**Summer Academy 2018**

**Ancient Northern Plains Native American Structures**

*This is a very dirty lab; suggest students wear old clothes.*

**Description:** Ancient Northern Plains Native Americanswere engineers with equal design capabilities used by modern day engineers but without the available technology: instruments, equipment, and computers. The Hidatsa, Arikara, and Mandan Indians designed low earth lodges in pre-Columbian times. The low earth lodges were built with a 30 to 40 ft circular floor below the earth’s surface and an upper frame 10 to 15 ft above earth’s surface in the center and 5 to 7 ft at the eaves (outer frame). The low earth lodges frame covering consisted of clay soils and grass cuttings to provide insulation during the cold season, wet season, warm season and protection from the wind. The low earth lodges were built near a water source. Many of the earth lodges were still inhabited in the early 1900s. The Pawnee, Omaha, Ponca and Oto Indians used a similar structures for their dwellings.

**Objectives:**

* Students will construct an ancient earth lodge and surface earth lodge using both modern and pre-Columbian material
* Students will test how the design of a dwelling affects the strength of the structure
* Students will learn the importance of the slope of the roof when designing a dwelling.
* Students will explore how slight changes in the design of a dwelling can affect the dwelling

**Standards covered:**

* HS-G-CO.1 Know precise definitions of angle, circle, perpendicular, parallel line and line segment, based on the undefined notions of points, line, and planes
* HS-G-CO.12 Basic geometric construction with a variety of tools and methods
* 9.10.2.7 Maintain clear and accurate records of scientific investigations
* 9.10.8.3 Explain how individuals and groups, from different disciplines in and outside of science, contribute to science at different levels of complexity
* 11-12.7.4 Explain how science and technology can influence personal, industry, and cultural decision making (e.g. organ transplant, cloning, stem cell, research, genetic manipulation, use of genetic profile, **archeological discoveries**, land management, resource management

**Materials required for Activities One, Two, Three and Four**

* **Gloves** (optional)
* **Large mixing bowl**
* **Flat cardboard** with the sides approximately 20 cm, cut off the flaps if present
* **Flat cardboard or trays** to build experimental roofs (need a 13 x 13 square per roof)
* **Swing-Arm Protractor** (can make a circle with a 7.5 cm radius)
* **Angle protractor**; measures angles in cm
* **A ruler** that can measures at least 6 cm
* **Scissors, knife, or wire cutter** to cut dowels and bamboo skewers
* **Spatula** to help pick up small frame sections (optional)
* **Small pebbles** for the fire pit
* **Spray bottles (50 ml or greater)**
* **Paper:** 2 sheets of 8 ½ by 11 inches, may be scrap paper as long as one side is clear.
* **Small plastic lids:** 2 lids approximately 10 cm in diameter from butter container, etc.
* **Pennies, beads, or other small objects** of the same weight to test the strength of the earth lodges
* **Heat Lamp** if the sun is not hot enough to dry the low earth lodges
* **Earth - Clay soil for 2 lodges :**16 cups of soil (dirt with few pebbles)
  + 1½ cup of Crayola Air-Dry-Clay
  + Enough water to make thick, damp mud
  + Approximately 3 cup grass shavings (lawn mower cuttings will work, better if dry)
* **Earth lodge frame for two lodges:** The dimensions for building the miniature lodges are approximately 0.5 cm per foot in a full-size lodge.

4 Wooden round dowels; 3/16 inch diameter

Approximately 30 – 40 bamboo skewers – 30.5 cm x 0.3 cm (12 in x 0.12 inches)

* **Roof Experimental Angle**: 9 pop sickle sticks per roof: total = 27 per activity
* **Tipi** – approximately 15 bamboo skewers

Yarn

**Session Organization**

**Morning session**

* Activity One: Worksheet
* Activity Two: Prepare earth lodge frame materials
* Activity Three: Prepare earth roof structures

**Lunch**

**Afternoon session**

* Complete Activity Two
* Complete Activity Three
* Activity Four – Build Tipi Frame and complete activity (*optional*)

