SOIL SCIENCE LESSON PLAN FOR THE CAL POLY LEARN BY DOING LAB

A Senior Project

Presented to

The Faculty of the Natural Resources Management and Environmental Sciences Department

California Polytechnic State University, San Luis Obispo

In Partial Fulfillment

Of the Requirements for the Degree

Earth Sciences; Bachelor of Science

By

Kelsey Ormonde

April 2017

Natural Resources Management and Environmental Sciences

APPROVAL PAGE

ERSC/SS SENIOR PROJECT AGREEMENT

1. Identification of parties:

Kelsey Ormonde, Earth Sciences major

Dr. Christopher Appel, faculty advisor
Natural Resources Management and Environmental Sciences department
California Polytechnic State University, San Luis Obispo

2. Identification of project (topic/subject & tentative title):

Soil Science Learn by Doing Lab

3. Agreement summary:

Kelsey Ormonde agrees to prepare a literature review focused on soil science education. Ormonde will also prepare a lesson plan to be utilized by the Learn by Doing Lab (LBDL) Program on the topic of soil science. Ormonde has registered for ERSC 461/462/463 and will accomplish work during winter quarter 2016, following the attached timeline. Upon satisfactory completion, Professor Appel will submit appropriate grades for this work and the NRES department will consider the senior project requirement fulfilled.

4. Conditions:

a. *Work to be performed:*

(1) Project purpose, objectives, and relevance to planning:

The purpose of the senior project was to develop a lesson plan to educate 5^{th} – 8^{th} grade students about soil science. Cal Poly's Learn by Doing Lab specializes in teaching various scientific topics and fields to elementary – middle school age students from all over California. Although the program was overseen by Cal Poly professors, the majority of activities, demonstrations, experiments and teaching was accomplished by Cal Poly students. The LBDL course (SCM 302) offered Cal Poly students the opportunity to experience teaching middle school age students using interactive experiments in STEM fields.

The project objectives were to 1) conduct a literature review of published papers focused on soil science education, teaching, enrollment trends, and employment to provide the necessary

background information to assist with the development of the lesson plan, and 2) to create a LBDL lesson plan about soil science.

Our Soils are a vital natural resource, and will continue to be so if managed sustainably. A LBDL focused on soil science is a great opportunity to educate students about soils and hopefully spark their interests in this little known field of science.

(2) Approach or method, including information sources:

The approach for this senior project was a case study in written form.

The information was obtained from the online journal resources provided by the Cal Poly Robert E. Kennedy Library, the Soil Science Society of America website, as well as course materials from soil science classes taken by Ormonde.

(3) Major headings, tentative chapter outline:

- Literature Review
    - Recent enrollment trends indications
    - How to increase interest and awareness in the field of soil science
    - What are methods currently being implemented in classrooms to teach soil science
- LBDL Soil Science Lesson Plan
    - What is Soil Science?
        - Define soil science
        - Include interactive demonstration
    - 3 disciplines of Soil Science
        - Physical
            - Interactive activity with soil texture
        - Chemical
            - Interactive experiment with soil filtration
        - Biological
            - Discuss soil macro and micro organisms
            - Prepare “worm terrariums” with students

b. *Considerations:*

(1) Work program schedule, progress report schedule, including due dates (to establish a

basis for grades):

Project Timeline for March 2016

Week	**Date**	**Tasks**
1	2/29-3/4	• Prepare Senior Project Agreement • Review Senior Project Agreement with faculty advisor
2	3/7-3/11	• Review research materials previously collected • Begin writing literature review • Begin developing lesson plan
3	3/14-3/18	• Finish writing literature review and lesson plan • Submit draft of senior project for review to faculty advisor • Revise senior project as needed and submit completed project

(2) Product (format):

8 ½ x 11 printed report

(3) Support services (e.g., use of laboratory, library, photographic equipment, data processing):

Access to desktop with Microsoft Office Suite

5. Signature of parties:

a. _____

student date

b. _____

faculty advisor date

ACKNOWLEDGEMENTS

Thank you, Natural Resources Management and Environmental Sciences Department, for allowing me the opportunity to study Earth Sciences and completing my project. I would not be where I am today without your help and support. I cherish my experiences and everything I have learned from my professors and the staff.

Special thanks to my advisor, Dr. Chip Appel for providing essential guidance for my major and my senior project. Thank you for your patience and understanding.

Thank you, Dr. Karen Vaughan, for helping me with picking a topic for my senior project and inspiring me to continue my education.

Thank you, Dr. Seth Bush, for your input and assistance with this project. May this report be of use to you for future Learn By Doing Labs.

Thank you, Dr. Thompson, for agreeing to be my secondary advisor. I appreciate all of your help and guidance.

Thank you, Paula, for helping me realize the importance of my project and encouraging me to pursue it further.

Thank you to my friends and family who supported me through the process of completing this project.

ABSTRACT

To increase interest in soil science and other related sciences, educational materials need to be tailored to appeal to younger students. The purpose of this project was to create a soil science lesson plan that could be utilized by the Cal Poly Learn By Doing Lab. Information from several articles, textbooks, lesson plans, and websites was reviewed to create a soil science lesson plan for students in 5-8th grade. The lesson plan focused on the three sub-disciplines of soil science; physical, chemical, and biological. Activities were created to correspond to the three sub-disciplines. Alternate activities were created to allow for substitutions. The concluding activity incorporated the three sub-disciplines by discussing the important processes soil provides for life on earth. The lesson plan was written to be educational, but also entertaining for students and teachers.

TABLE OF CONTENTS

LIST OF TABLES AND FIGURES

CHAPTER 1

INTRODUCTION

The purpose of this senior project was to develop a lesson plan to educate 5^{th} – 8^{th} grade students about soil science. Cal Poly's Learn by Doing Lab (LBDL) specializes in teaching various scientific topics to elementary through middle school age students from all over California. Although the program was overseen by Cal Poly professors, the majority of activities, demonstrations, experiments and teaching was accomplished by Cal Poly students. The LBDL course (SCM 302) offered at Cal Poly gives students the opportunity to experience teaching to middle school age students with interactive experiments in STEM fields.

The project objectives were to 1) conduct a literature review of published papers focused on soil science education, teaching, enrollment trends, and employment, and 2) to create a soil science LBDL lesson plan.

Our Soils are a vital natural resource, and will continue to be so if managed sustainably. A LBDL focused on soil science is a great opportunity to educate students about soils and hopefully spark their interests in this little-known field of science.

OBJECTIVES

- Educate 5^{th}-8^{th} grade students about soil science through interactive experiments
- Complete a literature review focused on articles discussing soil science education
- Write a soil science lesson plan for Cal Poly's Learn by Doing Lab
- Complete the senior project to fulfill the requirements for the B.S. Earth Sciences degree

CHAPTER 2

LITERATURE REVIEW

Introduction

Soils are a resource upon which every human being depends. However, the scientific discipline of soil science is a relatively new field, dating back to the late 1800s. Not only is soil science a distinct field of science, it is also inter-disciplinary. This created a problem for soil science in the academic and professional worlds, where it has been absorbed into other fields and professions. To keep soil science current with the ever-changing world of academics, updates needed to be utilized. The changes included adopting new teaching styles, educating the public in an entertaining and informative way, creating interactive teaching programs for primary school students, updating university programs to reflect the qualifications employers are looking for, and shifting the academic field from agricultural to environmental (Brevik et al, 2014).

History of Soil Science: Education

The academic history of soils is relatively short, but full of changes. Unlike other scientific disciplines dating back hundreds of years, soil science university programs were first established during the late 1800s, when the United States government began to conduct soil surveys. Scientists were hired to complete the surveys, though they lacked the necessary training. The demand for scientists with knowledge of soils prompted the formation of soil science programs at universities such as the University of North Carolina and Earlham College. One of the first soil science textbooks in the United States, *Soils, Their Properties and Management* was

written by T. Lyttleton Lyon, Elmer O. Fippin, and Harry O. Buckman in 1909 (Brevik et. al., 2014).

As the study of soils at the university level grew, liberal art schools that had helped start soil science programs were replaced by agricultural colleges and land grant universities. Land grant universities were created by the Morrill Act of 1862. These universities received federal funding to provide the working class practical education on agriculture, engineering, and military arts (Brevik et. al., 2014).

During the 20th Century, soil science became a standalone academic discipline, and was associated with land grant universities. Today, most soil science departments have been hybridized with other related programs, such as agricultural and environmental management, environmental sciences, and forest resources. About 5% of the universities offering a soils degree have a department strictly for soil science. The wide variety in names of departments indicated a strength and weakness of the discipline; soil science was interdisciplinary and could contribute to other fields, however this could also allow for it to become absorbed into related fields (Brevik et. al., 2014).

Interestingly, there was a decline in enrollment in soil science since the 1980s to the mid-1990s. However, since 2005, enrollments have increased. The increased interest in the field is promising, though the concern was how to retain interest in the future. Professors, universities, as well as the Soil Science Society of America (SSSA) researched what caused a drop in enrollment and methods to increase interest in soil science (Brevik et. al., 2014).

Enrollment Trends in Soil Science Programs

Enrollment trends in the past 20 years have dropped. In more recent years, however, enrollment has increased. A survey conducted by the Soil Science Society of America (SSSA) in 1992 with a follow-up in 2004 showed over 80% of the universities that participated experienced a decline in soil science students. Soil science enrollment data between the academic years of 2007-2008 through 2013-2014 at 14 colleges was analyzed by Dr. Brevik and his co-authors to determine if enrollment numbers were increasing or decreasing. The results were encouraging with a 46% increase in undergraduate enrollment and a 50% increase in graduate program enrollment. SSSA student membership has also increased, further supporting the determination of increasing student numbers in soil science in the United States. Additional evidence outside of enrollment supports the increased interest in soil science, such as a rise in global studies including soil science, the United Nation's declaration of 2015 as the International Year of Soils, and increased soils publications (Brevik et. al., 2014).

To find out the cause of the decrease in enrollment, surveys were conducted by the SSSA and Economic Sciences Research Center at Washington State University in 2008. The objectives of the surveys included enrollment trends, career opportunities, issues in soil science education, and faculty. The three target groups of the surveys were current undergraduate, graduate and recent graduates in soils programs, college departments, and employers in the United States and Canada (Halvin et. al., 2010).

Student Input

The majority of student responses (81%) were graduate students. That may have skewed the results of the survey in favor of pursuing a career in soil science due to masters programs' specific focus of soil science as opposed to the broader undergraduate programs that could be

more or less related to soil science. Responses to the survey provided interesting insight on how students, faculty, and professionals view soil science (Halvin et. al., 2010).

