the different kinds of rocks. Include the rock names so that the students can become familiar with using the rock names. Leave the samples out so that students can examine them. Have them compare their rocks with the sample rocks. Discuss where each rock type came from and the types of conditions that had to be present to create that rock.

Extension: Give small groups of students (3-4) the selected samples of rocks and a copy of the rock key. You may need to remind students how to use a classification key. The students need to examine the samples and then use the rock key to identify and name each sample. The students should work through all of the rock samples and then have the teacher check their work to ensure that each rock is correctly identified. Students with incorrect identifications should be allowed to keep working until they come up with the correct identification.

After each sample has been identified, the students should group the samples into sedimentary, metamorphic and igneous categories. Then they will reexamine the original categories that they created for their rocks. At this point they can make any corrections or modifications they desire. Then, they will come up with a correct identification for their rock.

Evaluation: Students will turn in their Rock Category Paragraph for assessment. These paragraphs should be logical descriptions of their categories and how they were generated. Students are also informally assessed as they are identifying the sample rocks. Teachers must monitor and observe student work and progress as they are working on the identifications. Finally, students will identify their rock based on what they have learned in this lesson.

Rock Key

Step 1.

- rock has crystals..................go to step 3
- rock has particles..................go to step 2

Step 2.

- has clay size particles..............................shale
- has sand size particles..............................sandstone
- has pebble size particles...........................conglomerate

Step 3.

- has microscopic crystals...............................go to step 4
- crystals are visible....................................go to step 5

Step 4.

- dark in color, no layers..............................basalt
- dark in color, has layers..............................slate
- light in color and weight.............................pumice
- glassy look..obsidian

Step 5.

- Variety of minerals .... granite
- Has layers...go to step 6

Step 6

- rock reflects light(sparkles)............................schist
- has black and white bands.............................gneiss

Fault Model Lab

Objective: The purpose of this activity is to make a simple model that shows fault movements.

California State Science Standard:

Earth Science Standard Set 3 - Dynamic Earth Processes

3b. Students know the principle structures that form at the three different kinds of plate boundaries.

3d. Students know why and how Earthquakes occur and the scales use to measure their intensity and magnitude.

Time Required: Two to three 55-minute class periods.

Materials: Scissors

Colored pencils

Ruler

Glue

Worksheet Masters: Student Handout

Fault Model available from

http://www.usgs.gov/education/learnweb/faultmodel.html

Procedure: Students work in pairs. Instruct to students to read and follow the directions carefully. They are making a paper model that will simulate fault movement.

Note: This activity was adapted from an activity found on the USGS Learning Web.

Engagement: Show video clips of actual Earthquakes and the damage that resulted from them. Ask the students if they have ever felt an Earthquake. Discuss what the motion felt like during the Earthquake. Talk about what the movement might have been like in the Earth.

Exploration: Students make paper models that illustrate the motion of the Earth during an Earthquake. Have students do Part I from the Faults Lab handout. This consists of the instructions for building the model. After students have constructed the model do not go on to Part II yet. First the students should manipulate the pieces of the model and determine what types of Earth movements are possible and what happens to the surface. They should also look at what happens to the layers of rock in the ground. Have students take notes on what they see and then demonstrate the types of movements they have discovered.

Explanation: Have the students demonstrate the different ways that motion can occur with their model. Discuss these types of motion and introduce students to the vocabulary associated with each fault type. Students can also use the Internet to research different types of faults.

Extension: Have students do Parts II, III and IV from the Faults Lab handout. They should write their notes and answers in the space provided on the worksheet. You can also have students research the locations of each of these different types of faults in the world. Students can take notes on their research and present their findings to the class. Have students complete the Conclusion questions on the handout and then go over the questions as a class discussion.

Evaluation: Students turn in their completed notes and answers from the Faults Lab worksheet. Make informal assessments of student understanding during the model manipulation and class discussions.

Name____________________ Name____________________

FAULTS LAB

Background: An Earthquake is a sudden movement of the Earth, caused by the abrupt release of strain that has accumulated over a long time. For hundreds of millions of years, the forces of plate tectonics have shaped the Earth as the huge plates that form the Earth's surface slowly move over, under and past each other. Sometimes the movement is gradual. At other times, the plates are locked together, unable to release the accumulating energy. When the accumulated energy grows strong enough, the plates break free. If the Earthquake occurs in a populated area, it may cause many deaths, injuries and extensive property damage. Earthquakes generally occur on faults. We are able to locate and study faults to give a better idea of how to estimate the locations that Earthquakes may occur. There are three types of faults: normal, thrust, and strike-slip.

Objective: To observe fault movements on a model of the Earth's surface.

Materials: Fault Model Sheet (1 per group), Colored pencils, Scissors, Glue, Construction paper, ruler

Exploration: You will work in groups of two.

I. Construct a fault model using the Fault Model Sheet.

a. Color the fault model according to the color key provided.

b. Glue the fault model onto a piece of construction paper.

c. Cut out the fault model and fold each side down to form a box with the drawn features on top.

d. Glue the corners together. This box is a three dimensional model of the top layers of the Earth's crust.

e. The dashed lines on your model represent a fault. Carefully cut along the dashed lines. You will end up with two pieces.

II. Normal Faults.

-Locate points A and B on your model. Move point B so that it is next to point A.

-Observe your model from the side (its cross-section).

1. Draw a sketch of the normal fault as represented by the model you just made.

2. Which way did point B move relative to point A? ________________

3. What happened to rock layers X, Y, and Z? ________________________

4. Are the rock layers still continuous? ____________________________

5. What happened to the river? ____________________ the road? _______

____________________the railroad tracks? _________________________

6. Is this type of fault caused by tension, compression or shearing? _______

III. Reverse or Thrust Fault.

-Locate points C and D on your model. Move point C next to point D on your model.

-Observe the cross-section of your model.

7. Draw a sketch of the thrust fault as represented by the model you just made.

8. Which way did point D move relative to point C? ____________________

9. What happened to rock layers X, Y, and Z? ____________________________

10. Are the rock layers still continuous? ______________________________

11. What happened to the river? ______________________ the road?

___________________ the railroad tracks? _________________________

12. Is this type of fault caused by tension, compression or shearing? _______

IV. Strike-slip fault.

-Locate points F and G on your model.

-Move the pieces of the model so that point F is next to point G.

13. Draw a view of the surface as it looks after movement along the fault.

14. If you were standing at point F and looking across the fault, which way did the block on the opposite side move? _____________________________

15. What happened to rock layers X, Y and Z? _______________________

16. Are the rock layers still continuous? ____________________________

17. What happened to the river? _____________________ the road?

____________________ the railroad tracks? ______________________

18. Is this type of fault caused by tension, compression or shearing? ______

19. If the scale used in this model is 1 mm = 2 m, how many meters did the Earth move when the strike-slip fault caused point F to move alongside point G? ________________________________

Conclusion:

Faults are often found near plate boundaries. Each type of fault is frequently associated with specific types of plate movements. However, you can probably find all types of fault movement associated with each type of plate boundary.

20. Normal faults are often associated with ____________plate boundaries.

21. Thrust faults are often associated with ____________ plate boundaries.

22. Strike-Slip faults are often associated with _________ plate boundaries.

23. What kind of faults would you expect to find in the Himalayas? ________

24. What kind of faults would you expect to find along the Mid-Atlantic Ridge? ______________

25. What kind of fault is the San Andreas Fault? ______________________

Virtual Earthquakes

Objective: The purpose of this activity is to do a computer activity to learn how geologists use data to determine epicenter, intensity and magnitude of Earthquakes.

California State Science Standard:

Earth Science Standard Set 3 - Dynamic Earth Processes

3d. Students know why and how Earthquakes occur and the scales used to measure their intensity and magnitude.

Time Required: One 55-minute class period.

Materials: Computers with Internet access.

Worksheet Masters: Student Handout

Procedure: If possible, each student should do the activity alone. Instruct to students to read and follow the directions on the website carefully. Observe and guide students as needed throughout the activity.

Note: This lab was adapted from the Virtual Lab website maintained by CSU Los Angeles.

Engagement: Ask students "How do scientists measure Earthquakes? How do they know where they are located?" Discuss as a class some of the possible answers. Make a list on the board of the solutions generated by the students during the discussion.

Exploration: Students use a computer and the Internet to visit the Virtual Earthquake website and work through the activities. Students will answer the questions on the student handout. When the students have successfully worked through the activities on the website they will earn a "Virtual Seismologist" certificate. They should print this out and turn in as evidence of successful work on the website.

Explanation: Discuss as a class the information presented on the website about the methods that scientists use to accurately measure and determine the locations of Earthquakes. Ask students about the types of tools and technology that are currently used and how could they make these calculations without the use of technology.

Extension: Students can research recent Earthquakes to find the S-P Interval and Epicenter distance for any Earthquake that interests them. They can use the data to determine on their own the exact epicenter and Richter Magnitude of the Earthquake. Students then compare their calculations to the calculations presented by the scientists.

Evaluation: Students turn in the Virtual Seismologist certificate as a sign of successful completion of the website activities. They should also turn in the student answer sheet that goes with the website. Students present their calculations of the Earthquake of their choosing and how they compared with the scientists calculations.

Virtual Earthquakes Lab Name ____________
Website Address
http://vcourseware5.castatela.edu/VirtualEarthquake/VquakeExecute.html
Please read all instructions and answer the following questions.

1. Why do Earthquakes occur?

2. Seismic waves can be detected by sensitive instruments called _________.
3. Shock waves radiate from their point of origin called the ___________.
4. What two types of waves are we most interested in?

3. Explain how an Earthquake's epicenter is located.

6. What location did you choose for the Earthquake?
7. How do you measure the S-P interval?

8. How do you determine distance from the S-P interval?

Fill in the following table for your Earthquake.

Location	S-P interval (seconds)	Epicenter distance (km)

9. Did you find the epicenter on your first attempt? If not, what do you think is wrong with your data? (click the back button and re-measure your S-P interval and distance)

10. How do you find the Richter magnitude of an Earthquake?

11. What is the magnitude of your Earthquake?
12. Why are three locations used to find the location and magnitude of an Earthquake?

Mt. St. Helens Activity

Objective: The purpose of this activity is to learn about the Ring of Fire, the type of volcanoes found there and specifically study the eruption of Mt. St. Helens.

California State Science Standard:

Earth Science Standard Set 3 - Dynamic Earth Processes

3e. Students know there are two kinds of volcanoes: one kind with violent eruptions producing steep slopes and the other kind with voluminous lava flows producing gentle slopes.

Time Required: One 55-minute class period.

Materials: Video or slide of the eruption of Mt. St, Helens

Topographic maps of Mt. St. Helens before and after the eruption.

Procedure:

Engagement: Show video, video clip or slides of the Mt. St. Helens eruption. Why did the mountain change shape? What more could have been done to warn people?

Exploration: What happened to the shape of the mountain after it erupted? Why did it change? Students build a topographic model of Mt. St. Helens both before and after the eruption. Then they make topographic profiles of both models. You may need to demonstrate what a topographic profile is and what it shows before students attempt the profile of Mt. St. Helens.

Explanation: Students write down an explanation of how the mountain changed shape. Student research the destruction caused by the Mt. St. Helens eruption. Was there a warning system? How did people prepare? Students design an emergency plan that could be used for a town near an active volcano.

Extension: Look at other historic eruptions. What happened to those volcanoes? Choose another volcano and determine its characteristics. If it were to erupt, what kind of eruption would it be? If you were in charge of the communities near the volcano, what type of emergency planning would you do?

Evaluation: Students turn in topographic profiles, explanations and their volcano emergency plans. Informally assess students' knowledge during class discussions.

Note: This activity was adapted from Lines to Landforms Lab Kit sold by Ward's Science.

Star Life Story

Objective: The purpose of this activity is to learn about the life cycle of stars.

California State Science Standard:

Earth Science Standard Set 2 – Earth's Place in the Universe (Stars, Galaxies, and the Universe)

2d. Students know that stars differ in their life cycles and that visual, radio, and X-ray telescopes may be used to collect data that reveal those differences.

Time Required: One – two 55-minute class periods.

Materials: Unlined paper or construction paper
Colored pencils
Student Instructions for Star Life Story

Procedure: Students work individually.

Engagement: What happens to a star when is runs out of fuel? How do stars begin and grow? Do all stars grow the same way? How do stars die?

Exploration: Students will be making a storyboard that illustrates the stages of the life cycle a solar type star and a supergiant star.

Explanation: Show students pictures of different stars at different stages in their life. Lots of great pictures are available from NASA. Go over the processes that occur in the sun and what happens when the elements are used up. NASA has a PowerPoint presentation called the Life Cycles of Stars that is very useful in presenting this information.

Extension: Research other stars nearby our solar system. What stage of life are they currently at? What will happen? Are any new stars near us? Compile research into a presentation for the class. Students can use PowerPoint, transparencies, slides, etc. to give their presentation.

Evaluation: Students will turn in or present their completed storyboard. Evaluate student performance on the presentation to the class.

Star Life Story

Instructions - Write and illustrate (draw) the life cycle of both a solar type star and a supergiant (massive) star.
First, put the following sentences in order for each type of star.
Second, fold your paper so that you have 8 boxes. (Fold the paper in half, then in half again and then in half again.)
Third, Write each sentence in order in the boxes for each type of star.
Fourth, Draw a picture in each box to show what is happening for each sentence. You should have 7 sentences for the solar type star and 8 sentences for the supergiant (massive) star.

SOLAR TYPE STAR

____ Outer layers expand and are expelled forming a planetary nebula
___ A white dwarf is formed.
_1__Gravity pulls Hydrogen together to form a cloud (nebula).
____ Nuclear fusion or hydrogen occurs which causes the star to glow.
____ Nuclear fusion of Helium occurs.
___ A main sequence star, which can live for millions of years is formed.
____ A red giant forms when the star's hydrogen level drops.

Supergiant (Massive) star

____ Iron, which acts as an energy sponge, forms within the star.
____ A supernova occurs.
_1_ Gravity pulls Hydrogen together to form a cloud (nebula).
____ Nuclear fusion or hydrogen occurs which causes the star to glow.
____ Nuclear fusion of Helium occurs.
___ A main sequence star, which can live for millions of years is formed.
____ A red giant forms when the star's hydrogen level drops.
___ If it is massive, a neutron star forms, if it is supermassive, a black hole forms.

Star Trails From a Rotating Earth

Objective: The purpose of this activity is to learn about the position of stars relative to the Earth.

California State Science Standard:

Earth Science Standard Set 1 – Earth's Place in the Universe (Solar System)

1d. Students know the evidence indicating that the planets are much closer to Earth than the stars are.

Time Required: One 55-minute class period and student time in the evening to take pictures.

Materials: Computers with Internet access

Camera

Procedure:

Engagement: Show star trails pictures. Ask students how someone could take a picture like that? What natural forces are at work to make a picture like this possible? Research the Internet to find out how to take star trails pictures.

Exploration: Determine the exact paths the stars take while moving in the night sky. Research the Internet about how scientists know exactly when and where a particular star will be. Students go out at night and look at the stars. They can use a star chart to help them identify stars.

Explanation: Discuss with students how the Earth rotates and why the stars appear to move in the sky. Include a discussion of why Polaris does not appear to move.

Extension: Use a camera to make a star trails picture of your own.

Evaluation: Observations of students during class discussion and research activities. Students turn in their star trails picture.

Carbon Dioxide and Global Warming

Objective: The purpose of this activity is to examine both short term and long-term trends in carbon dioxide concentrations in the atmosphere and identify some of the causes and effects of global warming.

California State Science Standard:

Earth Science Standard Set 4 – Energy in the Earth System

4c. Students know the different atmospheric gases that absorb the Earth's thermal radiation and the mechanism and significance of the greenhouse effect,

Time Required: One 55-minute class period.

Materials: Graph paper

Worksheet Masters: Student Handout

Carbon dioxide and Global Warming article

Procedure: Students work individually. Instruct to students to read and follow the directions carefully. Students need to read the article about carbon dioxide and global warming. Then they will be constructing a graph that shows the patterns of carbon dioxide concentration in the atmosphere over time. Finally, they will be answering the analysis questions.

Engagement: Show pictures of polluted areas, such as LA Basin in the summer, Denver, Las Vegas, and Mexico City. Discuss what might be making the air brown and where it might have come from. Bring up health issues, such as asthma, and environmental issues, such as global warming. Write the notes from the discussion on the board.

Exploration: Students use the carbon dioxide data to make a graph of variations of the carbon dioxide concentrations over a five-year period. Students analyze their graph to determine both short term (yearly) and long term (five year period) trends. They will answer the analysis questions from the worksheet and then discuss their answers in small groups.

Explanation: Ask about the information displayed on the students' graphs. Discuss what this data might show about the condition of the atmosphere. Introduce the students to information about atmospheric composition, structure of the atmosphere and greenhouse effect. Discuss the common gases in the atmosphere and the pollutants that are found in the atmosphere. Ask students to think about why this is a problem and what could they do about it.

Extension: Students research and find recent carbon dioxide data and compare the trends seen in their graph to the recent data. Students can also research the concentrations of other atmospheric gases and pollutants. They analyze this data and examine the trends. Students should do research about ways to reduce atmospheric pollution and then present them to the class.

Evaluation: Students will turn in their graphs, data and answers to questions. Informally assess student understanding during the small group and class discussion. Students will present their research on ways to reduce pollution.

Carbon Dioxide and Global Warming: Background Information

Is the threat of global warming myth or fact? Many observers look alarmingly to the 1980's, a decade of unprecedented warmth, to confirm their fears that global warming is real. Yet a short-term trend such as this can mean very little. What about global temperatures over the long term? As it turns out, long-term studies verify that global temperatures have indeed been increasing, although sporadically, since the turn of the century.

What is causing global temperatures to rise? Many environmental scientists point to the increasing atmospheric concentrations of greenhouse gasses: carbon dioxide (CO2), water vapor (H2O), methane (CH4), nitrous oxide (NO2), ozone (O3) and the chlorofluorocarbons (CFC's). A clear historical link has been established between CO2 concentrations and global temperature change. By analyzing tiny bubbles of air trapped in ice core samples, scientists have learned that, in the past, when atmospheric CO2 concentrations increased so did global temperatures. Periods of markedly low CO2 concentrations correspond to periods of extreme cold (for example, the ice age).

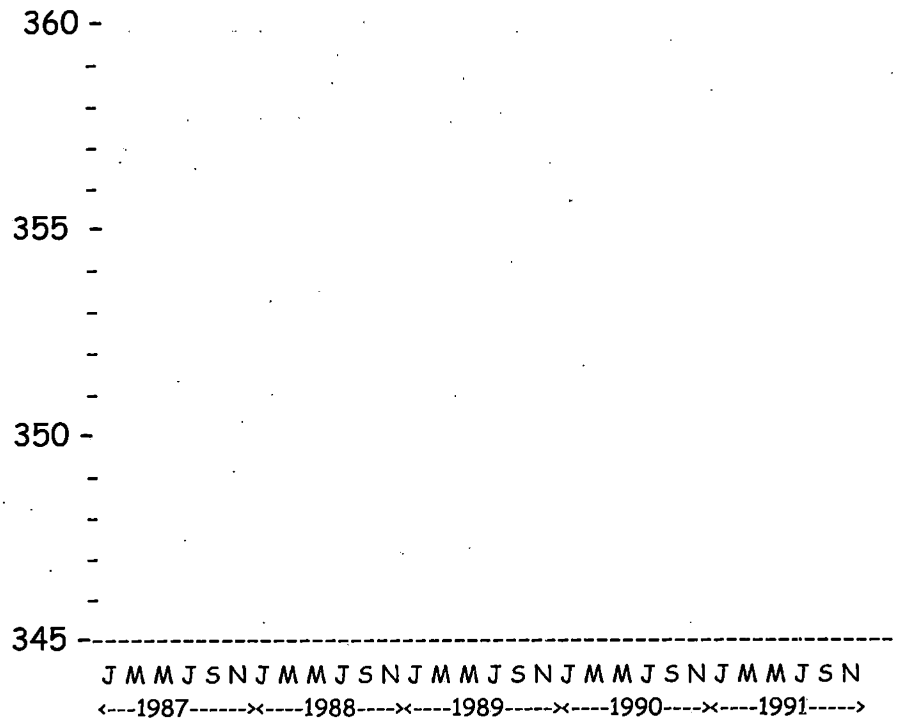
Carbon Dioxide and Global Warming Activity Name ____________

In this lab you will investigate both short term and long-term trends of concentrations of CO2 in the atmosphere and identify some of the causes and effects of global warming.

Graphing

The data in the table below are CO2 concentrations in parts per million (ppm) from 1987 - 1991. Use the data to plot CO2 concentrations as a function of date on the graph. Draw a smooth curve between your data points.

CO2 Concentrations (ppm)					
DATE	1987	1988	1989	1990	1991
January	348.2	350.2	352.7	353.7	354.6
March	349.2	352.1	353.7	355.6	357.1
May	351.9	354.2	355.7	357.1	359.0
July	349.8	352.6	353.8	354.5	356.1
September	346.4	348.8	349.8	351.0	352.2
November	347.7	350.1	351.3	352.7	



Analysis Questions

1. What two patterns of change in CO2 concentrations are evident from your graph? ____

2. During which month of the each year were the CO2 concentrations the highest? ____

3. During which month of the each year were the CO2 concentrations the lowest? ____

4. What effect is the destruction of forests likely to have on atmospheric CO2 concentrations? Explain. ______________________
____

5. What are two ways that the rate of change in atmospheric CO2 concentration could be reduced? ______________________
____

6. If, as predicted, increased concentrations of CO2 in the atmosphere lead to global warming, what might happen to the polar ice caps? __________

7. What might happen to the sea levels? ______________________

8. What might happen to the coastal communities? ______________

Managing California's Water

Objective: The purpose of this activity is to learn about the water resources in California.

California State Science Standard:

Earth Science Standard Set 9 - California Geology

9c. Students know the importance of water to society, the origins of California's fresh water, and the relationship between supply and need.

Time Required: One-two 55-minute class periods.

Materials: Colored pencils

Worksheet Masters: Instructions

Map of California's regions

Map of California's Waterways

Map of California's geologic regions

Road Map of California

Blank or county line map of California

Tracing paper

Procedure: Students will be making a map of California that shows where the waterways, the geographic regions and geologic regions are located. Students should do their drawing on the blank or county line Map of California. They will use the Map of California's regions, waterways map and geologic regions map as a reference.

Notes: This activity was adapted from California Geography developed by the Metropolitan Water District of California.

Engagement: Have students find their city on a road map of California. Ask questions like "Where is the beach from your city? The mountains? Any lakes, rivers, etc?" Ask if they know what the geographic region is where they live. Do they know what geologic features are near their city? Where do they get the water for their city? Write notes from the discussion on the board.

Exploration: Students work in groups of three to complete a map of CA. They will use the waterways, geographic and geologic maps as reference material. Assign one person in each group to be responsible for the waterways, another person for the geographic regions and the third person for the geologic regions. Each person will obtain the required information and transcribe it on the tracing paper. After all the information has been collected, the students will layer their information on the tracing paper over the blank map of California. The students will be able to see the relationship between the waterways, geographic and geologic regions all together on one map.

Explanation: Ask students to explain the information about the different regions, resources and hazards in California. Discuss the history of the water supply in CA and where water comes from for each of the different regions. Discuss the geologic hazards and their locations in CA and what the implications may be for the population of California.

Extension: Students research and find information about CA population. They should put this information on another tracing paper overlay for their CA map. This will show how the population is distributed in CA and the relationship between the population distribution, water and geologic hazards. Students analyze their graphs as a small group. They will discuss and answer the analysis questions in their group and then use their group's answers in a class discussion about California.

Evaluation: Students will turn in their completed map of California with the four tracing paper overlays and their answers to the analysis questions. Informally assess student understanding during the small group and class discussions.

California Maps – Analysis Questions

1. Most of the large rivers within CA begin at what geologic feature?
2. What is the major natural force involved in water movement?
3. What mountain range is Lake Shasta located in?
4. Lake Tahoe and Hetch Hetchy Valley are located in what mountain range?
5. The Sacramento River, Feather River, American River, and San Joaquin River all flow towards the delta, which is located near the city of ____________________.
6. What are the four Southern CA reservoirs that store the water from the California Aqueduct?
7. What two reservoirs does the Colorado River carry water to?
8. Describe where the majority of CA's population is located.
9. How does this relate to CA' water supply?
10. What are the problems associated with this situation?
11. As CA's population continues to increase, what problems will arise regarding water supply, land, and hazards?
12. List at least five possible solutions to the problem.

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