**Activity One – Northern Plains Native American Ancient Dwellings**

1. **Provide the definition and primary purpose of the following structures**

Tipi

Long House

Earth Lodge

Low Earth Lodge

Wigwam

**B. Determining the slope of roofs and other structures**

**How to use a protractor**  <https://www.wikihow.com/Use-a-Protractor>

1. **Approximate the measure of your angle.** Angles can be classified in three ways: acute, obtuse, and right. Acute angles are narrow (less than 90 degrees), obtuse angles are wide (greater than 90 degrees), and right angles are exactly 90 degrees (two lines perpendicular to each other).[[1]](https://www.wikihow.com/Use-a-Protractor#_note-1) You can easily identify by eye, the category of angle you are trying to measure. Doing this step first helps you identify which scale to use on the protractor.
2. **Rotate the protractor to align one leg of the angle with the baseline.** Maintain the vertex of the angle in the origin and gently rotate the protractor so that one of the legs of the angle falls on the baseline of the protractor.[[3]](https://www.wikihow.com/Use-a-Protractor#_note-3)

* The baseline is parallel to the edge, but is not the flat edge of the protractor. It is aligned with the center of the origin and the line projects to the start of the scale on either side.

1. **Follow the opposite leg of the angle up to the measurements on the protractor's arc.** If the line does not pass through the protractor’s arc, extend the angle's line until it does. Alternatively, you can align the edge of a piece of paper with the angle’s leg to pass beyond the edge of the protractor, continuing the line of the angle. The number the line passes through is the angle's measurement in degrees.
2. Draw a horizontal line 5 cm in length
   1. At one end of the 5 cm line draw a 4 cm line perpendicular to the horizontal line.
   2. Draw an line connecting the two lines to illustrate the slope
   3. Place the origin of the protractor at the vertex of the slope to be measured
   4. It may be necessary to extend the line to read the slope on the protractor
   5. Determine and record the slope lining. **\_\_\_\_\_\_\_**
3. Draw a horizontal line 4 cm in length
   1. At one end of the 4 cm line draw a 2 cm line perpendicular to the horizontal line.
   2. Draw an line connecting the two lines to illustrate the slope
   3. Place the origin of the protractor at the vertex of the slope to be measured
   4. It may be necessary to extend the line to read the slope on the protractor
   5. Determine and record the slope lining. **\_\_\_\_\_\_\_**
4. Draw a horizontal line 2 cm in length
   1. At one end of the 2 cm line draw a 3 cm line perpendicular to the horizontal line.
   2. Draw an line connecting the two lines to illustrate the slope
   3. Place the origin of the protractor at the vertex of the slope to be measured
   4. It may be necessary to extend the line to read the slope on the protractor
   5. Determine and record the slope lining. **\_\_\_\_\_\_\_**

The slope of a low earth lodge roofs is constructed at a 30o slope

The supports for the outside frame of low earth lodge are at a 45o slope.

**ACTIVITY TWO – Building design of a low earth lodge and a surface earth lodge**

To complete this exercise the student group should be divided into two groups, 2A and 2B. Group 2A will build the low earth lodge and Group 2B will build the surface earth lodge.

1. **Frame building; Group 2A only**
2. Cut 10 bamboo skewers 4 cm in length for the outer frame
3. Cut 20 bamboo skewers 5 cm – 6 cm in length for the roof saplings
4. Cut 10 bamboo skewers 6 cm in length for the cross-beam on top of the outer frame
5. Cut 4 dowels approximately 7.5 cm in length for the inside center poles
6. Cur 4 dowels approximately 5 cm in length for the cross-beams
7. Slash one end of each of the 7.5 cm dowel approximately 1cm deep
8. Cut 10 bamboo skewers 2 cm in length for the outer frame supports.

**Frame building; Group 2B only**

1. Cut 10 bamboo skewers 2 cm in length for the outer frame
2. Cut 20 bamboo skewers 5 cm in length for the roof saplings
3. Cut 10 bamboo skewers 6 cm in length for the cross-beam on top of the outer frame
4. Cut 4 dowels 4 cm in length for the center pole
5. Cur 4 dowels approximately 5 cm in length for the cross-beams
6. Slash one end of each of the 5 cm dowels approximately 1cm deep
7. **Building the center cross-beams for the low earth lodge; Group 2A and 2 B will each build a center cross beam**

