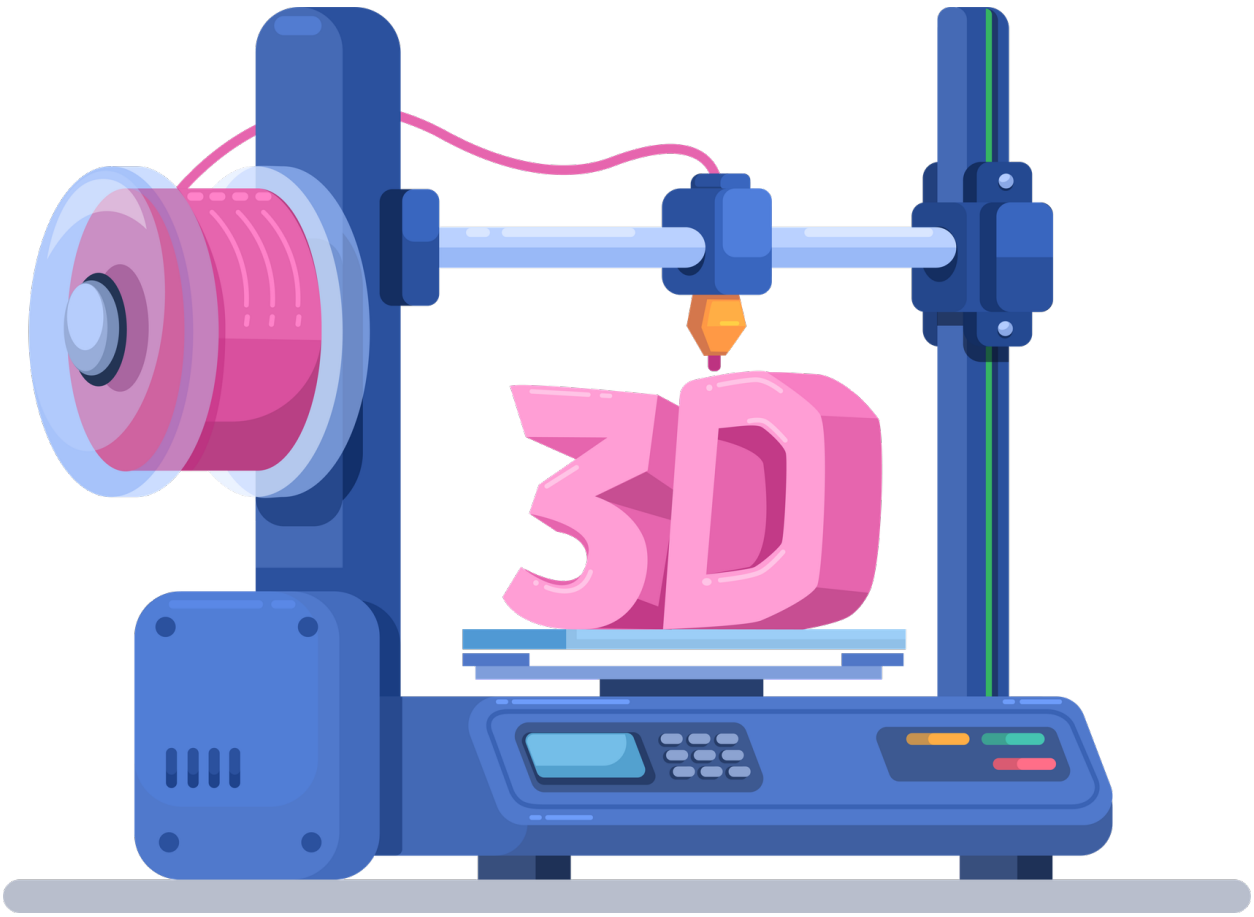
Print, Play, and Prototype: Creating Custom STEM Learning



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Standards for Possible Activities/Lessons

Elementary (K-5)

3D Print / Activity	Grade	Florida Science Standard	How the 3D Print Addresses It
🌸 Parts of a Flower	1	SC.1.L.14.2	Students identify the major parts of plants, including stem, roots, leaves and flowers.
🌸 Build-a-Flower / Flower Anatomy	3	SC.3.L.14.1	Students describe plant structures and their roles in food production, support, transport of water/nutrients and reproduction. This is the best standard for your detailed 3D flower model.
🌱 Plant Life Cycle Puzzle	2	SC.2.L.16.1	Students observe and describe major stages in plant and animal life cycles, specifically including beans and butterflies.
🦋 Butterfly Life Cycle	2	SC.2.L.16.1	Students arrange 3D models of egg → larva → pupa → adult and describe the stages of the life cycle.
🌻 Florida Plant/Animal Life Cycles	4	SC.4.L.16.4	Students compare major stages in the life cycles of Florida plants and animals, including metamorphosis and flowering/nonflowering seed-bearing plants.

🧠🫀 Human Body Parts Model	2	SC.2.L.14.1	Students identify the brain, heart, lungs, stomach, muscles and skeleton and describe their basic functions.
🐓 Animal Classification / Adaptation Models	3	SC.3.L.15.1	Students classify mammals, birds, reptiles, amphibians, fish, arthropods, vertebrates and invertebrates according to physical characteristics and behaviors.
🌿 Flowering vs. Nonflowering Plant Models	3	SC.3.L.15.2	Students classify flowering and nonflowering plants according to physical characteristics.
🌻🌱 Plant Needs Model	3	SC.3.L.17.2	Students use the model to demonstrate that plants use energy from the Sun, air and water to make food.
🌱🌻 Plant Response Model	3	SC.3.L.14.2	Students model how roots and stems respond to light and gravity.
🔬 3D Model Investigation	3	SC.3.N.1.1	Students ask questions, investigate, make observations and generate explanations from their investigation. This can accompany almost any of the Grade 3 3D-print activities.

Middle School (6-8)

3D Print / Activity	🔬 Science	📐 B.E.S.T. Math	💻 Computer Science / Technology	Student Activity

🌋 Plate Boundary Simulator	SC.7.E.6.5 œ Explore plate tectonics and how plate movement relates to earthquakes, volcanoes and mountain building. SC.7.E.6.7 œ Relate Earth's internal processes to changes in Earth's surface.	MA.7.AR.3.2 œUse ratios/proportions in real-world problems. MA.7.AR.3.3 œ Convert measurements.	SC.7.CO.1.1 œ Identify content associated with different file types. SC.7.CO.1.2 œ Differentiate file types. SC.7.CO.1.3 œ Describe relationships between hardware and software.	Students manipulate printed convergent, divergent and transform boundaries. They can then design or modify a plate model, prepare the digital file and print/test it.
🪨 Build the Rock Cycle	SC.7.E.6.2 œ Identify patterns within the rock cycle and relate them to surface and geologic processes.	MA.7.AR.3.2 œ Apply proportional reasoning. MA.7.AR.4.5 œ Solve real-world problems involving proportional relationships.	SC.7.CO.1.1–1.3 œ File types and hardware/software relationships.	Students use 3D-printed igneous, sedimentary and metamorphic rocks plus process pieces to construct multiple pathways through the rock cycle.
🌎 Layers of Earth Puzzle	SC.7.E.6.1 œ Describe Earth's layers and their characteristics.	MA.7.AR.3.2 œ Proportions. MA.7.AR.3.3 œ Measurement conversions.	SC.7.CO.1.1–1.3 œ Digital file types and hardware/ software.	Students assemble a 3D cross-section of Earth. They measure the radius/diameter of each layer

				and compare the model's proportions with Earth's actual dimensions.
🏝️ Florida Landforms: Weathering, Erosion & Deposition	SC.6.E.6.1 œ Describe how Earth's surface is built up and torn down through weathering, erosion and deposition. SC.6.E.6.2 œ Recognize landforms found in Florida.	MA.6.AR.3.1 œ Interpret ratios. MA.6.AR.3.2 œ Determine rates/unit rates. MA.6.AR.3.5 œ Solve real-world ratio/rate problems, including ratios of lengths.	SC.6.CO.1.1 œ Identify multiple file formats, explicitly including three-dimensional drawings.	Students print a Florida landscape containing features such as a coastline, river, dune and wetland and predict how erosion and deposition will change the landscape.
🧩 Reconstruct Pangaea	SC.7.E.6.5 œ Plate tectonics and plate movement. Students use fossil, rock, climate and geographic evidence to reconstruct Pangaea.	MA.7.AR.3.2 œ Ratios/proportions. MA.7.AR.3.3 œ Measurement conversions. MA.7.AR.4.5 œ Proportional relationships in real-world contexts.	SC.7.CO.1.1 œ Identify content associated with file types. SC.7.CO.1.2 œ Differentiate file types. SC.7.CO.1.3 œ Explain hardware/software relationships	

High School

3D Print / Activity	🔬 Science Standards	📐 Math Standards	💻 Computer Science Standards	Student Activity
🌸 Parts of a Flower Model	SC.912.L.14.7 œRelate major plant organs/tissues to physiological processes. SC.912.N.1.1 œ Scientific investigation, observation, measurement and analysis.	MA.912.GR.4 œ Geometric measurement/modeling. MA.912.AR.1 œ Algebraic relationships and proportional reasoning. MA.912.DP.1 œCollect and analyze data.	SC.912.CO.1.1 œ Select/evaluate digital tools. SC.912.CO.1.2–1.3 œDigital file formats/types. SC.912.CO.3 œ Create computational artifacts.	Students model the parts of a flower identifying the structures and the arrangement. Compare to diagrams and to actual collected flower specimens.
💀 Human Skull /	SC.912.L.14.12 œOrganization of the human body. SC.912.N.1.1 œ Investigation and evidence.	MA.912.GR.4 œ Measurement and geometric modeling.	SC.912.CO.1.1, SC.912.CO.3	Print out different hominid skull types. Have students compare jaw size, forehead and cranial capacity using calipers. Students will build the evolutionary tree of hominid evolution

🦴 Male/Female Pelvis Comparison	SC.912.L.14.12 œHuman body organization. SC.912.N.1.1 œ Observation and analysis.	MA.912.GR.4 œ Measurement, dimensions and geometric comparison. MA.912.DP.1 œData analysis.	SC.912.CO.1.1, SC.912.CO.3	Students compare pelvis shapes and angles. Students examine the reason for the differences and make a prediction based on their understanding
🦴 Long Bones / Height Estimation	SC.912.N.1.1 œ Collect and analyze scientific evidence.	MA.912.AR.1 œ Algebraic relationships/modeling. MA.912.DP.1 œData analysis.	SC.912.CO.1.1, SC.912.CO.3	Print out
🧬 DNA Double Helix Model	SC.912.L.16.3 œDNA replication. SC.912.L.16.4 œDNA, RNA and protein synthesis.	MA.912.DP.1 œData and probability applications.	SC.912.CO.1.1, SC.912.CO.3	Students assemble a DNA double helix and an RNA strand. Note which pieces fit together Identify the other parts of the strand and label them. have them hold it up to show the twisted nature of the model.

Goals & Objectives

- Transform 3-D printing from a novelty into a powerful instructional tool that supports both teacher-created resources and student-driven innovation.

Part 1: Teacher created items: Participants will learn how to design and print affordable classroom manipulatives, models, and lab equipment that make abstract STEM concepts easier to visualize while reducing instructional costs.

Part 2: Student experience: Learn how to use 3-D printing to facilitate design thinking, engineering, and problem-based learning.

- Teachers will explore strategies for guiding students through the process of designing, testing, refining, and printing solutions to authentic scientific and engineering challenges.
- By combining practical classroom applications with student-centered design, this approach strengthens spatial reasoning, creativity, critical thinking, and problem-solving while increasing student ownership and engagement.

Part 3: Receive ready-to-use ideas for integrating 3-D printing into STEM instruction in ways that are innovative, cost-effective, and immediately applicable.

Goals for Students:

- **Scientific Investigation:** Use 3-D printed anatomical, geological, and engineering models to explore concepts that are difficult to observe in real life.
- **Comparative Analysis:** Measure and compare anatomical models, fracture patterns, and tectonic plate movements to draw evidence-based scientific conclusions.
- **Engineering Design:** Design, print, test, and improve original 3-D solutions to authentic scientific and engineering challenges.
- **Biomimicry:** Create structures inspired by nature that maximize strength while minimizing material use.
- **Environmental Engineering:** Design and evaluate 3-D printed water filtration systems by testing how different structures affect water flow.
- Astronomical Modeling: Build and investigate 3-D topographical models to understand how surface features, light, and shadows influence astronomical observations.

Goals for Teachers

- Instructional Integration: Learn how to use 3-D printing to teach STEM concepts through hands-on investigations rather than technology demonstrations.

- Digital Design Resources: Discover how to locate, customize, and prepare high-quality 3-D models for classroom instruction using beginner-friendly design tools.
- Engineering Design Process: Explore strategies for guiding students through testing, troubleshooting, and redesign while using failed prints as valuable learning opportunities.
- Hands-On STEM Investigations: Experience classroom activities that use 3-D printed models to collect data, solve problems, and explore scientific concepts.
- Quantitative Analysis: Learn how to design investigations that incorporate measurement, data collection, and evidence-based analysis using 3-D printed models.
- Cost-Effective Prototyping: Implement simple prototyping techniques that help students refine designs before printing, reducing material waste while strengthening design-thinking skills.

Materials

- 3-D printer
- 3-D printer filament
- Access to a computer with free 3-D software (Tinkercad)

Project Overview

In this hands-on workshop, the focus shifts from simply "how to print" to "how to teach with the technology." You will engage in demonstrations and strategies for project design.

Workflow for Curating vs Creating

Problems	Educational Impact	Solutions
Time	• 3D models helps build understanding • Students become leaders • High quality - accurate builds helps reinforce challenging concepts	• Plan a unit ahead - a class set takes some time to print • Get students to help you--choose students that can be your printer experts/helpers • Use all the free sites where prints are already planned out--a lot of the troubleshooting has already occurred!

Why Bother?	• Increase engagement • Students as problem solvers • Hands on education so students can really get it • Engineering interwoven into your topic seamlessly	• Plan an activity for every unit - 1x a week or every other week. • Most can be done ahead of time. • For student projects: they need to be ongoing... don't expect to finish in one week.

Engineering - Failure to Fix Loop

Curating

Problems	Solutions
Time Crunch	• Only plan 1 creative "make" a term to allow time for students to plan and for you to print their designs.
Materials	• Use lighter colored filaments - let the students paint their designs - saves time and money on changing out the filament often for their preferences. • Taking the time to paint is OK as others are still waiting for their prints.
Student Ideas floundering	• Get them started with sites that have completed similar designs. Teach them how they can get inspired by others ideas and how to make their own. • You can model with playdough or similar to get an idea of what you are trying to create. • Have student experts lead others in how to make the fixes and to perfect their ideas and designs.

Hands-on Lab Integration

Print Class Sets	*Create a set of Challenges*	*Additional Suggestions*
• 1 per table/group • Make it manipulative • Students may have to assemble the pieces like a puzzle • Students hold it, turn it, refer to other sources such as text or online references	• Decide on your goals of the assignment • Students answer questions as they manipulate the items • Have them label the diagram by drawing on the table œOr use cut out labels that they can arrange • Ask students questions that are challenging but age appropriate.	• Give students an opportunity to discover on their own. Don‘t give them all the details/answers yet. • Provide a problem and have them figure it out just by studying the printed object(s) .

Lesson Plans - Examples

Elementary	What to Print	Summary
Parts of a flower **SC.1.L.14.2** **SC.3.L.14.1**	Print out separate flower parts and ask them to assemble	• Students identify the role of each part of the flower • Students go outside and find real flowers (from weeds in the grass) • Use a magnifying glass and identify the same parts. • Label them on a sheet of paper.

How can we tell what animals eat?	Print out different jaws with teeth • Omnivores • Herbivores • Carnivores	• Students examine the teeth and determine why those type of teeth are required for those kind of foods





Middle School	What to Print	Summary
How Has the Earth Changed Over time?	Continents with markings of fossils found across continents Create a set for each group Consider each major continent in a different color (paint or print them separately)	• Have students explore the shape of the continents and how they might have moved over time. • Relate our understanding of plate tectonics to the slow movement of the continents



High School	What to Print	Summary

Parts of a Flower
SC.912.L.14.7
https://www.printables.com/model/1629333-parts-of-a-flower
	Print out the parts of a flower including
	• petals
	• stem
	• pistil
	• ovary
	• stamen
	Use the same filament to save time and paint them different colors.
		• Have students examine a real flower picked from the flowering weeds on campus.
		  ○ Provide magnifying glasses for each student
		  ○ They should separate the parts
		  ○ Try and assemble the 3D version identifying the same parts
		  ○ Label the parts from a diagram in the text or handout.

Skin Layers https://www.printables.com/model/312446-skin-layer-model-improved/files	Print out sets of skin layers that students can assemble • Epidermis • Dermis • Hypodermis • Hair • Blood vessels Print in different colors or paint them separately	• Students will explore the layers of skin by assembling the skin layers model. • See what is happening at each level: function and structures • Determine where skin cancer types occur and why • How our skin is the first level of our immune system • Where our pigmentation comes from • The difference between a temporary tattoo such as henna vs a permanent tattoo based on the depth the ink is placed.

What Can We Learn from Bones https://www.printables.com/model/1275355-human-vertebral-column/files SC.912.L.14.1 – Cell theory SC.912.L.14.12 – Organization of human body SC.912.N.1.1 – investigation MA.912.GR.4 – Geometric measurement/modeling SC.912.CO.3 – Use software to create computational artifacts	Print out the Vertebrae (all portions) pieces • Lumbar • Thoracic • Cervical Additionally: • Male pelvis • Female pelvis	**Backbone** • First have them attempt to assemble the pieces without any guidance • Then provide a 'map' • Explore the size and shape differences for each section • Identify the attachment points, names and shape and their purpose Examine the structure and how it protects your spinal cord but still allows movement **Structure of the Pelvis** • Students examine the difference in shape and angles. • Ask students to try and determine which is male and female by the shape and differences in each type. • Interesting as we consider body shape and the ability to birth a baby

Full Lesson Plans

🌸 3D-Printed Flower Investigation

Florida Grade 3 Science — Parts and Functions of a Flower

Grade Level: 3
Subject: Science / STEAM
Topic: Plant Structures and Functions
Time: Approximately 60 minutes
Grouping: Pairs or groups of 3–4 students

Florida Science Standard

SC.3.L.14.1

Describe structures in plants and their roles in food production, support, water and nutrient transport, and reproduction.

This is a current State Board-approved Grade 3 Life Science benchmark. Florida's assessment guidance emphasizes students' ability to identify and describe plant parts and their roles. For assessment purposes, major plant structures include the **stem, leaf/needle, root, flower, seed, and fruit**.

Focus of This Lesson

This lesson concentrates specifically on the **flower** and its role in plant reproduction. Students use an enlarged 3D-printed flower to examine structures that can be difficult to see clearly on a real flower.

Learning Goals

By the end of the lesson, students will be able to:

- Identify a **flower** as a reproductive structure of a flowering plant.
- Identify major structures of a flower on a 3D model.
- Describe the basic function of each structure.
- Assemble the flower structures in their correct locations.
- Explain how the structures work together to help a plant reproduce.
- Use observations from a physical model as evidence when answering questions.

Student-Friendly Learning Goal

I can identify the parts of a flower and explain how the parts help the plant reproduce.

Vocabulary

Term	Student-Friendly Meaning

Flower	The part of many plants involved in making seeds
Petal	Often colorful structures that can help attract pollinators
Sepal	Structures that protect the developing flower bud
Stamen	Male reproductive structure of the flower
Anther	Part of the stamen where pollen is produced
Filament	Stalk that supports the anther
Pistil/Carpel	Female reproductive structure of the flower
Stigma	Sticky surface that receives pollen
Style	Connects the stigma to the ovary
Ovary	Structure containing the ovules
Ovule	Structure that can develop into a seed after fertilization
Pollen	Contains the male reproductive cells of flowering plants

Teacher note: Florida's Grade 5 Statewide Science Assessment specifications associated with SC.3.L.14.1 limit assessed flower reproductive structures to concepts including **stamen, pistil, ovary, petal, sperm, and egg**. Therefore, students can explore the additional structures on the model without requiring memorization of every term for assessment purposes.

Materials

Per Student Group

- 1 large **3D-printed flower model**
- Detachable:
    - Petals
    - Sepals
    - Stamens
    - Anthers
    - Filaments
    - Stigma
    - Style
    - Ovary
    - Ovule(s)
    - Flower base/receptacle
- Student **3D Flower Investigation Guide Sheet**
- Pencil
- Colored pencils
- Hand lens, optional
- Real flower for comparison, optional but highly recommended

Teacher Materials

- Completed 3D flower model
- Enlarged flower diagram or projected image
- Extra flower pieces
- Vocabulary cards
- Small containers or labeled bags for storing each model set

🖨️ Teacher Preparation: Preparing the 3D Prints

Step 1 — Select the Model

- Choose a flower model that:
- Can be printed relatively large.
- Has clearly distinguishable structures.
- Can be taken apart and reconstructed.
- Has sturdy pieces appropriate for repeated student handling.
- Shows a cross-section of the ovary if possible.

Recommended finished size: approximately **6–10 inches across**.

The goal is not perfect botanical detail. The model should **simplify and enlarge structures so third-grade students can understand their location and function**.

Step 2 — Print the Pieces

- Print enough models for students to work in groups of approximately **3–4**.

For a class of 24 students:

- **6–8 flower sets** should work well.
- Print replacement petals, stamens, and other small pieces because these are the pieces most likely to be misplaced.

Step 3 — Color the Model

- If using multicolor filament, print the structures in contrasting colors.
- If using one filament color, paint the finished pieces with acrylic paint.

Suggested Color Coding

Flower Structure	Suggested Color
Petals	Pink, purple, red, or another bright color
Sepals	Green
Anther	Yellow
Filament	Light green or white
Stigma	Purple
Style	Light purple
Ovary	Green
Ovules	White or yellow

- The colors do **not** need to represent the actual colors found in nature. Explain to students that the color coding helps them distinguish structures.

Step 4 — Prepare Student Sets

- Place each flower set in a numbered container:
    - **Flower Investigation Set #1**
    - **Flower Investigation Set #2**, etc.
- Initially, give students the flower **disassembled**.
    - This is important. The activity becomes an investigation rather than simply looking at a completed model.

⏱️ **Lesson Sequence — Approximately 60 Minutes**

Time	Activity
5 min	Engage — What's Inside a Flower?
10 min	Mini-Lesson — Plant Structures & Flower Function
10 min	Explore the 3D Pieces
15 min	Build the Flower
10 min	Student Guide Sheet
5 min	Group Discussion
5 min	Exit Ticket

🌺 **Part 1 — ENGAGE: What's Inside a Flower?**

- 5 minutes
- Show students a real flower.
- Do not immediately identify all of its structures.

Ask:

What do you notice about this flower?

- Allow students to share observations.

Then ask:

- Why do you think plants make flowers?
- Are flowers just decorations for plants?
- What might be hiding inside the flower?
- Why might some flowers be brightly colored?
- What do you think happens after a flower dies?

Tell students:

Today you are going to take apart a giant flower and investigate what each structure does.

🌱 Part 2 — MINI-LESSON: Plants Have Structures With Jobs

10 minutes

Briefly review:

- **Roots** — absorb water and nutrients and help anchor the plant.
- **Stem** — supports the plant and helps transport water and nutrients.
- **Leaves** — help the plant produce food.
- **Flowers** — help flowering plants reproduce.

Introduce the idea:

Structure → Function

Explain:

- **Structure** = a part of an organism.
- **Function** = the job that structure performs.

Ask:

"If I tell you the structure is a root, what is one of its functions?"

Then transition:

"A flower also has several structures, and each has a job."

🔎 Part 3 — EXPLORE: Mystery Flower Pieces

- 10 minutes
- Give each group its container of **disassembled 3D flower pieces**.

- **Do not give students the answer diagram yet.**

Tell students:

Your first challenge is simply to investigate.

Students should:

- Remove the pieces.
- Sort similar pieces together.
- Count how many different types of structures they think they have.
- Compare shapes.
- Predict where each piece might belong.
- Predict what each piece might do.

Student Investigation Questions

Ask groups:

- Which structures are repeated?
- Which structure is the largest?
- Which structures are located toward the center?
- Why might the flower have several petals?
- Why do you think some structures are long and thin?
- Which structures do you think are involved in making seeds?
- What evidence from the shape or location supports your idea?

There are **no penalties for incorrect predictions** at this stage.

🧩 **Part 4 — BUILD THE FLOWER**

- 15 minutes
- Now distribute the **3D Flower Investigation Guide Sheet**.
- Students use the guide to assemble the flower.
- As each structure is added, students should identify its function.

Recommended Assembly Sequence

1. Sepals
Protect the flower while it develops.

↓

2. Petals
Often help attract pollinators.

↓

3. Filaments
Support the anthers.

↓

4. Anthers
Produce pollen.

↓

5. Stigma
Receives pollen.

↓

6. Style
Connects the stigma with the ovary.

↓

7. Ovary
Contains the ovules.

↓

8. Ovules
Can eventually develop into seeds following fertilization.

When completed, students should have a fully assembled flower.

Name: _____

Date: _____

My 3D Flower Investigation Guide

Part A — Meet Your Flower

Look carefully at your 3D flower pieces.

1. How many petals does your model have?

2. Which structure is located in the center of the flower?

3. Which structures occur several times around the center?

Part B — Match the Structure With Its Job

Draw a line or write the correct letter.

Structure	Job
Petal	A. Produces pollen
Sepal	B. Receives pollen
Anther	C. Protects the developing flower
Filament	D. Often helps attract pollinators
Stigma	E. Supports the anther

Style	F. Contains ovules
Ovary	G. Connects the stigma and ovary

Part C — Build Your Flower

1. Assemble your flower.
2. When your group thinks it is correct, raise your hand for a teacher check.

Teacher Check

Flower assembled correctly: ✓

Part D — Structure and Function

Complete the sentences.

1. The anther is important because it: _____

_____

2. The stigma is important because it: _____

_____

3. The ovary is important because it: _____

_____

4. The petals may help the flower by: _____

_____

🐝 **Part E — THINK LIKE A SCIENTIST**

Look at your completed flower.

1. A bee lands on the flower and brushes against an anther. **What might get onto the bee?**

2. The bee flies to another flower. **What structure might receive the pollen?**

3. Why might having brightly colored petals help some flowering plants reproduce?

4. Evidence Question A student says: "Flowers are only there to make plants look pretty." Do you agree or disagree? **Use evidence from your 3D flower model to explain your answer.**

💭 Class Discussion Questions

After students assemble their models, bring the class together.

Ask:

- What is the main function of a flower?
- Which structures produce pollen?
- Which structure receives pollen?
- Where are the ovules located?
- Why do you think the reproductive structures are located near the center of many flowers?
- What might happen if a flower had no anthers?
- What might happen if pollen never reached the stigma?
- How could petals help reproduction even though petals don't make pollen or seeds?
- How is our 3D model similar to a real flower?
- How is our model different from a real flower?

That final question is important because students should understand that a **scientific model represents reality but is not identical to the real object**.

🎟️ Exit Ticket — The Flower Challenge

1. What is the main role of a flower?

    A. Absorb water
    B. Support the plant
    C. Help the plant reproduce
    D. Make food for the plant

Answer: C

2. Which flower structure produces pollen?

    A. Petal
    B. Anther
    C. Ovary
    D. Sepal

Answer: B

3. Which structure contains the ovules?

    A. Ovary
    B. Petal
    C. Filament
    D. Anther

Answer: A

4. Explain one way a flower structure helps the plant reproduce.

Assessment

Formative Assessment

- Observe students during the activity for their ability to:
- Correctly identify structures.
- Assemble the flower.
- Match structures with functions.
- Discuss observations with their group.
- Use scientific vocabulary appropriately.

Student Product

- Collect the **3D Flower Investigation Guide Sheet**.

Mastery

- Students demonstrate mastery when they can:
- Identify the flower as a reproductive plant structure and correctly describe the function of major flower structures using the 3D model as evidence.

Differentiation

Students Needing Additional Support

- Color-code the model and guide sheet.
- Provide labeled picture cards.
- Reduce vocabulary initially to **flower, petal, stamen, pistil and ovary**.
- Allow students to physically point to a structure while explaining its function.
- Pair students strategically.

Advanced Students

- Challenge students to explain:
- How pollen could move from one flower to another.
- Why flowers have different shapes.
- How insects might help flowering plants reproduce.
- What happens to the ovary and ovules after fertilization.

An excellent extension is **SC.4.L.16.1**, which addresses pollination, fertilization/seed production, seed dispersal and germination in flowering plants. Florida's assessment specifications explicitly connect this Grade 4 benchmark with SC.3.L.14.1.

🌼 Optional Extension — Real Flower vs. 3D Flower

Give each group a real flower to dissect.

Students compare the actual flower with their model.

Structure	Found on 3D Model?	Found on Real Flower?
Petal	✓	
Sepal	✓	
Anther	✓	
Filament	✓	
Stigma	✓	
Style	✓	
Ovary	✓	

Then ask:

Which model made the flower structures easier to see—the real flower or the 3D print? Why?

This reinforces an important idea: scientists use **models to study structures and processes that may be difficult to observe directly.**

Teacher Preparation at a Glance

- **Several days before:** Print the flower models.
- **1–2 days before:** Remove supports, inspect pieces, paint/color-code if necessary, and organize models into numbered sets.
- **Day before:** Print student guide sheets and check that every kit contains all pieces.
- **Lesson day:** Place one disassembled flower kit at each group station. Keep the completed teacher model hidden until after students make their initial observations.

Recommended Total Preparation

- **Teacher hands-on preparation:** approximately 30–60 minutes, excluding 3D printer run time.
- **Instructional time:** approximately **60 minutes**.
- **Optional real-flower extension:** add **20–30 minutes**.

🌎 Inside Earth: 3D-Printed Layers of the Earth Puzzle

Florida Middle School Science + Math + Computer Science STEAM Lesson

Grade Level: 7
Subject: Earth & Space Science / STEAM
Topic: Earth's Internal Structure
Lesson Length: 60–75 minutes
Grouping: Pairs or groups of 3–4 students
3D Print: Interlocking/cutaway Layers of the Earth Puzzle

Florida Science Standard

- **SC.7.E.6.1**
  - **Describe the layers of the solid Earth, including the lithosphere, the hot convecting mantle, and the dense metallic liquid and solid cores.**
- Supporting Science Practice
- **SC.7.N.1.1**
  - Students define problems, use appropriate reference materials, conduct investigations, organize and interpret data, analyze information, make predictions, defend conclusions, and determine alternative explanations.

Florida Mathematics Connections

- The strongest authentic mathematics connection for this activity is **scale and proportional reasoning**.
- Students compare the actual dimensions of Earth's layers with the dimensions represented by the 3D model.

Math skills include:

- Ratios
- Proportional relationships
- Radius and diameter
- Measurement
- Unit conversion
- Scale
- Percentages
- Comparing quantities

Students should recognize an important limitation of many classroom Earth models:

- **The thicknesses of Earth's layers may not be accurately represented to scale.**
- This becomes an excellent mathematical and scientific-modeling discussion.

Florida Computer Science / Technology Connections

- **SC.7.CO.1.1**: Students work with and identify appropriate digital file types.
- **SC.7.CO.1.2**: Students differentiate among file types and their uses.
- **SC.7.CO.1.3**: Students describe relationships between hardware and software.

The activity provides a real-world example:

- **Digital 3D Model → 3D File → Slicer Software → Printer Instructions → 3D Printer → Physical Model**
- Students do not need to operate the printer for these standards to be discussed. However, allowing students to view the digital model and sliced file before working with the finished print makes the technology connection considerably stronger.

Learning Goals

By the end of the lesson, students will be able to:

- Identify the major internal layers of Earth.
- Correctly assemble a 3D model showing Earth's internal structure.
- Distinguish between the **lithosphere, mantle, outer core, and inner core**.
- Describe important physical characteristics of each layer.
- Explain which layers are solid and which are capable of flowing or are liquid.
- Compare the relative thicknesses of Earth's layers.
- Use measurements and proportional reasoning to evaluate a scientific model.
- Explain at least one limitation of the 3D model.

Student-Friendly Learning Goals

Today I will…

- Identify → Assemble → Compare → Explain
- I can identify Earth's major layers and explain how they differ.
- I can use a 3D model to investigate Earth's internal structure.
- I can explain why a scientific model is useful even when it isn't exactly like the real object.

Essential Question

🌎 If we cannot travel to the center of Earth, how do scientists know what is inside our planet?

Key Vocabulary

Term	Student-Friendly Definition

Lithosphere	Earth's rigid outer layer, including the crust and uppermost mantle
Crust	Earth's thin outermost rocky portion
Mantle	Thick layer of hot rock beneath the crust
Convection	Movement caused by differences in temperature and density
Outer Core	Liquid metallic layer surrounding the inner core
Inner Core	Dense, solid metallic center of Earth
Density	Amount of matter in a given volume
Scientific Model	A representation scientists use to understand something
Scale	Relationship between the size of a model and the actual object

Materials

Per Student Group

- 1 **3D-printed Layers of the Earth puzzle**
- Individual removable/interlocking Earth layers
- Student **Inside Earth Investigation Guide**
- Pencil
- Metric ruler
- Calculator
- Colored pencils
- Layer information cards

- Optional digital device for viewing the original 3D model

Teacher Materials

- Completed teacher Earth model
- Projected diagram of Earth's interior
- Digital version of the 3D model
- Extra puzzle pieces
- Earth's layer information cards
- Student guide sheets
- Optional globe

🖨️ Preparing the 3D-Printed Model

- Recommended Model Design
- Choose or design a model that is:
- A sphere or hemisphere
- Cut away to expose Earth's interior
- Made from removable/interlocking layers
- Large enough for students to handle
- Clearly divided into major layers
- Durable enough for repeated classroom use
- A model approximately **10–15 cm in diameter** works well for small-group investigations.

Pieces to Include

At minimum, the model should distinguish:

- Lithosphere / outer rigid layer
- Mantle
- Outer Core
- Inner Core

If your print has enough detail, the crust can be shown separately from the upper mantle.

🎨 Color Coding the Model

- If you have a multicolor printer, print the layers in contrasting colors.
- If using one filament color, paint the pieces with acrylic paint.

Suggested classroom color scheme:

Layer	Suggested Color

Crust/Lithosphere	Brown
Mantle	Orange
Outer Core	Red
Inner Core	Yellow

Teacher Note: Tell students that these colors are for identification. Earth's interior is **not actually divided into these colors**.

That itself provides a good discussion about the limitations of scientific models.

Teacher Preparation

Several Days Before

- Download or create the 3D Earth model.
- Check that the model separates into appropriate layers.
- Slice the files.
- Print enough sets for groups of 3–4 students.
- Print a few replacement pieces if possible.

1–2 Days Before

- Remove supports.
- Sand rough edges if necessary.
- Paint or color-code pieces.

Label storage containers:

- **Earth Investigation Set #1**
- **Earth Investigation Set #2**

Make sure every model assembles correctly.

Day Before

Print:

- Student investigation guides
- Layer information cards

- Exit tickets

⏱️ Lesson Timeline

Time	Lesson Component
5 min	Engage — Journey to Earth's Center
10 min	Explore — Mystery Earth Pieces
10 min	Mini-Lesson — What's Inside Earth?
15 min	3D Earth Puzzle Challenge
15 min	Measure & Analyze the Model
10 min	Discussion & Model Evaluation
5 min	Exit Ticket
70 min	**Approximate Total**

For a 50-minute class, complete the measurement/model evaluation portion on Day 2.

🚀 **PART 1 — ENGAGE**

- Journey to the Center of Earth
- 5 minutes
- Show students a globe.

Ask:

- "How far into Earth do you think humans have actually traveled?"
- Then ask:
- Have humans ever reached the mantle?
- Have we reached the core?

- How could scientists know what is inside Earth without seeing it directly?
- Do you think Earth is made of the same material all the way through?

Do not immediately give students the answers.

Introduce today's challenge:

Your team has received pieces representing Earth's interior. Your job is to determine where they belong and what they tell us about the structure of our planet.

🧩 **PART 2 — EXPLORE**

- Mystery Earth Pieces
- 10 minutes
- Give each group its **disassembled Earth puzzle**.
- Do NOT provide the completed diagram yet.

Tell students:

- Examine first. Assemble later.

Students should:

- Remove all pieces.
- Examine their shapes.
- Compare their sizes.
- Determine which pieces might fit together.
- Predict which piece represents Earth's center.
- Predict which piece represents Earth's surface.
- Arrange the pieces without using the answer guide.

Student Questions — Initial Investigation

Ask:

- Which piece do you think represents Earth's center? Why?
- Which layer appears largest?
- Which layer appears thinnest?
- What clues helped you decide where pieces belong?
- Do you think all of Earth's layers are solid?
- Which layer do you predict is hottest?
- Which layer do you predict is densest?
- Do you think the model is actually to scale?

Students should record their predictions before receiving the correct information.

🏫 PART 3 — MINI-LESSON

- What's Inside Earth?
- 10 minutes
- Introduce the major structures.

🪨 Lithosphere

- Earth's rigid outer region.
- It includes the crust and the rigid uppermost portion of the mantle.
- The lithosphere is broken into tectonic plates.

🔥 Mantle

- The mantle makes up most of Earth's volume.
- It consists primarily of hot rock.
- Although mostly solid, mantle material can deform and flow extremely slowly over long periods.
- Heat-driven movement within Earth is associated with convection.

🟠 Outer Core

- The outer core is:
  - **Metallic** AND
  - **Liquid**
  - It consists primarily of iron and nickel.
  - Movement within the liquid outer core is associated with Earth's magnetic field.

🔴 Inner Core

- The inner core is:
  - **Metallic**
  - **Extremely hot** and
  - **Solid**

Ask:

If the inner core is hotter than the outer core, why might it still be solid?

Introduce the concept of enormous **pressure** deep inside Earth.

🧩 PART 4 — BUILD EARTH

- 3D Puzzle Challenge
- 15 minutes
- Students now receive their layer information cards.

Their challenge:

- Assemble Earth from the inside out.
- Start with:
    - **Inner Core**
      ↓
    - **Outer Core**
      ↓
    - **Mantle**
      ↓
    - **Lithosphere / Crust**

As students add each piece, they complete their investigation guide.

📋 STUDENT GUIDE SHEET

Name: _____

Date: _____

Inside Earth: 3D Investigation

Part A — Before You Build

- Examine the pieces.

1. Which piece do you think belongs at Earth's center?

Why?

2. Which layer appears to be the thickest?

3. Do you think all the layers are solid?

☐ Yes

☐ No

Explain:

Part B — Build Your Earth

Complete the table as you assemble the model.

Layer	Location	Solid/Liquid	One Important Characteristic
Lithosphere			

Mantle			
Outer Core			
Inner Core			

📏 **PART 5 — MATH + SCIENCE**

Is Our Earth Model Really Accurate?

- 15 minutes
- Scientific models are useful, but they have limitations.
- Students use a ruler to measure their model.

Measure your model.

Diameter of model: _____ cm

Radius of model: _____ cm

Examine the Layers

1. Which layer appears thickest? _____
2. Which appears thinnest? _____
3. Think About Scale: Earth's radius is approximately: **6,371 km**. If our model represents Earth, how many kilometers does **1 cm on our model** represent? _____

Model Scale

Earth radius ÷ Model radius = km represented by 1 cm

6,371 km ÷ _____ cm = _____ km/cm

🧠 **Model Evaluation**

Now examine your model critically.

1. Is the model perfectly to scale?

☐ Yes

☐ No

☐ I'm not sure

2. Why might a designer make Earth's outer layer thicker than it really should appear?

3. Why would making the crust perfectly to scale make the model difficult to use?

4. What does our model represent well?

5. What does our model NOT represent well?

💻 PART 6 — TECHNOLOGY CONNECTION

How Did This Become a Physical Object?

Show students the original digital model.

Ask them to put these steps in order:

- **3D Printer**
- **Slicer Software**
- **Digital 3D Model**
- **Physical Earth Model**

Correct sequence:

Digital Model

↓

Slicer Software

↓

3D Printer

↓

Physical Model

Discuss:

- **Software** tells the computer/printer what needs to be done.
- **Hardware** includes the physical computer and 3D printer.

Ask:

- What would happen if we had the printer but no digital model or software?

Then ask:

- What would happen if we had the perfect digital Earth model but no 3D printer?
- Connect this discussion to the relationship between **hardware and software**.

🔬 PART 7 — THINK LIKE A SCIENTIST

Students examine the completed model.

Ask the following questions:

1. Which layer makes up most of Earth's interior?
2. Which major layer is liquid?

3. Which layer is located at Earth's center?
4. Why is the inner core solid even though it is extremely hot?
5. Why can't scientists simply travel to Earth's core to study it?
6. Evidence Question: A student says: "Earth is just one giant solid ball of rock." Do you agree or disagree? Use evidence from your 3D model and what you learned today.

💭 CLASS DISCUSSION QUESTIONS

Use the completed models during the discussion.

Ask:

- What are Earth's major internal layers?
- Which layer is thickest?
- Which layer is liquid?
- Which layer is solid because of tremendous pressure?
- Where is the lithosphere?
- Where are Earth's tectonic plates located?
- Why can't we see Earth's layers directly?
- How can scientists investigate something they cannot directly observe?
- Why are scientific models useful?
- How is our model different from the real Earth?
- Why isn't our model perfectly to scale?
- What could we change to make our model more scientifically accurate?

🎟️ EXIT TICKET

Journey Inside Earth

1. Which layer is liquid?

A. Lithosphere
B. Mantle
C. Outer core
D. Inner core

Answer: C

2. Which layer is at Earth's center?

A. Mantle
B. Inner core
C. Outer core
D. Lithosphere

Answer: B

3. Which statement best describes the mantle?

A. A thin layer of liquid metal
B. A thick region of hot rock that can slowly deform and flow
C. Earth's solid metallic center
D. Earth's atmosphere

Answer: B

4. Why do scientists use models of Earth's interior?

5. Give ONE limitation of the 3D Earth model you used today.

Assessment

Formative Assessment

During the investigation, evaluate whether students can:

- Correctly arrange Earth's layers.
- Identify each layer.
- Distinguish solid and liquid regions.
- Compare relative layer sizes.
- Use measurements appropriately.
- Explain observations using evidence.
- Recognize limitations of scientific models.

Student Products

- Collect:
    - **Inside Earth 3D Investigation Guide**
    - Scale calculations
    - Model evaluation questions
    - Exit ticket

Evidence of Mastery

- Students demonstrate mastery when they can:
    - **Correctly identify Earth's major layers and describe important characteristics of the lithosphere, mantle, outer core and inner core using evidence from the 3D model.**

Differentiation

Students Needing Additional Support

Provide:

- Color-coded models
- Layer vocabulary cards
- Partially labeled diagrams
- Sentence starters
- Partner support
- Sentence starters could include:
- The _____ is located _____.
- The _____ is solid/liquid because _____.
- One limitation of our model is _____.

Advanced Students

- Challenge students to investigate:
    - Why the inner core remains solid.
    - How scientists use seismic waves to investigate Earth's interior.
    - Why the outer core is liquid.
    - How Earth's magnetic field is generated.
    - How mantle convection relates to plate tectonics.

🌋 **EXTENSION — Connect to Plate Tectonics**

- This lesson pairs especially well with the **3D Pangaea Reconstruction** and **Plate Boundary Simulator** activities.
- After students understand Earth's internal structure, ask:
- **How could processes happening inside Earth cause the surface of Earth to change?**

Students can then use 3D-printed tectonic plates to investigate:

- Convergent boundaries
  → Plates move toward one another
- Divergent boundaries
  → Plates move apart
- Transform boundaries
  → Plates slide past one another

This creates a natural progression:

Earth's Layers

↓

Internal Heat & Mantle Movement

↓

Plate Movement

↓

Pangaea

↓

Earthquakes, Volcanoes & Mountain Building

Teacher Preparation at a Glance

When	Preparation
Several days before	Download/design, slice and print Earth models
1–2 days before	Remove supports, paint/color-code and test models
Day before	Organize model sets, print guide sheets and information cards
Lesson day	Place one disassembled Earth set at each student station

Teacher Hands-On Preparation

- Approximately **30–60 minutes**, excluding 3D printer run time.
- 3D Printing Time
- Varies considerably depending on model size, infill, printer speed and number of pieces.
- Instructional Time

Approximately 60–75 minutes

or

Two 45–50 minute class periods if students complete the mathematics/technology investigation separately.

Teacher Answer Key — Core Concepts

Layer	State/Behavior	Key Feature
Lithosphere	Solid/rigid	Includes crust and rigid uppermost mantle; broken into tectonic plates
Mantle	Mostly solid but capable of very slow flow/deformation	Thickest major region; heat-driven movement occurs within Earth
Outer Core	**Liquid**	Primarily iron and nickel; movement contributes to Earth's magnetic field
Inner Core	**Solid**	Dense metallic center; enormous pressure keeps it solid despite high temperature

Final Student Takeaway

Earth is not the same throughout. It contains layers with different compositions, physical properties, and behaviors. Scientists use evidence and models to investigate Earth's interior even though we cannot directly travel there.

💀 Hominid Skull Detectives

A 3D-Printed Comparative Anatomy Investigation

Grade Level: 9–12
Primary Course: Biology
Subject Areas: Biology / Evolution / Anatomy / STEAM
Lesson Length: 75–90 minutes or two 45–50 minute class periods
Grouping: Teams of 3–4 students
3D Print: Comparative hominid skull/cranium models

Florida Science Standards

Primary Standard — SC.912.L.15.10

Identify basic trends in hominid evolution from early ancestors six million years ago to modern humans, including brain size, jaw size, language, and manufacture of tools.

- Students use 3D-printed hominid skulls to investigate observable anatomical trends including:
  - Changes in cranial capacity/braincase size
  - Changes in jaw size
  - Changes in tooth size
  - Changes in facial projection
  - Changes in brow ridges
  - Changes in skull shape
  - Students use these observations as evidence to construct a proposed evolutionary sequence.

Supporting Florida Science Standards

- SC.912.L.15.1: Explain how the scientific theory of evolution is supported by evidence including the **fossil record and comparative anatomy**.
- SC.912.L.15.11: Discuss specific fossil hominids and what they show about human evolution.
- SC.912.N.1.6: Describe how scientific inferences are made from observations and identify examples from the content being studied.

Florida Mathematics Connections

The mathematics in this lab should come from students **measuring and comparing the skulls**, rather than adding unrelated calculations.

Students will use:

- Metric measurement
- Ratios
- Proportional reasoning

- Percent change
- Data tables
- Graphs
- Comparing quantitative measurements
- Scale
- Possible measurements include:
- Skull length
- Skull width
- Jaw length
- Facial projection
- Cranial dimensions

Students can then graph measurements against estimated age of the specimens.

Florida Computer Science Standards

- SC.912.CO.1.1 Describe the efficiency and effectiveness of digital tools or resources used for real-world tasks.
- SC.912.CO.1.2 Identify and select file formats based on trade-offs such as size, quality and accessibility.
- SC.912.CO.1.3 Select and use the correct file type for specific tasks.

These standards connect naturally to the process of turning a digital scientific specimen into a physical teaching model:

Digital Scan → 3D Model → Printable File → Slicer → 3D Printer → Physical Skull

Learning Goals

By the end of the investigation, students will be able to:

- Compare anatomical characteristics of multiple hominid skulls.
- Identify trends in hominid evolution.
- Describe changes in braincase size and jaw size over time.
- Collect quantitative measurements from 3D models.
- Organize observations and measurements in a data table.
- Use anatomical evidence to place specimens into a proposed chronological sequence.
- Support conclusions with evidence.
- Distinguish **observation** from **inference**. Explain advantages and limitations of using 3D-printed models to study fossils.

Student-Friendly Learning Goals

- I can Observe → Measure → Compare → Infer → Defend

- I can compare hominid skulls and identify anatomical changes that occurred during human evolution.
- I can use measurements and observations as evidence to support a scientific conclusion.

Essential Question

💀 What can a skull tell us about human evolution?

Guiding Question

If you were given several unknown fossil skulls, could you use anatomical evidence to determine which probably came from earlier and later hominids?

Important Scientific Idea

- Evolution should **not** be presented as a straight ladder in which one species simply turns into the next.
- Human evolution involved a **branching evolutionary history**, with multiple hominin species existing at overlapping times.
- The sequencing portion of this activity is therefore a simplified investigation of **anatomical trends over time**, not a claim that every skull represents a direct ancestor of the next skull.

Vocabulary

Term	Student-Friendly Definition
Hominin	Humans and species more closely related to humans than to chimpanzees
Evolution	Change in inherited characteristics of populations over generations
Fossil	Preserved evidence or remains of past life
Comparative anatomy	Comparing body structures among organisms
Cranium	Portion of the skull surrounding the brain

Cranial capacity	Volume of the space inside the cranium; used as an estimate of brain size
Mandible	Lower jaw
Prognathism	Forward projection of the jaws/face
Brow ridge	Ridge of bone above the eye sockets
Foramen magnum	Opening in the skull through which the spinal cord passes
Observation	Information obtained directly through examination or measurement
Inference	An explanation or conclusion based on observations and evidence
Scientific model	Representation used to investigate or explain an object, system or process

3D-Printed Skull Collection

A strong classroom collection could include approximately **5–7 specimens**.

Suggested models:

- *Australopithecus afarensis*
- *Australopithecus africanus*
- *Homo habilis*
- *Homo erectus*
- *Homo neanderthalensis*
- *Homo sapiens*

An optional chimpanzee skull can serve as an **outgroup comparison**, but students should understand that modern chimpanzees are **not human ancestors**.

Materials

Per Student Group

- 4–6 different 3D-printed hominid skulls/crania
- Metric ruler
- Flexible measuring tape
- Digital or manual calipers, if available
- Hominid Skull Investigation Guide
- Pencil
- Calculator
- Graph paper or digital graphing tool
- Specimen cards
- Optional digital device for viewing 3D scans

Teacher Materials

- Complete 3D skull collection
- Skull identification cards
- Estimated age/time-period cards
- Hominid evolutionary tree
- Projected skull anatomy diagram
- Digital versions of selected skulls
- Student guide sheets
- Answer key
- Storage containers

🖨️ **Preparing the 3D-Printed Skulls**

Step 1 — Select Appropriate Models

- Choose scientifically sourced or anatomically accurate digital models whenever possible. Here is a link to a variety of possible skulls: https://www.thingiverse.com/search?q=hominin+skull&page=1
- Models should clearly show:
    - Cranium
    - Jaw (Mandible)
    - Teeth when available
    - Eye sockets
    - Brow ridge
    - Facial projection
    - Foramen magnum when the skull base is preserved

Avoid highly stylized or decorative models.

Step 2 — Decide on Scale

Ideally, print every skull at the same scale.

For example:

- **50% of actual size**

or

- **75% of actual size**

Printing specimens at a consistent scale makes visual and mathematical comparisons much more meaningful.

If models are printed at different scales, clearly label the scale and require students to account for it mathematically.

Step 3 — Print the Models

- Print enough skulls for teams of 3–4 students.
- You do not necessarily need a complete skull collection for every group.

A station system works very well.

For example:

- Station 1 *Australopithecus afarensis*
- Station 2 *Australopithecus africanus*
- Station 3 *Homo habilis*
- