Lesson Objectives:
- Students define seed germination, identify seed anatomy and understand what requirements are needed for seeds to germinate
- Using the Scientific Method, students will design an experiment that tests a variable against a control group
- Students will predict and summarize an experiment and data
- Teachers can apply various math concepts/objectives which are appropriate for the grade level

Teacher Background: Most plant reproduction includes the development and dispersal of seeds. Since plants do not care for their offspring, seeds are equipped with most everything they need to survive. But before seeds can germinate (grow/sprout), certain external environmental conditions must be met. These include appropriate amounts and types of water, light, soil (substrate to grow in), and temperature. Each species of plants has different requirements as well as different ranges of tolerability. Seeds will stay dormant until minimum requirements are met. When the students begin to design their experiments, the students should control everything but one variable.

Target Grade Level: 3, 4, 6

Common Core State Standards:
- 3-LS1-1 (1)
- 3-LS1-3 (1)
- 4-LS1-1 (1,2,3)
- MS-LS2-2 (2,3,4,7)

Time: 45-60 min
Inquiry project will take an additional 45-60 minutes, plus daily observations and measurements

Materials:
- Lima bean seeds: some dry and some soaked in water for 1+hr (for dissection)
- Various craft supplies
- Inquiry project materials (Ziploc bags, paper towels, rulers, string, water)

Engage: Distribute dry seeds. Ask students:
- Are these seeds alive or dead? Why do you think that?
- Just like animals, reproduction is vital for the species. When plants reproduce, what do their babies look like? (not all plant species produce seeds)
- How does a plant care for its offspring?
- Let’s review. What do seeds need to grow? (Soil, water, sun, air, correct temperature)
Explore: Parts of a seed
- Distribute the following for each student or pair: 3-5 dry lima bean seeds, 3-5 lima beans soaked in water for 1+ hour.
  - Observe and compare the lima beans. (Magnifying glasses optional)
    - What differences are observed in the pre-soaked and un-soaked seeds?
      - Size, feel, presence of seed coat, etc.
  - Using your finger, remove the outer shell of a soaked seed.
  - Carefully split open one of each of the seeds. What do you see?
  - Observe what’s inside. Can the students recognize any plant parts?
    - Look for the baby plant inside. Can you see the leaves, roots, and stem? (The plant parts can be hard to identify. Maple tree seeds tend to have green embryos, making them easier to observe)
  - Observe the large area inside the seed coat that is not the baby plant. Why is this portion so important?

Explain: Seed anatomy and germination requirements
Ask students to make inferences about the function of the seed parts that they have observed during their dissection. How could the function of these parts help the seed get what it needs to grow?

Seeds have special structures to protect and help them come “alive” and grow. When a seed begins to grow, it **germinates**. Germination requires certain conditions. Seeds will not germinate until the right conditions are met for that type of seed. Sometimes this takes years! Let’s take a closer look at the seed.

- **Protection**: Baby plants need protection—the seed is surrounded by a hard outer layer called the **seed coat**. The seed coat helps keep the seed warm and safe. It also expands to allow air and water in.
- **Water**: Look closely at a seed. Notice a small spot on the seed coat. This is called the **micropyle**. The micropyle is a small opening that allows the seed to absorb water. This is why the seeds that were soaked in water are so much larger than the dry seeds. As the seed absorbs water it expands. Eventually the seed will expand so much that the seed coat will split and come off the seed.
- **Embryo**: The smallest part inside the seed is the baby plant. A small leaf and root are present. Eventually the leaf will push up through the soil; and the root down into the soil.
- **Food**: The embryo needs food, but is yet unable to get food from the sun or the soil. Instead, most of the seed is the **endosperm**. The endosperm provides all of the food and nutrients the embryo needs. This is why birds, humans, and other animals eat seeds. They are packed with nutrients!
- **Air**: As the seed coat expands, air enters. The oxygen that is in the air helps the embryo burn the food and nutrients packed in the endosperm. This in turn produces energy, which the embryo will use to help it grow.
Elaborate: Seed Germination & Plant Growth Questions
What do most seeds need to germinate? (light/sun, soil, water, temperature, air). Write these horizontally across the board.