a. Place the four 5 cm dowels together to form a square as illustrated below

b. Use the slashes to hold the cross-beams together

1. **Preparing the earth soil (Group 2A and 2B together)**
2. Prepare one batch on the earth soil to ensure the composition of the earth soil is the same for each structure
3. Double the recipe for the earth clay soil described in Materials
4. Add the dirt/soil
5. Add the clay but first break it into clumps
6. Add the grass shavings
7. Add water: the earth – clay soil should be fairly damp but still stay in clumps
8. Knead the earth-clay material until it has an even composition
9. **Earth floor (Group 2A only )**
10. Use the swing-arm protractor to draw a circle with a 7.5 cm radius on the flat board to produce a 15 cm circle
11. Completely cover the 15 cm circle with the earth soil until it is 3 cm thick
12. Extend the 15 cm circle another 2 cm with the earth soil until it is 3 cm thick
13. Use a swing-arm protractor to draw a 7.5 cm radius in the earth soil
14. Remove the earth soil (save) from the 15 cm circle until the circle area is 1 cm below the surface earth soil

**Earth floor (Group 2B only)**

1. Use the swing-arm protractor to draw a circle with a 7.5 cm radius on the flat board to produce a 15 cm circle
2. **Fire Pit (Group 2A and 2B will each do for their own dwelling)**
3. In the center of the 15 cm circle draw a 2 cm radius circle for the fire pit.
4. Remove the earth soil from the fire pit until it is 0.5 cm deep (Group 2A only)
5. Place small pebbles around the rim of the fire pit
6. **Center frame (Group 2A)**
7. Place the 4 dowels 7.5 cm in length in square around the fire place.
8. Sink the dowels until only 5 cm are above the floor surface

**Center frame (Group 2B)**

1. Place the 4 dowels 4 cm in length in a square around the fire place.
2. It may be necessary to use a little earth soil to keep the dowels upright
3. **Building the outer frame (Group 2A)**
4. Place the 10 bamboo skewers, each 4 cm in length, along the inside rim until only 2 cm are above the soil.
5. The space between each pole should be around 5 cm.

**Building the outer frame (Group 2B)**

1. Place the 10 bamboo skewers, each 2 cm in length, along the inside rim, a little earth soil may be used to keep the skewers upright.
2. The space between each pole should be around 5 cm.
3. **Adding the outer supports** **(Group 2A only)**
4. Add a 2 cm bamboo skewer to each outside frame dowel at a 45o angle.
5. Sink the base of the skewer into the mud a little ways to provide support.
6. To determine the 45o angle use a piece of scrap paper to draw horizontal line approximately 5 cm in length
7. Draw a perpendicular line 2 cm line.
8. Use the protractor to draw a 45o angle between the two lines
9. Cut the triangle out and use it to determine how to place the supports against the outer poles.
10. **Adding the earth soil to the frame** **(Group 2A and Group 2B)**
11. Carefully add the earth soil around the outer frame. Leave an opening between to supports for the door.
12. The earth soil should be at an equal thickness around the whole structure (Group 2A and Group 2B lodges should have the same thickness)
13. As the outer frame is covered with earth soil, carefully add the 10-6 cm cross-beams on top of the outer frame using the earth soil to hold the cross-beams in place
14. Rest 15 to 20 5 cm bamboo skewers to form the roof saplings between the center frame and the outer frame; it may be necessary to add earth soil to hold the structure together. (Note the slope of the roof.)
15. Finish adding the earth soil to the roof, leaving an opening for the smoke hole.
16. Allow the earth lodges to dry before completing the rest of Activity Two.
17. **Testing the strength of the earth lodge design (Group 1A and 2A should do at the same time)**

Write a hypothesis (or null hypothesis) as to which dwelling will collapse first.

1. Prepare 10 piles of pennies or beads, each pile containing 10 pennies
2. Weigh (grams) and record the weight of each pile in the table below

|  |  |
| --- | --- |
| Penny Piles (or other small object) | Weight of pile |
| 1. |  |
| 2. |  |
| 3. |  |
| 4. |  |
| 5. |  |
| 6. |  |
| 7. |  |
| 8. |  |
| 9. |  |
| 10. |  |
|  |  |
|  |  |

1. Add one pile of pennies to the cover on the roof of the earth lodge; pressure is being placed to the top of the roof. The pressure is spread from the roof to all the other supports in earth lodge.
2. Continue to add pile of pennies until one of the earth lodge roof collapses. It may be necessary to add more than 10 piles to the cover.