The main reasons students were drawn to the major were classes and projects in college, previous experience working in agriculture, professor-suggested, or a class or project during or before high school. Student interest in soils programs increased after completing soil science courses. The results suggested the best method to increase interest in soil science would be to offer courses that complement other majors, as well as attract students who are undeclared. Furthermore, the lack of soil science education in primary schools suggested that including soil science and related disciplines in K-12 may increase interest. Students also chose more contemporary majors when asked about employment fields, such as environmental science, land management, and agronomy (Halvin et. al., 2010).

The survey results suggested that the discipline needs to develop an environmental focus, instead of mainly agricultural. The survey also indicated several areas for improvement, including difficulty in finding a job, updating soil science's image to the public, finding ways to better engage younger generations in soils, and the imperative role of soil judging for field experience (Halvin et. al., 2010).

Department Input

The department respondents had a different view of the soil science discipline when compared to the student respondents. Most responded that enrollment had not significantly changed in the past 10 years, nor would it likely change in the next 10 years. Department respondents also indicated that job opportunities had increased in the past 10 years. In contrast to the college departments, students seemed to predict a decline in enrollment if soil science continued to be associated with agriculture (Halvin et. al., 2010).

Employer Input

Employer respondents differed from college departments, and indicated that it will be more challenging to find trained soil scientists in the future. This response suggested a lack of effective communication between the needs of employers and the training and education offered by university soil science departments. When compared to other disciplines, soil science was viewed as part of the responsibilities of professionals, as opposed to a separate expertise. Employers seemed most concerned with the association of soil science with traditional agronomy and the lack of marketing for licensing and certification (Halvin et. al., 2010).

Solutions

Several associations in and outside the United States have made efforts to promote and retain interest in soil science. A group of faculty from Australian universities concluded that soil science was a unique discipline, and requires teaching methods that were tailored to the discipline. After a survey and several cycles of review, 11 teaching principles were developed for soil science education. The principles were a mix of generic and discipline-specific, and were explained in detail in Field's article. The teaching principles included uniqueness, fieldwork, jargon, active learning, connections, systems, communication, authentic problems, feedback, assessment, and outcomes (Field et. al., 2011).

Starting in 1994, the SSSA teamed with the Smithsonian Institute to develop an interactive soil science exhibit aimed at teaching the general public about the importance of soil science in a non-traditional setting. Throughout the planning process, several lessons were developed to aid those in the future who may undergo a similar educational project. In order to complete the massive undertaking of developing an exhibit for the Smithsonian as well as a traveling exhibit, persistence, flexibility, planning economically, willingness to compromise, and

thinking outside the box were necessities. In 2008, the "Dig It! The Secrets of Soil" exhibit opened at the Smithsonian NMNH. After two successful years at the museum, the exhibit was closed and reopened as a traveling exhibit until 2014. In preparation for the future of soil science and the SSSA, six goals were created to maintain and increase interest in the field. The goals were to embrace the public, strong branding of the SSSA with soil science, expand the political presence of soil science, branch out to related disciplines and scientific associations, rethink delivery of soils information, and develop a leading think tank on soil (Drohan et. al., 2010).

In the civil engineering discipline, David Elton created an educational program called *Soils Magic*. Alike to the decrease in interest and enrollment in soil science during the late 1990s and early 2000s, civil engineering experienced a similar decrease. Elton focused capturing the interest of students from kindergarten through 12th through interactive civil engineering experiments. His efforts served two purposes: encouraging students to study math and science in elementary school, and encouraging students to pursue engineering in college. Elton worked with several K-12 teachers and designed the experiments in *Soils Magic* to be simple, low cost, and quick setup time. Elton found his experiments worked well with middle school students, and by keeping the activities short was able to capture their attention for the duration of the activities. Allowing students to participate in the experiments or assist with testing were also effective in teaching the concepts or objectives of the activities. Feedback from teachers was positive; many felt the program was more interactive and entertaining than conventional methods used in laboratory classes (Elton et. al., 2006).

Conclusion

When compared to other scientific disciplines, soil science is relatively new. Over the past century, the discipline has gone through several changes as the needs and requirements of

academics and professionals in the field have changed. The study of was created from the government's need for soil scientists to complete surveys in the late 1800s. In the academic realm, soil science began at a handful of liberal arts universities. Soil science shifted to an agricultural focus when land grant universities began to offer soils programs. Today, this small niche has grown into the inter-disciplinary field of soil science. To help keep soil science a distinct discipline, several surveys of faculty, students, and professionals have been conducted. The results of these surveys showed a disconnect between what universities require of soil science students, the expectations of students and what the professional world required. Enrollment in soil science programs peaked during the 1980s and declined until the early 2000s. In response to the declining enrollment, universities merged soil science into related departments, or stopped offering soils programs. Although soil science has been strongly associated with agriculture in the past, the discipline has shifted to an environmental focus. In response to several surveys, solutions to increase enrollment in soil science and the public's awareness of the scientific field have been developed. These included developing new teaching styles specific to soil science, creating the interactive soils exhibit, Dig It! The Secrets of Soil at the Smithsonian Museum of Natural History, updating university programs to include professional qualifications, and including soil science in primary school education. In order for soil science to remain a distinct discipline in the future, a balance needs to be made between the requirements in academic and professional fields. Increased efforts to educate the public about soil science will also help increase interest in the scientific field.

CHAPTER 3

LESSON PLAN

LBDL Soil Science Lesson Plan

- Introduction
    - Interactive demonstration with different organic and inorganic components of soil
- 3 sub-disciplines of Soil Science
    - Activity 1: Physical
        - Interactive activity with soil texture
    - Activity 2: Chemical
        - Interactive experiment with soil filtration
    - Activity 3: Biological
        - Discuss soil macro and micro organisms
        - Prepare “worm terrariums” with students
- Closing Activity
    - Ecological processes soil provides that are vital to our lives

ACTIVITY BOOKLET

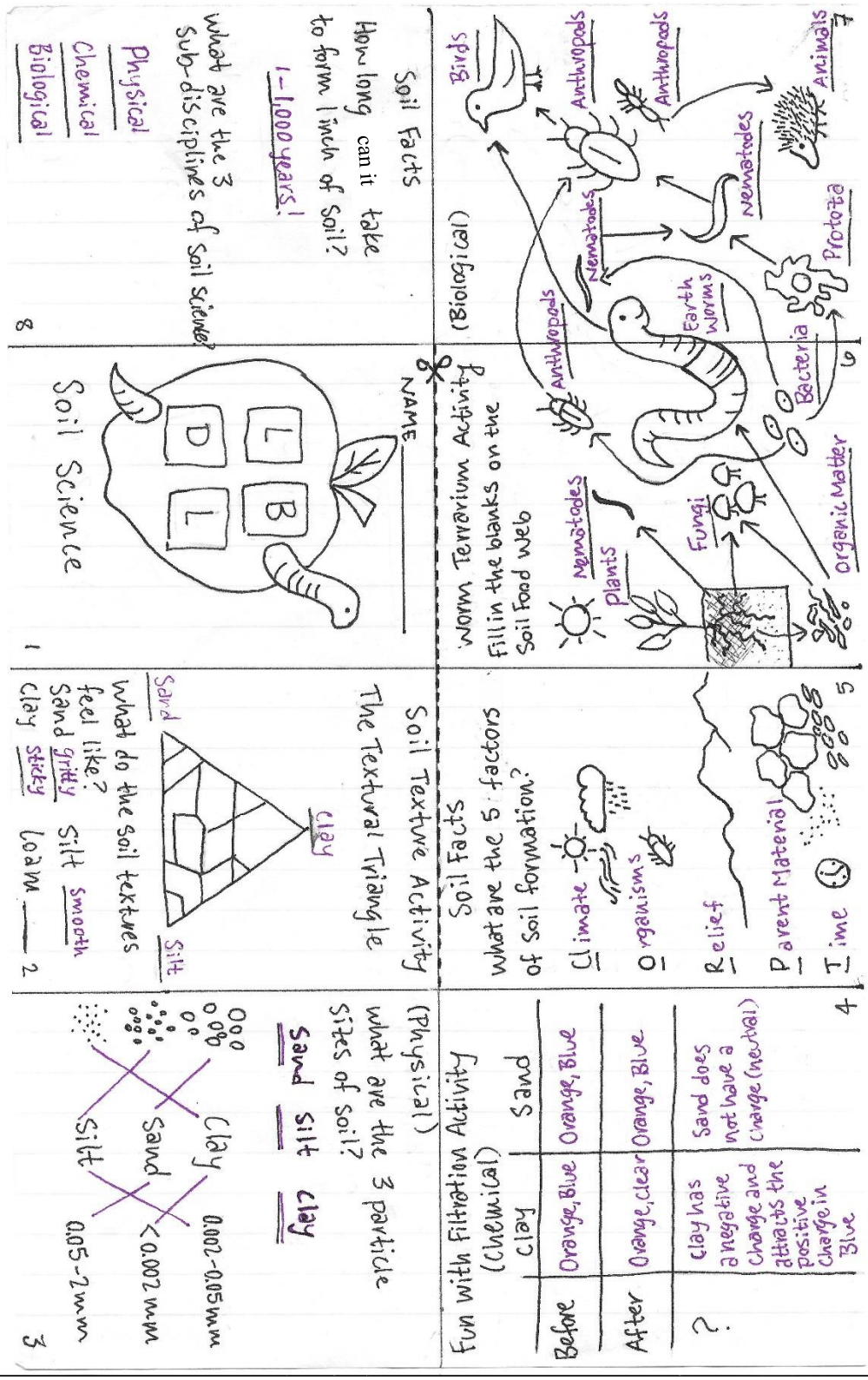

Figure 1 - Soil Science LBDL Activity Booklet (Ormonde, 2017).

Please Note:

- Cut the paper along the dotted line, and fold along the solid lines to make a booklet
- The pages of the booklet correspond to each activity (physical, chemical, and biological)
- The answers to the fill-in questions are written in purple

ACTIVITY 1 - INTRODUCTION

Title: What Am I?!

Figure 2 - Root Hairs (Nielsen, 2013).

Learning Objectives/Brief Description:

- Introduce the lesson to students via a guessing game of what they think they are looking at
- Introduction to the lesson/general definition of soil
- Three main components of soil; physical, biological, chemical

Activity Booklet Pages: N/A

Duration: 5 minutes


Figure 3 - Fungus (Fleming, 2014).

Materials Needed:

- Microscope
- Projector
- Soil samples with interesting features such as:
    - Root hairs/fungi
    - Soil macro-organisms
    - Organic matter vs inorganic matter
- Samples that represent the different components of soil
    - Rocks, minerals, humus, water, etc.