1. What are different ways that light could affect seed germination? (intensity of light, absence of light, color of light, or amount of light). Write these answers directly on board beneath “Light.”
2. What are different ways that soil could affect seed germination? (sand, clay, gravel, absence, etc. Different types of soil will impact the amount of water available) Write these answers directly on the board beneath “Soil.”
3. What are different ways that water could affect seed germination? (pollution, quality, and absence of) Write these answers directly on the board beneath “Water.”
4. What are different ways that temperature could affect seed germination? (freezing seeds before or during, keeping seeds warm, and heating seeds). Write these answers directly on the board beneath “Temperature”.
5. What are different ways air could affect seed germination? (nutrients can’t be used for energy; leaves of plant can’t perform photosynthesis/respiration). Write these answers directly on the board beneath “Air.”

Evaluate: Seed Model and/or Inquiry Project

Seed Model
Ask students: If you were to create a seed that would germinate in a particular Idaho biome, what would it look like? What would the seed need to germinate? Using various craft supplies and creativity (Styrofoam balls cut in half, felt, paper, etc.), have students construct a model of a seed. Students will present their model to the class, using correct terminology describing their seed models.

Inquiry Project
Using the Scientific Method, students will design and conduct a seed germination experiment, lasting up to 2 weeks. Students will use their knowledge of germination requirements as well as optimal conditions posted on seed packs.

- Break students into groups.
- Each group will create a testable hypothesis and design their experiment. Each group will be testing 1 variable against a control.
- Sample size = 5 seeds/treatment.
- For better observation and measurement, paper towels and Ziploc bags can be used instead of soil and a plant pot respectively.
- Students can measure number of seeds germinated, number of leaves, length of root, and total length. Measure growth rates of plants after the seeds germinate by dividing height (length of stem and longest leaf) of the plant by the time they have been growing.
- Rulers only measure straight lines. To better measure height, use a string measured against a ruler.
- For a better classroom comparison, all groups should use the same control protocol.
- To speed up germination, seeds can be soaked in water (this could also be used as a variable).
- Record findings in a notebook.
**Experiment Structure:**

- **Materials:** seeds, paper towel, Ziploc bags, water, rulers, string
- **Question:** How will ______ (amount of water, substrate/soil, light, or temperature) affect seed germination?
- **Hypothesis:** We believe that seeds germinated in ________ will/will not grow as well as those grown in ________.
- **Experimental Design:**
  1. 5 seeds will be tested as the variable in one Ziploc bag and 5 seeds will be tested as the control in a second Ziploc bag.
  2. **Control Protocol & Conditions:**
     a. **Water:** Damp (dampen a paper towel with water and place it inside a Ziploc bag. Check the paper towel daily (except weekends) and moisten as needed)
     b. **Substrate/Soil:** Paper Towel (place the 5 seeds inside the control bag on top of the dampened towel)
     c. **Light:** Light (seal the Ziploc bag and place it in a well-lit area)
     d. **Temperature:** Warm (place the Ziploc bag in a warm, climate-controlled environment)
  3. For the variable, ask students to adjust one of the above requirements (amount of water, paper towel (representing soil), light, or temperature) needed for seed germination
  4. **Reminder:** when students are designing their experiment they should keep all variables other than the tested variable consistent with the control treatment.
- **Data Collection:** Observe and record findings daily for the next 2 weeks. Entries may include measurements, drawings, description, etc. The length of time it takes for each seed to germinate will be recorded (# of days) and a seed will be considered un-germinated after 1 week of no growth. After the seeds germinate, growth will be determined by measuring the height of the plant with a ruler.
- **Data Analysis** (graphs, calculations, etc.)
- **Draw Conclusions:** Our hypothesis was/was not supported by our results.
- **Report Results:** Present to class
- **Reflection:** What affected the results, what would each group do differently next time, do the results make sense, what was learned, why does it matter?

**Examples of Testable Hypothesis:**

- *How will the absence of water affect seed germination?* We believe that seeds germinated on a dry paper towel (variable) will not grow as well as those germinated on a damp paper towel (control).
- *How will the type of substrate (soil/paper towel) affect seed germination?* We believe that seeds germinated on a damp cotton ball (variable) will grow as well as those germinated on a damp paper towel (control).
- *How will absence of light affect seed germination?* We believe that seeds germinated inside of a dark box in the classroom (variable) will not grow as well as those germinated outside of a dark box in a classroom (control).
- *How will cold temperatures affect seed germination?* We believe that seeds germinated on the outside of a window (variable) will not grow as well as those germinated on the inside of a window (control).