Which earth lodge (low earth lodge or surface earth lodge) collapsed first?

How many grams were required for the lodge to collapse?

**ACTIVITY THREE – The slope of the roof (only one group of students)**

**Preparing the roof structures for Activity three**

1. Place 4 pop sickle sticks in parallel to form a square
2. Cover the pop sickle sticks with 5 perpendicular to the parallel pop sickle sticks
3. Each frame will be approximately a 12 to 13 cm square
4. Prepare a total of three different roof frames
5. If it appears you will do not have enough earth soil from Activity Two to cover three roof frames add more dirt, clay, and grass to the already prepared earth soil to ensure each roof frame will be covered with earth soil of the same composition.
6. Allow the frames to dry

**Activity Three Experimental Procedure**

1. Place one of the earth roof structures on a flat surface
2. Place the second earth roof structures at a 30o angle
3. Place the third earth roof structures at a 60o angle
4. Using a spray bottle spray each roof with 50 sprays of water
5. Describe the results below
6. Earth roof structure with a flat slope (180o):
7. Earth roof structure at a 30o slope:
8. Earth roof structure at a 60o slope

**ACTIVITY FOUR – Comparing the design of the 3-pole or 4-pole tipi frame**

**Preparing the frame: different groups will prepare one of the two frames**

1. Make the tipi frame on a 8 X 11.5 sheet of clear paper
2. Decrease the length of the poles (bamboo skewers) for the 3-pole tipi by 10 cm (8 poles total)
3. Mark where the plume begins for the poles near the tip with a marker, pen, or pencil. *The pole area above the yarn (buffalo hides) are referred to as a plume*.

* 3-pole 3cm from tip
* 4-pole 10 cm from tip
* *The pole area above the yarn (buffalo hides) are referred to as a plume*.

1. For the **3-pole tipi** use yarn to tie the poles (bamboo skewer) together 3 cm from the pointed end. For the **4-pole tipi** use yarn to tie the poles (bamboo skewer) together 10 cm from the pointed end.
2. Mark the center poles near the tip with a marker, pen, or pencil.
3. **3–pole tipi:** Rest an additional 5 poles against the 3-pole center frame; make sure the plumes extend 3 cm above the point where the center frame was tied.

**4–pole tipi:** Rest an additional 4 poles against the 4-pole center frame; make sure the plumes extend 5 cm above the point where the center frame was tied.

7. Carefully tie the poles to the center poles

1. Once all the poles are tied together, carefully trace the structure of the base on the paper, using the center poles as a guideline

Are you able to determine whether one of the tipi frames is more oval than the other? If so, which tipi frame is more oval?

Does the plume size affect the shape of the tipi?

1. Remove the tipi frame from the paper
2. Place the swing-arm protractor to draw a circle around the poles.

What is the diameter of the base circle?

3-pole tipi \_\_\_\_\_\_\_\_\_\_

4-pole tipi \_\_\_\_\_\_\_\_\_\_

Is there a difference between the diameter of the 3-pole and 4-pole tipi base?

**Review Questions and Discussion**

1. What type of fiber is added to the earth soil to strengthen the earth soil?
2. If the fiber is not added, what would happen to the earth soil as it dries in the sun? (*Hint: think of mud when it dries after a rainstorm.*)
3. Provide two examples of why the ancient Native American design of the low earth lodge provides more strength to the lodge than the surface earth lodge.
4. The center frame of the low earth lodge was 10 to 15 ft in height. Provide a reasonable explanation of how the ancient Native Americans were able to cover the complete frame with earth soil.
5. The outer frame of the Knife River earth lodge is encircled with poles to support the frame. Provide an explanation of why Northern Plains Native Americans in pre-Columbian times used earth soil to cover the outer frame instead of more poles?
6. How does the slope of the roof affect the strength of the low earth lodge?
7. What is the ratio of the height of the poles between the 3-pole tipi and 4-pole tipi?
8. What is the ratio of the tipi frame plumes between the 3-pole tipi and 4-pole tipi?
9. Describe how the ratio of the plumes affects the diameter of the base for the 3-pole tipi and 4-pole tipi.
10. Describe the shape of the 3-pole tipi plum and the 4-pole tipi plume. Which plume appears to have a more organized structure? Can you provide a reason why a more organized plume would benefit the dwellers of the tipi?