Figure 4 – Soil Humus (California Quarry Products, 2017).

- Biological components

Setup Procedure:

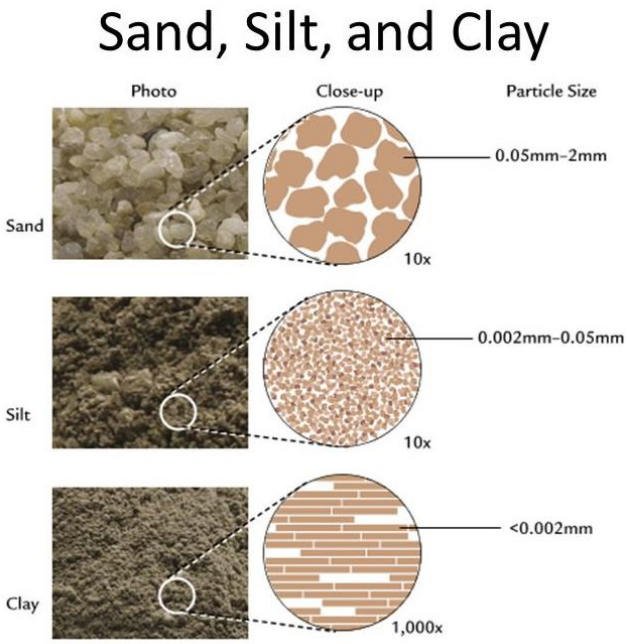

Figure 5 – Magnified illustration of particle sizes (RainMachine, 2017).

1. This experiment should be set up before the students enter the room to help keep the element of surprise.

2. Separate each specimen into containers. Line up containers to enable specimens to be swapped out easily from the microscope.

Operation of the Activity/Experiment:

1. Welcome and introduce the students to the Learn By Doing Lab. Allowing students to participate, ask them, "what do these things have in common?" Let them make a few guesses, offer hints if needed to help guide them to the right answer-soil! Explain that all the specimens are different components of soil, the stuff below our feet. Explain that the lab will be about the three main components that make up soil (physical, chemical, biological). Ask the students what they think soil is. Define soil as a mix of minerals, gases, liquids, organic matter, and organisms that support our lives on Earth.

Figure 6- Earthworms (Edwards, 2017).

2. After the introduction, hand out booklets, and divide students into 3 groups.

Notes/Helpful Tips:

- Capturing the student's attention can be difficult at times. Do your best to show enthusiasm in the introduction, and they'll be hooked! Having a few interesting facts about soil can help as well.

Figure 7 - Root nodules containing rhizobium bacteria (Temple, 2017).

ACTIVITY 2 - PHYSICAL

Title: Soil Texture (Physical)

Learning Objectives/Brief Description:

Figure 8 - Making a soil ribbon (Slide Share, 2011).

- Students will learn about the physical properties of soil including:
    - Soil texture
    - Particle size
- students will learn about soil texture by texturing different samples
- Make the connection on why soil texture is important for water filtration and storage.

Activity Booklet Pages: 2-3

Duration: 15 minutes

Materials Needed:

- Soil samples
    - Sandy soil (sandy loam or loamy sand)
    - Silty soil (silt loam)
    - Clay (clay loam or clay)
    - Loam
- Spray bottles
- Water and squeezable pray water bottles
- Mortar and pestle
- 2-mm sieve
- Soil texture triangle poster
- Newspaper print roll or old newspapers

- Paper towels
- Hand broom and dustpan

Setup Procedure:

1. Cover lab tables with newspaper print or any paper to help keep surfaces clean.

2. Place the tubs of soil so they have enough space in between to allow multiple students to reach them (or use separate tables if there's enough room). Label the samples with numbers 1-3, and the loam as "Goldilocks."

3. Place paper towels, hand brush and dustpan, and any other materials nearby for easy cleanup.

Operation of the Activity/Experiment:

1. Introduce the activity and separate the students into 3 groups; one for sand, one for silt, and one for clay. Leave the actual textures a surprise until after the students have textured all the samples. Explain the texture triangle and what it represents. For example, relate the fibers that make up fabrics; like the many different textures of fabrics, there are also many different textures of soil (12). Explain how particle size affects soil texture (the smaller the particle, the smoother the texture, etc.).

2. Have each student start with a small handful of soil. Add water slowly, and knead the soil in your hand until the water is absorbed. Add more water if the sample is too dry, or add more dry soil if it's too saturated. The soil should have a putty-like consistency; sand will not adhere easily as opposed to the silt and clay.

3. Ask the students to describe the how the soil feels; is it sticky, smooth, gritty etc. Help students fill out answers in the corresponding pages of the activity booklet. Ask what sample corresponds with what texture on the texture triangle. Ask students which sample they think will hold the most water (clay). Which soil will allow the most water to move/percolate through it (sand)?

4. Switch between the three soil samples, and compare their similarities and differences. Ask the students which particle size corresponds to which of the three samples they worked with. Once all three groups have handled the different soil samples, bring out the "Goldilocks Soil." Have each student work up a sample, and guess what they think the texture is (it's a mix of all three!). Make the connection between the perfect mix of the loam, and why it is the "Goldilocks Soil" (it's the most ideal for growing plants; doesn't drain too quickly or too slowly, holds nutrients well, doesn't get too compacted, etc.).

Variation:

Challenge the students to a ribboning contest. With a moistened soil sample, form it into a ball in the palm of your hand. Squeeze the ball between your thumb and forefinger to make a ribbon; see Figure 7 for making a soil ribbon. See which soil makes the longest ribbon, and who can make the longest ribbon.

Notes/Helpful Tips:

- Texturing soil can be rather messy, especially with young students and you may want to do it outside. Having a hand washing station nearby (or a bucket full of warm water for rinsing and dipping hands into), or aprons/lab coats can help minimize the mess.

- The soil textures do not necessarily need to be entirely one particle size (for example, pure clay). Consult the soil textural triangle in the Appendix for similar textures of the samples you plan to include in the activity.

Figure 9 - Mortar and pestle (UnidanX, 2016).

- Depending on the soil samples used, they may need to be ground down with a mortar and pestle and passed through a 2-mm sieve. See figures 9 and 10 for photos of a mortar/pestle and sieve. Use the finer particles that passed through the sieve for texturing. Save the coarser particles that did not pass through the sieve for the soil chemistry activity. Grinding soil and using a sieve is easy, and can be a fun addition to texturing for students.

Figure 10 - 2-mm sieve (Ormonde, 2017).

ACTIVITY 3 - CHEMICAL

Title: Fun with Filtration (Soil Chemistry)

Learning Objectives/Brief Description:

- Educate students on the importance of soil filtration
- Define cations and anions

Materials Needed:

- 50 mL graduated burettes
- Funnels
- Cheese cloth or Coffee filter/filter paper
- Eosin Yellow solution (negative charge)
- Methylene Blue Solution (positive charge)
- Deionized Water
- 2-mm sieve
- Mortar and pestle
- Containers for holding the soil (100 mL)

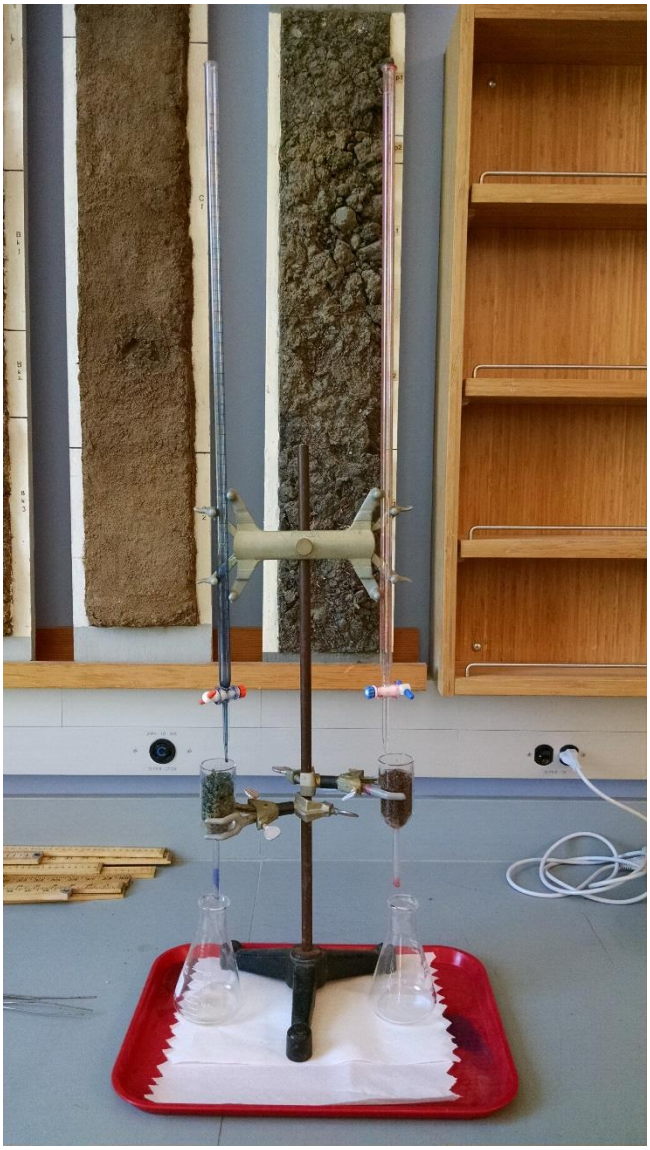

Figure 11 - Lab equipment set up (Ormonde, 2017).

- 2 containers for collecting the filtrate (100 mL)
- Stands
- Soil with a clayey texture and good structure
- Sand (optional)

Activity Booklet Page: 4

Duration: 15-20 minutes

Setup Procedure:

Figure 12 - Eosin Y as a solid (Sololewski, 2017).

1. Setup the experiment before the activity. Fix the 50 mL graduated burettes and funnels to the stands, and place a 100 mL beaker under each. Have the solutions off to the side and ready for the experiment.

Figure 13 - Glass funnel with clay soil (Ormonde, 2017).

2. Pass the clay soil through a 2-mm sieve. The coarser particles that don't pass through the sieve (approximately pea-sized) work well for this experiment. Save the finer particles for the soil texturing activity.

3. For the sand soil sample, use a texture similar to beach sand that is fairly uniform with little to no impurities. Including sand in the experiment is optional.

4. Line the bottom of the funnel with cheese cloth or filter paper (or a coffee filter) and add soil. Leave space at the top for the solutions to sink in. See Figure 13 for a funnel filled with soil.

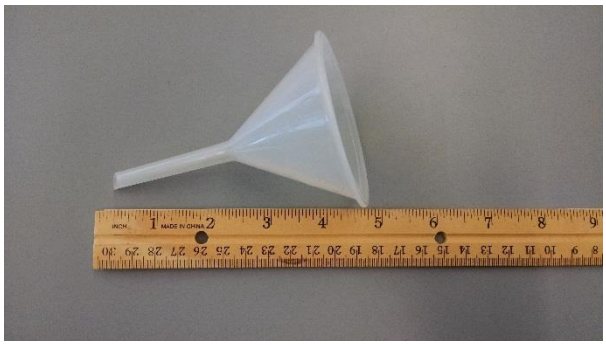

Figure 14 - Funnel (Ormonde, 2017).

5. Moisten the soil until saturated with water before leaching to help expedite the process.

Operation of the Activity/Experiment:

1. Introduce the activity to the students. Explain how the experiment works. Ask each student to observe the solutions, and write down the color (orange and blue).

2. Begin with the clay soil, since the change is more noticeable. With two of the graduated burettes and funnels ready, begin pouring the Eosin Yellow solution on the soil until it is saturated. Add more as necessary, and the leachate should begin to collect in the beaker below. Ask the students to watch closely. Write down the color of the leachate, and if they noticed any changes (shouldn't be any).

Figure 15 - Methylene blue in aqueous solution (Wikipedia, 2017).

3. Use the second unused leaching tube for the Methylene Blue solution. Pour the solution over the soil until it is saturated, and begins to filter out leachate into the beaker below. Add more solution as needed to produce an observable amount of leachate, this may take a few minutes.

4. While the soil is filtering the solutions, explain the basics of what is happening. Like everything that surrounds us, soil is made of atoms and molecules. Molecules, which are

made up of atoms, can have a positive or negative charge, like a magnet. The clay has molecules with a charge, as does the solution. After enough leachate has collected, ask the students what colors they see. The blue from the Methylene blue solution has been filtered out, but why not the Eosin Yellow?

5. Ask the students to guess why, and help guide them to the answer. The solutions have different charges, and the opposing charge is attracted to the clay and is filtered out. Since the Methylene Blue has a positive charge, and the clay has a negative charge, it sticks to the clay like a magnet and is filtered out. Since the Eosin Yellow has a negative charge, it is not filtered out by the clay. This experiment is a basic example of how soil can filter out pollutants and fertilizers that have negative charge (e.g. nitrate NO_3^-) that can get into groundwater and contaminate it.

6. With the remaining two graduated burettes, run the experiment again with the samples of sand. The solutions will move through the sand much quicker than the clay. Ask the students if there was any change in color (there shouldn't be). Explain that the sand does not have a charge like the clay, and therefore will not filter out the colors.

7. Conclude the experiment by making the connection between fertilizers. Nitrate pollution of groundwater is a concern in areas near farms because it cannot be filtered out by the soil. Soils also can only filter out so much pollutants, like a sponge that can only hold a set amount of water. That's why it is important to know what type of soil crops are grown on, and how much fertilizer to use.

Variation:

See the Soil Filtration Activity in the Alternate Activities Section The alternate activity uses grape Kool-Aid instead of the harder to obtain Eosin Y and Methylene Blue.

Notes/Helpful Tips:

- If time is limited, the experiment can be conducted with the clay soil, instead of both the sand and clay soils. Sand was included to show that soils can have different charges.
- Depending on the soil samples used, they may need to be ground down with a mortar and pestle and passed through a 2-mm sieve. See figures 9 and 10 for photos of a mortar/pestle and sieve. Grinding soil and using a sieve is fairly easy, and can be a fun addition to texturing for students.
- For safe handling of Eosin Y and Methylene Blue, see the MSDS in the Appendix.

ACTIVITY 4 - BIOLOGICAL

Title: Worm Terrariums (Soil Biology)

Learning Objectives/Brief Description:

- Educate students on the importance of the biological components of soil via a worm terrarium

Materials Needed:

- Empty plastic soda containers (preferably 16 ounces and clear plastic)
- Potting soil
- Sand
- water
- Construction paper
- Glue
- Drawing/painting materials
- Plastic wrap
- Scissors
- Dried organic matter (hay or straw, leaves, sawdust, etc.)
- Worms

Figure 16 - Rinsed soda bottles (Hillbilly Jillies, 2009).

Activity Booklet Pages: 6-7

Duration: 15-20 minutes

Setup Procedure:

1. Rinse out the plastic containers and cut off the top about 2 inches.

2. Fill the containers with alternating layers of potting soil, sand, and dried organic matter (give some examples of what to use). Leave roughly 1 inch of space at the top.

Figure 17 - Terrariums with soil, organic matter, and worms (Hillbilly Jillies, 2009).

3. Add 3-6 worms in each container. Cover with a layer of dried leaves and hay. Indicate where they can get the worms

4. Add water until the soil is moistened (be careful not to over saturate, worms may drown).

5. Cover the top of the plastic container with plastic wrap. Poke holes into the top to allow for air flow.

Figure 18 - Covering the top with plastic wrap (Hillbilly Jillies, 2009).

6. Cut construction paper to the appropriate length and height of the plastic container, and glue both ends together to create a removable sleeve. Students can

Figure 19 - Gluing the sleeve (Hillbilly Jillies, 2009).

decorate their sleeve if they wish. The sleeve acts as a shade for the worms so they do not over-heat, but can also be removed to view them.

7. Place the worm terrarium in a cool place and check daily if water needs to be added. Within a few days, worm activity should be visible, such as trails and casts.

Figure 20 - Completed Worm Terrarium (Hillbilly Jillies, 2009).

Notes/Helpful Tips

- Instead of using markers and other art materials to decorate the sleeves, gather several soil samples with varying colors and moisten to the consistency of water color paints. Allow time for the soil paint to dry before gluing the sleeve.
- Be sure to instruct students how to properly care for the worms at home. It may be helpful to have the instructions printed on the sleeves so students and parents know how to care for the terrarium.

ACTIVITY 5 - CLOSING

Title: What Can Soils Do for You?

Learning Objectives/Brief Description:

- Educate students about the important processes that soils provide for our lives

Materials Needed:

- Soil ecological processes illustration (see Figure 21)

Setup Procedure: None

Operation of the Activity/Experiment:

1. Once the students have completed each of the three activities, conclude the lab by discussing some of the processes soil provides for our lives (soil filters out pollutants and stores water, provides habitat for organisms, supports our roads and buildings, absorbs carbon dioxide from the atmosphere, enables us to grow crops, etc.). See Figure 21 for illustrations of the ecological processes.

2. Ask the students what they have learned, and if they have any questions.

3. Thank the students for participating in the Learn by Doing Lab.

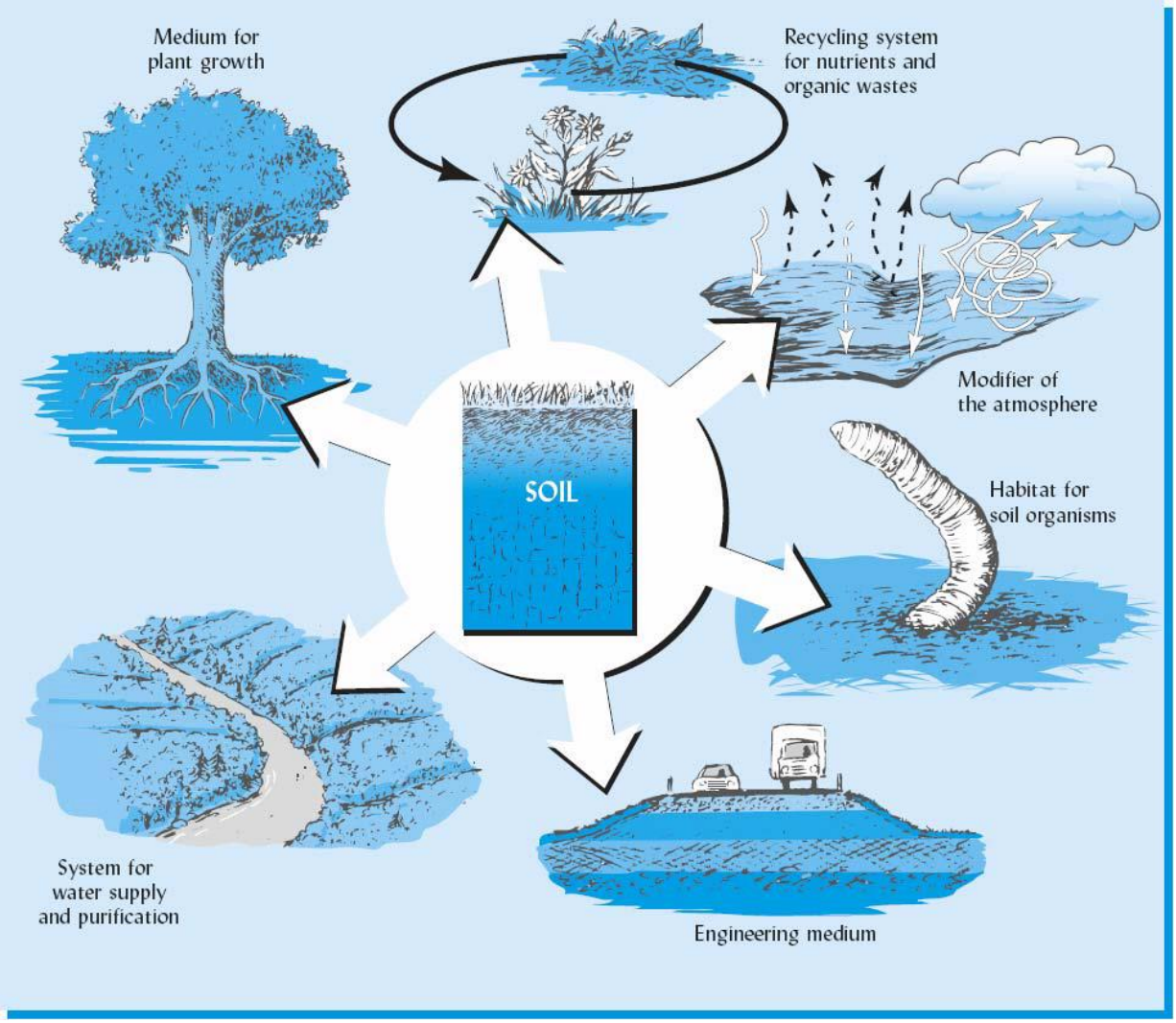

Figure 21 - Ecological Processes of Soil (Brady and Weil, 2010).

ALTERNATE ACTIVITIES

- Soil Monoliths/Profiles:
    - find the horizons (why are they different colors)
        - amount of organic matter, minerals, parent materials, etc.

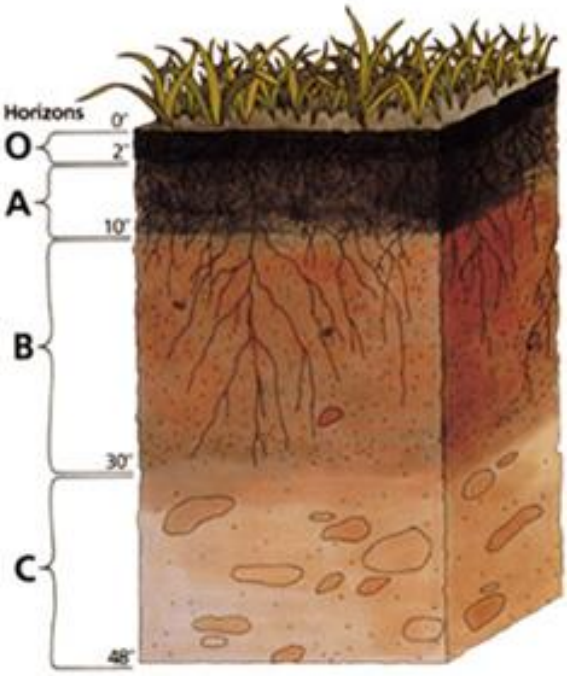

Figure 23 - Diagram of a soil profile (USDA NRCS, 2017).)

Figure 22 - Soil Monoliths (Ormonde, 2017).

- Clay Animals
    - Use moistened clay as if it was modeling clay to create animals that live in/near soil (worms/snails/nematodes/beetles etc.).

Figure 24 - Insects made of clay (Pottery Space, 2017).

- Soil Food Web
    - Use a poster of the soil food web or draw a food web on a dry erase board. Have the students help make the connections between the soil, the plants, and organisms. See Figure 25 for an illustration of the soil food web.
    - In addition to teaching the soil food web by using a drawing, you can help the students fill in the blanks on their activity booklet on pages 6 and 7.

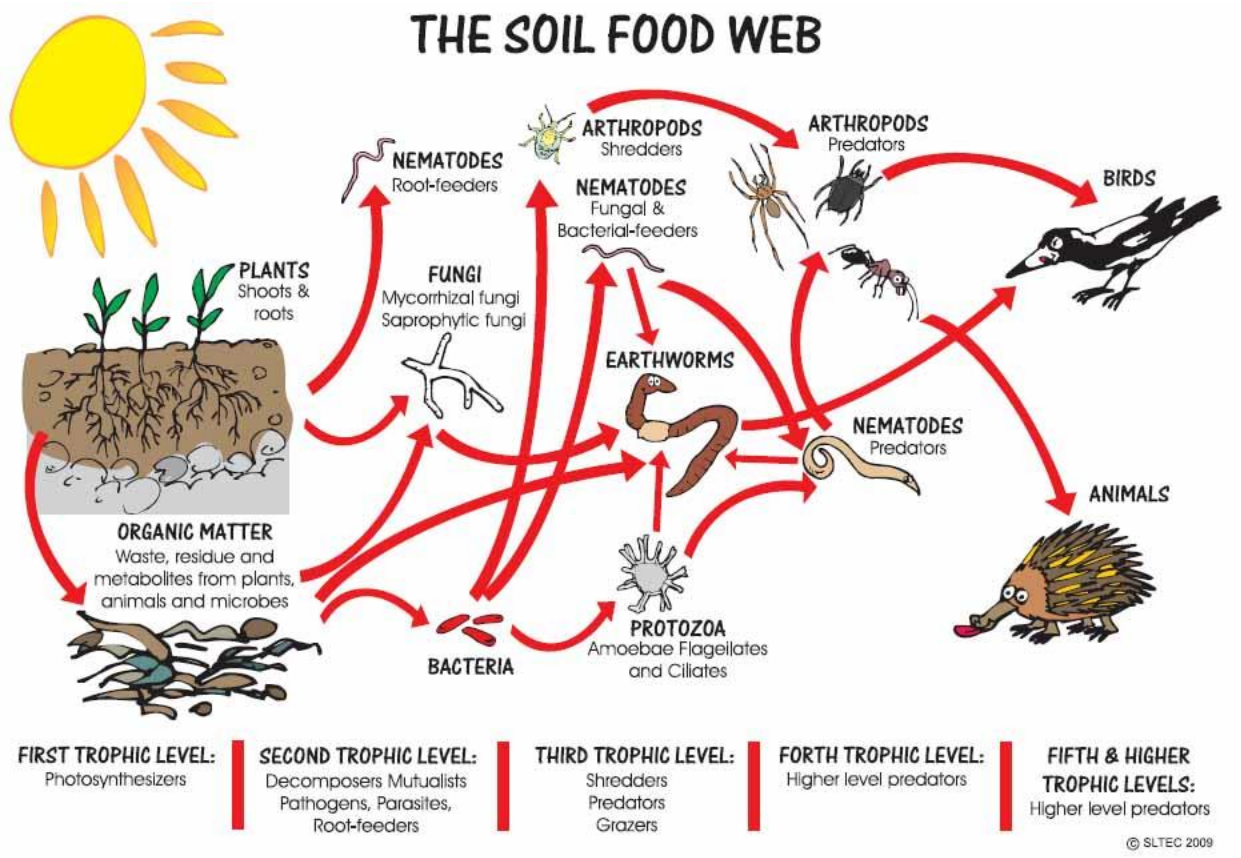

Figure 25 - The Soil Food Web (Pinterest, 2017).

- Particle Size Separation
    - Fill mason jars with approximately 1/3 soil, and 2/3 water. Tighten the lid and shake the jar.
    - Observe the jar every few minutes to see which particles settle out first. Ask the students which particle size will sink to the bottom first and why (larger particles/sand will settle to the bottom first because they are denser than the smaller particles). This experiment ties in with the soil texture activity.

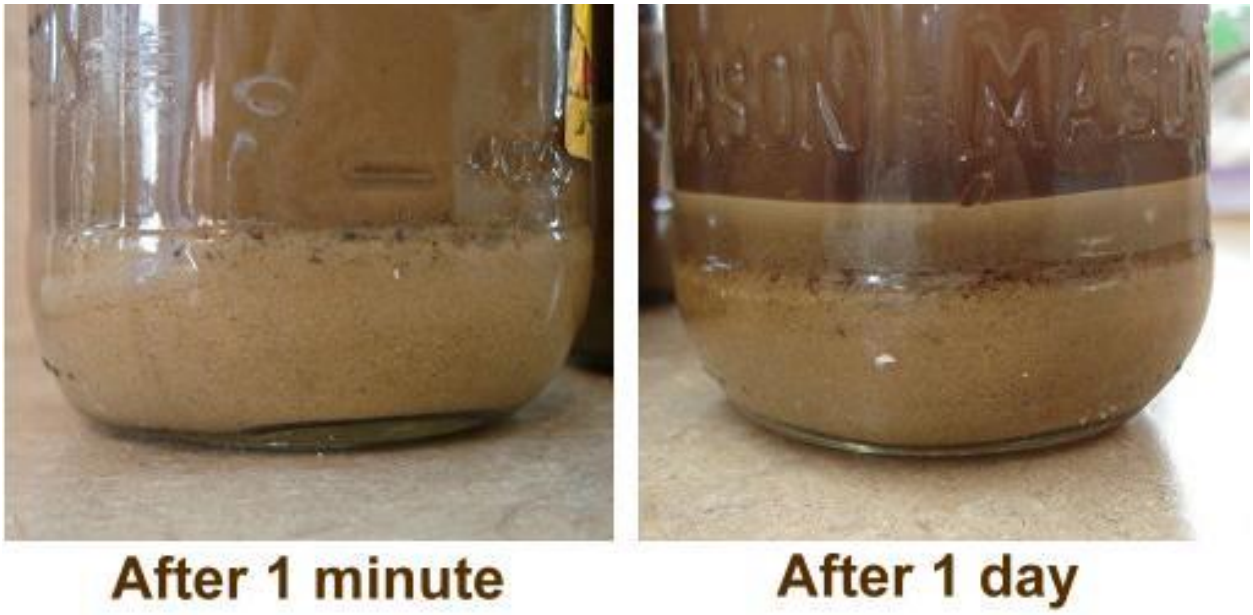

Figure 26 - Larger particles separated out of solution first (Day, 2017).

- Soil Filtration
    - Dr. Clay Robinson from Iowa State University came up with a similar experiment that uses Grape Kool-Aid. The experiment is similar, and uses paper cups instead of formal lab equipment. The results are not as dramatic as using the Eosin Yellow and Methylene Blue solutions. However, the solutions are not as easy to obtain as Grape Kool-Aid.

Figure 27 - Dr. Robinson instructing students during soil filtration activity (Robinson, 2017).

    - Place 2 funnels in a funnel rack. Fill one funnel with the pea-sized play and the other with beach sand. Moisten the soil with water until saturated. Place a 100 mL beaker (or cup) under each funnel to catch the leachate. The leachate from the clay will be a red/pinkish color. The leachate from the sand should have no change in color.

Figure 28 - Soil filtration results (Robinson, 2017).

- Mix Grape Kool-Aid powder into water until dissolved. Use a smaller amount of water than directed on the packaging to make the solution more concentrated.

- The dye in the Grape Kool-Aid is made up of red and blue to make purple. The blue dye has a positive charge, and is attracted to the negative charge of the clay and filtered out. The red dye has a negative charge, and is not attracted to the clay. The leachate from the clay should only have a reddish color due to the blue dye being filtered out.

- The leachate from the sand should not a change in color since the sand has a neutral charge and doesn't attract the ions in the dye.

HELPFUL TIPS

- Allow for a few minutes in between each activity to allow for a smooth transition from one activity to the next.
- The three main activities (excluding the introduction and conclusion) can be completed in any order. The goal is allowing students to start at any of the three and rotate between them.
- Alternate activities are included to keep the students engaged.
- See Additional Resources in the Appendix for resources that provide additional background information about soil science.

CHAPTER 4

CONCLUSION

The goal of this senior project was to create a soil science lesson plan for the Learn by Doing Lab at Cal Poly. The lesson was intended for 5-8th grade students. Although the lesson plan was written for the LBDL, it can also be used by other instructors who wish to teach their students about soil science. The combination of activities and experiments were not tested during the project. However, the activities were all from reputable sources and were entertaining and educational for students. The activities were chosen for their simplicity, content, educational value, and because they are fun. Alternate activities were included to give the instructor options if a particular experiment was not possible.

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APPENDIX

i. Eosin Y Material Safety Data Sheet (MSDS).

SAFETY DATA SHEET

Revision Number 1

Revision Date 23-Apr-2014

1. Identification

Product Name **Eosin Y**
Cat No. : **AC152880000; AC152880250; AC152881000; AC152885000**
Synonyms Eosin Yellowish; C.I. 45380; Acid Red 87; 2`,4`,5`,7`-Tetrabromofluorescein, disodium salt

Recommended Use Laboratory chemicals

Uses advised against No Information available

Details of the supplier of the safety data sheet

Company
Fisher Scientific One
Reagent Lane Fair
Lawn, NJ 07410 Tel:
(201) 796-7100

Entity / Business Name
Acros Organics One
Reagent Lane
Fair Lawn, NJ 07410

Emergency Telephone Number
For information **US** call: 001-800-ACROS-01 /
Europe call: +32 14 57 52 11
Emergency Number **US:**001-201-796-7100 /
Europe: +32 14 57 52 99
CHEMTREC Tel. No.**US:**001-800-424-9300 /
Europe:001-703-527-3887

2. Hazard(s) identification

Classification
This chemical is considered hazardous by the 2012 OSHA Hazard Communication Standard (29 CFR 1910.1200)

Serious Eye Damage/Eye Irritation	Category 2

Label Elements Signal Word
Warning

Hazard Statements
Causes serious eye irritation

Precautionary Statements Prevention
Wash face, hands and any exposed skin thoroughly after handling Wear eye/face protection

Eyes
IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing If eye irritation persists: Get medical advice/attention.

Hazards not otherwise classified (HNOC)
None identified

3. Composition / information on ingredients

Haz/Non-haz

Component	CAS-No	Weight %
Acid red 87	17372-87-1	>95

4. First-aid measures

Eye Contact Rinse immediately with plenty of water, also under the eyelids, for at least 15 minutes. Obtain medical attention.

Skin Contact Wash off immediately with plenty of water for at least 15 minutes. Get medical attention if symptoms occur..

Inhalation Move to fresh air. If breathing is difficult, give oxygen. Get medical attention if symptoms occur.

Ingestion Do not induce vomiting. Obtain medical attention.

Most important symptoms/effects No information available
Notes to Physician Treat symptomatically.

5. Fire-fighting measures

Suitable Extinguishing Media Use water spray, alcohol-resistant foam, dry chemical or carbon dioxide.

Unsuitable Extinguishing Media No information available.

Flash Point No information available.
Method - No information available

Autoignition Temperature No information available.
Explosion Limits
Upper No data available
Lower No data available
Sensitivity to Mechanical Impact No information available

Sensitivity to Static Discharge No information available

Specific Hazards Arising from the Chemical
Thermal decomposition can lead to release of irritating gases and vapors.

Hazardous Combustion Products Carbon monoxide (CO), Carbon dioxide (CO_2), Hydrogen halides, Bromine, Sodium oxides.
Protective Equipment and Precautions for Firefighters
As in any fire, wear self-contained breathing apparatus pressure-demand, MSHA/NIOSH (approved or equivalent) and full protective gear.

NFPA

Health	Flammability	Instability	Physical hazards
1	0	0	N/A

6. Accidental release measures

Personal Precautions Use personal protective equipment. Ensure adequate ventilation. Avoid dust formation. Avoid contact with skin, eyes and clothing.

Environmental Precautions Avoid release to the environment. See Section 12 for additional ecological Information.

Methods for Containment and Clean Up Sweep up or vacuum up spillage and collect in suitable container for disposal. Avoid dust formation.

7. Handling and storage

Handling Wear personal protective equipment. Ensure adequate ventilation. Avoid dust formation. Avoid contact with skin and eyes. Avoid ingestion and inhalation.

Storage Keep containers tightly closed in a dry, cool and well-ventilated place.

8. Exposure controls / personal protection

Exposure Guidelines This product does not contain any hazardous materials with occupational exposure limits established by the region specific regulatory bodies.

Engineering Measures Ensure adequate ventilation, especially in confined areas. Ensure that eyewash stations and safety showers are close to the workstation location.

Personal Protective Equipment

Eye/face Protection Wear appropriate protective eyeglasses or chemical safety goggles as described by OSHA's eye and face protection regulations in 29 CFR 1910.133 or European Standard EN166

Skin and body protection Wear appropriate protective gloves and clothing to prevent skin exposure.

Respiratory Protection Follow the OSHA respirator regulations found in 29 CFR 1910.134 or European Standard EN 149. Use a NIOSH/MSHA or European Standard EN 149 approved respirator if exposure limits are exceeded or if irritation or other symptoms are experienced.

Hygiene Measures Handle in accordance with good industrial hygiene and safety practice

9. Physical and chemical properties

Physical State Powder Solid
Appearance Red brown
Odor Odorless
Odor Threshold No information available.
pH 7-10
Melting Point/Range 300°C / 572°F
Boiling Point/Range No information available.
Flash Point No information available.
Evaporation Rate No information available.
Flammability (solid,gas) No information available
Flammability or explosive limits
Upper No data available
Lower No data available
Vapor Pressure negligible
Vapor Density No information available.
Relative Density 1.018

9. Physical and chemical properties

Solubility No information available.
Partition coefficient; n-octanol/water No data available
Autoignition Temperature No information available.
Decomposition temperature > 300°C
Viscosity No information available.
Molecular Formula C20 H6 Br4 Na2 O5
Molecular Weight 691.85

10. Stability and reactivity

Reactive Hazard None known, based on information available.

Stability Stable under normal conditions. Moisture sensitive.

Conditions to Avoid Avoid dust formation. Incompatible products. Excess heat. Exposure to moisture.

Incompatible Materials Strong oxidizing agents, Strong acids, alkaline, Strong reducing agents

Hazardous Decomposition Products Carbon monoxide (CO), Carbon dioxide (CO_2), Hydrogen halides, Bromine, Sodium oxides

Hazardous Polymerization Hazardous polymerization does not occur.

Hazardous Reactions None under normal processing

11. Toxicological information

Acute Toxicity

Product Information No acute toxicity information is available for this product
Component Information
Toxicologically Synergistic Products No information available.

Delayed and immediate effects as well as chronic effects from short and long-term exposure Irritation Irritating to eyes
Sensitization No information available.

Carcinogenicity The table below indicates whether each agency has listed any ingredient as a carcinogen

Component	CAS-No	IARC	NTP	ACGIH	OSHA	Mexico
Acid red 87	17372-87-1	Not listed	Not listed	Not listed	Not listed	Not listed

Mutagenic Effects Not mutagenic in AMES Test

Reproductive Effects No information available.

Developmental Effects No information available.

Teratogenicity No information available.

STOT - single exposure None known.
STOT - repeated exposure None known.

Aspiration hazard No information available.

Symptoms / effects, both acute and delayed: No information available

Endocrine Disruptor Information No information available

Other Adverse Effects The toxicological properties have not been fully investigated..

12. Ecological information

Ecotoxicity
Do not empty into drains.

Component	Freshwater Algae	Freshwater Fish	Microtox	Water Flea
Acid red 87	Not listed	LC50= 1200 mg/L/48h (Oryzias latipes)	Not listed	Not listed

Persistence and Degradability No information available. **Bioaccumulation/ Accumulation** No information available **Mobility** .

Component	log Pow
Acid red 87	4.80

13. Disposal considerations

Waste Disposal Methods Chemical waste generators must determine whether a discarded chemical is classified as a hazardous waste. Chemical waste generators must also consult local, regional, and national hazardous waste regulations to ensure complete and accurate classification

14. Transport information

DOT Not regulated
TDG Not regulated
IATA Not regulated
IMDG/IMO Not regulated

15. Regulatory information

International Inventories

Component	TSCA	DSL	NDSL	EINECS	ELINCS	NLP	PICCS	ENCS	AICS	IECSC	KECL
Acid red 87	X	X	-	241-409-6	-		X	X	X	X	X

Legend:
X - Listed
E - Indicates a substance that is the subject of a Section 5(e) Consent order under TSCA. F - Indicates a substance that is the subject of a Section 5(f) Rule under TSCA.
N - Indicates a polymeric substance containing no free-radical initiator in its inventory name but is considered to cover the designated polymer made with any free-radical initiator regardless of the amount used.
P - Indicates a commenced PMN substance
R - Indicates a substance that is the subject of a Section 6 risk management rule under TSCA. S - Indicates a substance that is identified in a proposed or final Significant New Use Rule
T - Indicates a substance that is the subject of a Section 4 test rule under TSCA.

XU - Indicates a substance exempt from reporting under the Inventory Update Rule, i.e. Partial Updating of the TSCA Inventory Data Base Production and Site Reports (40 CFR 710(B).
Y1 - Indicates an exempt polymer that has a number-average molecular weight of 1,000 or greater.
Y2 - Indicates an exempt polymer that is a polyester and is made only from reactants included in a specified list of low concern reactants that comprises one of the eligibility criteria for the exemption rule.

U.S. Federal Regulations

TSCA 12(b) Not applicable

SARA 313 Not applicable

SARA 311/312 Hazardous Categorization
Acute Health Hazard Yes
Chronic Health Hazard No
Fire Hazard No
Sudden Release of Pressure Hazard No
Reactive Hazard No

Clean Water Act Not applicable

Clean Air Act Not applicable

OSHA Occupational Safety and Health Administration Not applicable

CERCLA
Not applicable

California Proposition 65 This product does not contain any Proposition 65 chemicals.

State Right-to-Know Not applicable

U.S. Department of Transportation
Reportable Quantity (RQ): N
DOT Marine Pollutant N
DOT Severe Marine Pollutant N

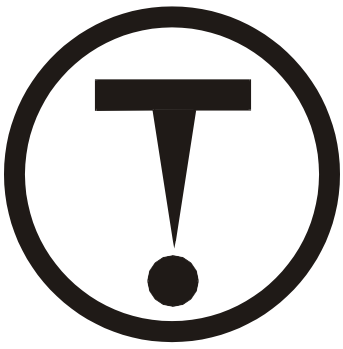
U.S. Department of Homeland Security
This product does not contain any DHS chemicals.

Other International Regulations

Mexico - Grade No information available

Canada
This product has been classified in accordance with the hazard criteria of the Controlled Products Regulations (CPR) and the MSDS contains all the information required by the CPR.

WHMIS Hazard Class D2B Toxic materials



16. Other information

Prepared By Regulatory Affairs Thermo Fisher Scientific
Email: EMSDS.RA@thermofisher.com

Revision Date 23-Apr-2014
Print Date 23-Apr-2014
Revision Summary This document has been updated to comply with the US OSHA HazCom 2012 Standard replacing the current legislation under 29 CFR 1910.1200 to align with the Globally Harmonized System of Classification and Labeling of Chemicals (GHS).

Disclaimer
The information provided on this Safety Data Sheet is correct to the best of our knowledge, information and belief at the date of its publication. The information given is designed only as a guide for safe handling, use, processing, storage, transportation, disposal and release and is not to be considered as a warranty or quality specification. The information relates only to the specific material designated and may not be valid for such material used in combination with any other material or in any process, unless specified in the text.

End of SDS

ii. Methylene Blue MSDS.

Fisher Scientific

Part of Thermo Fisher Scientific

SAFETY DATA SHEET

Creation Date 23-Feb-2010 **Revision Date** 22-Dec-2015 Revision Number 1

1. Identification

Product Name **Methylene Blue**
Cat No. : **BP117-100**
Synonyms Basic Blue 9

Recommended Use Laboratory chemicals.

Uses advised against No Information available

Details of the supplier of the safety data sheet

Company
Fisher Scientific One
Reagent Lane
Fair Lawn, NJ 07410
Tel: (201) 796-7100

Emergency Telephone Number
CHEMTRECÒ, Inside the USA: 800-424-9300 CHEMTRECÒ, Outside the USA: 001-703-527-3887

2. Hazard(s) identification

Classification

This chemical is considered hazardous by the 2012 OSHA Hazard Communication Standard (29 CFR 1910.1200)

Acute oral toxicity	Category 4

Label Elements

Signal Word
Warning

Hazard Statements
Harmful if swallowed

Precautionary Statements Prevention
Wash face, hands and any exposed skin thoroughly after handling Do not eat, drink or smoke when using this product
Ingestion

IF SWALLOWED: Call a POISON CENTER or doctor/physician if you feel unwell Rinse mouth
Disposal
Dispose of contents/container to an approved waste disposal plant
Hazards not otherwise classified (HNOC)
None identified

3. Composition / information on ingredients

Component	CAS-No	Weight %
Methylene blue	61-73-4	>95

4. First-aid measures

Eye Contact Rinse immediately with plenty of water, also under the eyelids, for at least 15 minutes. Obtain medical attention.

Skin Contact Wash off immediately with plenty of water for at least 15 minutes. Get medical attention if symptoms occur.

Inhalation Move to fresh air. If breathing is difficult, give oxygen. Do not use mouth-to-mouth method if victim ingested or inhaled the substance; give artificial respiration with the aid of a pocket mask equipped with a one-way valve or other proper respiratory medical device. Obtain medical attention.

Ingestion Do not induce vomiting. Call a physician or Poison Control Center immediately.

Most important symptoms/effects No information available.
Notes to Physician Treat symptomatically

5. Fire-fighting measures

Suitable Extinguishing Media Use water spray, alcohol-resistant foam, dry chemical or carbon dioxide.

Unsuitable Extinguishing Media No information available

Flash Point No information available
Method - No information available

Autoignition Temperature Explosion Limits
Upper No data available
Lower No data available
Sensitivity to Mechanical Impact No information available
Sensitivity to Static Discharge No information available

Specific Hazards Arising from the Chemical
Thermal decomposition can lead to release of irritating gases and vapors. Keep product and empty container away from heat and sources of ignition.

Hazardous Combustion Products
Hydrogen chloride gas Nitrogen oxides (NOx) Carbon monoxide (CO) Carbon dioxide (CO_2)
Protective Equipment and Precautions for Firefighters
As in any fire, wear self-contained breathing apparatus pressure-demand, MSHA/NIOSH (approved or equivalent) and full protective gear.

NFPA

Health	Flammability	Instability	Physical hazards
2	1	0	N/A

6. Accidental release measures

Personal Precautions Use personal protective equipment. Ensure adequate ventilation. Avoid dust formation. Avoid contact with skin, eyes and clothing.

Environmental Precautions Avoid release to the environment. See Section 12 for additional ecological information.

Methods for Containment and Clean Up Sweep up or vacuum up spillage and collect in suitable container for disposal. Avoid dust formation.

7. Handling and storage

Handling Wear personal protective equipment. Ensure adequate ventilation. Avoid dust formation. Avoid contact with skin, eyes and clothing. Avoid ingestion and inhalation.

Storage Keep containers tightly closed in a dry, cool and well-ventilated place.

8. Exposure controls / personal protection

Exposure Guidelines This product does not contain any known or suspected reproductive hazards

Engineering Measures Ensure adequate ventilation, especially in confined areas. Ensure that eyewash stations and safety showers are close to the workstation location.

Personal Protective Equipment

Eye/face Protection Wear appropriate protective eyeglasses or chemical safety goggles as described by OSHA's eye and face protection regulations in 29 CFR 1910.133 or European Standard EN166.

Skin and body protection Wear appropriate protective gloves and clothing to prevent skin exposure.

Respiratory Protection Follow the OSHA respirator regulations found in 29 CFR 1910.134 or European Standard EN 149. Use a NIOSH/MSHA or European Standard EN 149 approved respirator if exposure limits are exceeded or if irritation or other symptoms are experienced.

Hygiene Measures Handle in accordance with good industrial hygiene and safety practice.

9. Physical and chemical properties

Physical State Solid
Appearance Dark green
Odor Odorless
Odor Threshold No information available
pH 3 - 4.5 (1 %)
Melting Point/Range 190 °C / 374 °F
Boiling Point/Range No information available
Flash Point No information available
Evaporation Rate Not applicable
Flammability (solid,gas) No information available
Flammability or explosive limits
Upper No data available
Lower No data available
Vapor Pressure negligible
Vapor Density Not applicable
Specific Gravity No information available
Solubility Slightly soluble in water
Partition coefficient; n-octanol/water No data available

Autoignition Temperature
Decomposition Temperature 190 °C
Viscosity Not applicable
Molecular Formula C16H18ClN3S
Molecular Weight 319.85

10. Stability and reactivity

Reactive Hazard None known, based on information available

Stability Stable under normal conditions.

Conditions to Avoid Avoid dust formation. Incompatible products. Excess heat.

Incompatible Materials Strong oxidizing agents

Hazardous Decomposition Products Hydrogen chloride gas, Nitrogen oxides (NOx), Carbon monoxide (CO), Carbon dioxide (CO_2)

Hazardous Polymerization Hazardous polymerization does not occur.

Hazardous Reactions None under normal processing.

11. Toxicological information

Acute Toxicity

Product Information Component Information

Component	LD50 Oral	LD50 Dermal	LC50 Inhalation
Methylene blue	LD50 = 1180 mg/kg (Rat)	Not listed	Not listed

Toxicologically Synergistic Products No information available

Delayed and immediate effects as well as chronic effects from short and long-term exposure Irritation No information available
Sensitization No information available

Carcinogenicity The table below indicates whether each agency has listed any ingredient as a carcinogen.

Component	CAS-No	IARC	NTP	ACGIH	OSHA	Mexico
Methylene blue	61-73-4	Not listed	Not listed	Not listed	Not listed	Not listed

Mutagenic Effects No information available

Reproductive Effects No information available.

Developmental Effects No information available.

Teratogenicity No information available.

STOT - single exposure None known
STOT - repeated exposure None known

Aspiration hazard No information available

Symptoms / effects,both acute and delayed No information available

Endocrine Disruptor Information No information available

Other Adverse Effects The toxicological properties have not been fully investigated. See actual entry in RTECS for complete information.

12. Ecological information

Ecotoxicity
Do not empty into drains.

Persistence and Degradability Soluble in water Persistence is unlikely based on information available.
Bioaccumulation/ Accumulation No information available.

Mobility Will likely be mobile in the environment due to its water solubility.

13. Disposal considerations

Waste Disposal Methods Chemical waste generators must determine whether a discarded chemical is classified as a hazardous waste. Chemical waste generators must also consult local, regional, and national hazardous waste regulations to ensure complete and accurate classification.

14. Transport information

DOT Not regulated
TDG Not regulated
IATA Not regulated
IMDG/IMO Not regulated

15. Regulatory information

All of the components in the product are on the following Inventory lists: Australia Complete Regulatory Information contained in following SDS's X = listed China Canada The product is classified and labeled according to EC directives or corresponding national laws The product is classified and labeled in accordance with Directive 1999/45/EC Europe TSCA Korea Philippines

International Inventories

Component	TSCA	DSL	NDSL	EINECS	ELINCS	NLP	PICCS	ENCS	AICS	IECSC	KECL
Methylene blue	X	X	-	200-515-2	-		X	-	X	X	X

Legend:
X - Listed
E - Indicates a substance that is the subject of a Section 5(e) Consent order under TSCA. F - Indicates a substance that is the subject of a Section 5(f) Rule under TSCA.
N - Indicates a polymeric substance containing no free-radical initiator in its inventory name but is considered to cover the designated polymer made with any free-radical initiator regardless of the amount used.
P - Indicates a commenced PMN substance
R - Indicates a substance that is the subject of a Section 6 risk management rule under TSCA. S - Indicates a substance that is identified in a proposed or final Significant New Use Rule
T - Indicates a substance that is the subject of a Section 4 test rule under TSCA.
XU - Indicates a substance exempt from reporting under the Inventory Update Rule, i.e. Partial Updating of the TSCA Inventory Data Base Production and Site Reports (40 CFR 710(B).
Y1 - Indicates an exempt polymer that has a number-average molecular weight of 1,000 or greater.
Y2 - Indicates an exempt polymer that is a polyester and is made only from reactants included in a specified list of low concern reactants that comprises one of the eligibility criteria for the exemption rule.

U.S. Federal Regulations

TSCA 12(b) Not applicable

SARA 313 Not applicable

SARA 311/312 Hazard Categories
Acute Health Hazard Yes
Chronic Health Hazard No
Fire Hazard No

Sudden Release of Pressure Hazard No
Reactive Hazard No

CWA (Clean Water Act) Not applicable

Clean Air Act Not applicable

OSHA Occupational Safety and Health Administration Not applicable

CERCLA
Not applicable

California Proposition 65 This product does not contain any Proposition 65 chemicals

U.S. State Right-to-Know Regulations Not applicable

U.S. Department of Transportation

Reportable Quantity (RQ): N
DOT Marine Pollutant N
DOT Severe Marine Pollutant N

U.S. Department of Homeland Security
This product does not contain any DHS chemicals.

Other International Regulations

Mexico - Grade No information available

Canada
This product has been classified in accordance with the hazard criteria of the Controlled Products Regulations (CPR) and the MSDS contains all the information required by the CPR

WHMIS Hazard Class Non-controlled

16. Other information

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Print Date 22-Dec-2015
Revision Summary This document has been updated to comply with the US OSHA HazCom 2012 Standard replacing the current legislation under 29 CFR 1910.1200 to align with the Globally Harmonized System of Classification and Labeling of Chemicals (GHS)
Disclaimer
The information provided in this Safety Data Sheet is correct to the best of our knowledge, information and belief at the date of its publication. The information given is designed only as a guidance for safe handling, use, processing, storage, transportation, disposal and release and is not to be considered a warranty or quality specification. The information relates only to the specific material designated and may not be valid for such material used in combination with any other materials or in any process, unless specified in the text

End of SDS

iii. Guide to Texture by Feel

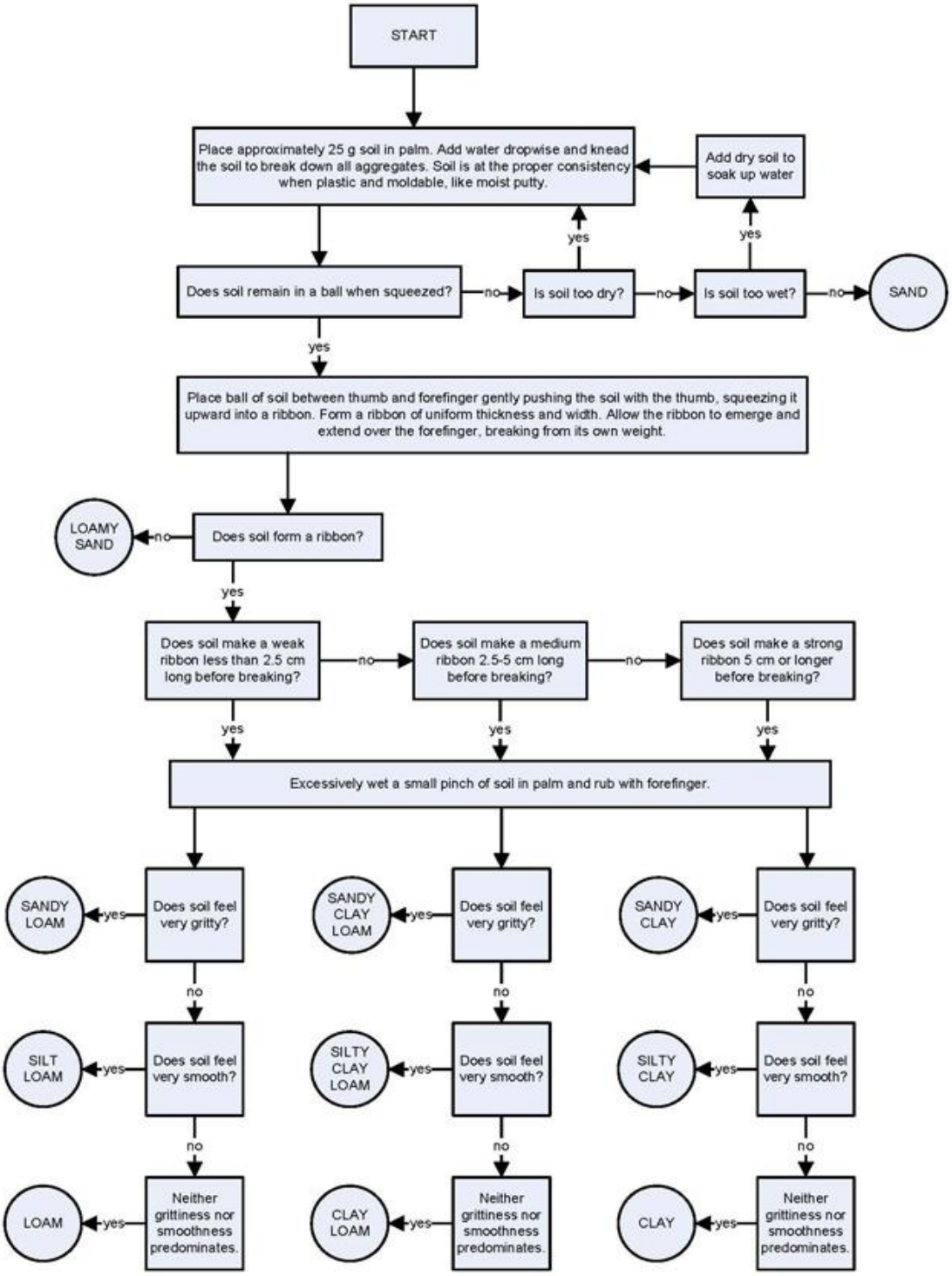

Figure 29 - Soil Texture by Feel (Thein, 1979).

iv. Soil Texture Triangle

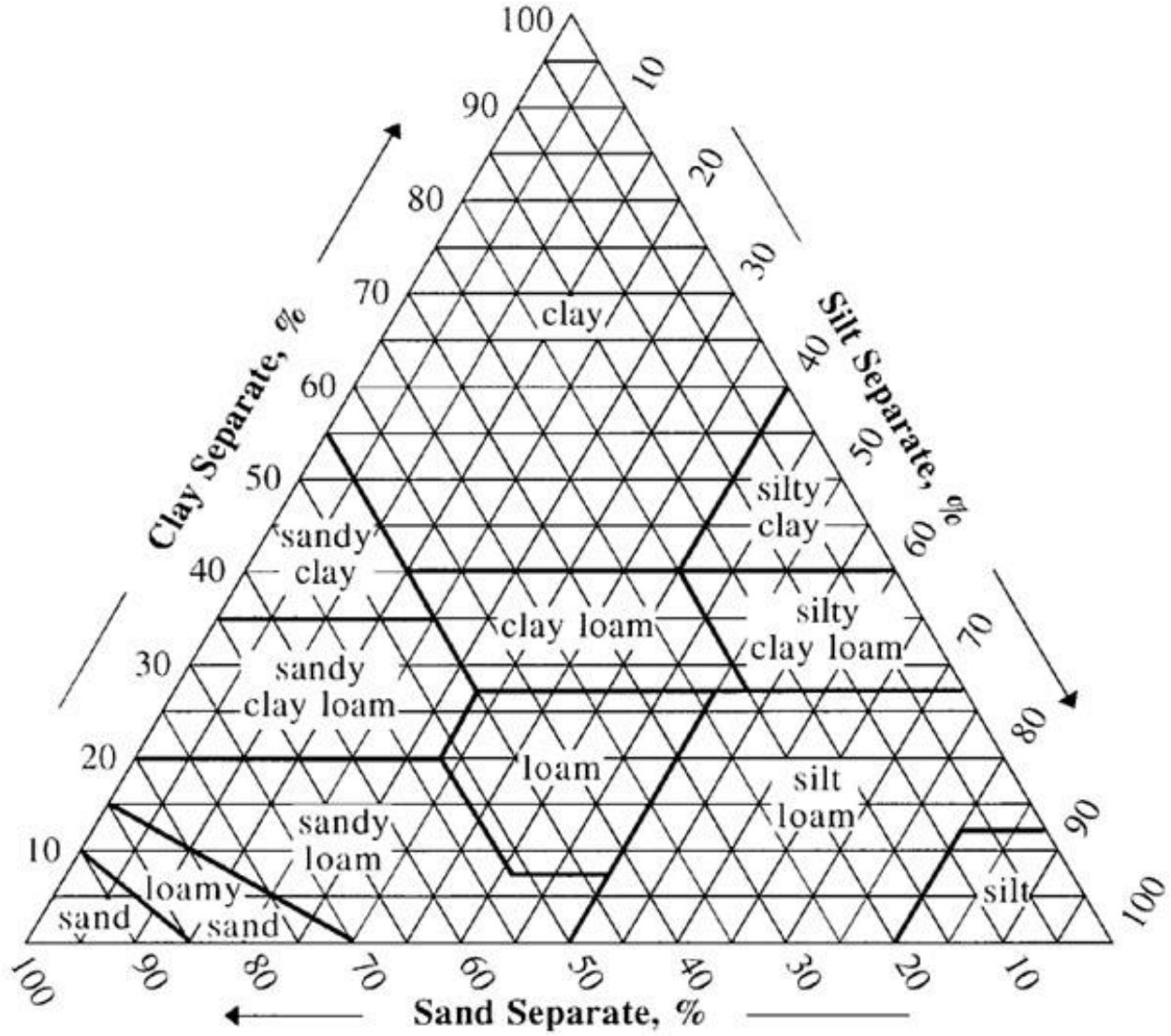

Figure 30 - Soil Texture Triangle (USDA NRCS, 2017).

v. Additional Resources

1. *Elements of the Nature and Properties of Soils* by Nyle Brady and Ray Weil

   This textbook is used to teach introductory soil science at Cal Poly (SS 121). It provides a wealth of information about soil science.

2. *Soils Magic* by David Elton

   This is an informative guide on various civil engineering experiments.

3. *K – 12 Soil Science Teacher Resources*, SSSA

   Website that lists activities by soil subject and grade level. This is a great source for soil science activities and experiments. Available at **http://www.soils4teachers.org/lessons-and-activities**.

4. *Dr. Dirt, K-12 Teaching Resources* by Dr. Clay Robinson

   Website with entertaining soil science activities and experiments. Available at **http://www.doctordirt.org/home**.

vi. Next Generation Science Standards (NGSS) Disciplinary Core Ideas (DCI)

Although the focus of this project was soil science, the experiments and activities relate to other disciplines, such as chemistry and biology. The activities also relate to a few of the DCIs created by the NGSS; specifically Structures and Properties of Matter, Earth's Systems, Chemical Reactions, and Interdependent Relationships in Ecosystems. The activities were written for the 5-8th grade age group of the LBDL at Cal Poly. The table below shows the activities and the DCIs they relate to. See the NGSS website for more information regarding DCIs.

Fifth Grade		Middle School (6-8)	
DCI	SS LBDL Activity	DCI	SS LBDL Activity
ESS2.A: Earth Materials and Systems	Activity 5: What Can Soils Do for You?	PS1.B: Chemical Reactions	Activity 3: Fun with Filtration
ESS2.C: The Roles of Water in Earth's Surface Processes	Activity 5: What Can Soils Do for You?	LS2.A: Interdependent Relationships in Ecosystems	Activity 4: Worm Terrariums
PS1.B: Chemical Reactions	Activity 3: Fun with Filtration	ESS2.A: Earth's Materials and Systems	Activity 5: What Can Soils Do for You?
		Ess2.C: The Roles of Water in Earth's Surface Processes	Activity 5: What Can Soils Do for You?
		ESS3.A: Natural Resources	Activity 5: What Can Soils Do for You?

Table 1 - NGSS DCIs and the related SS LBDL activities (NGSS, 2017).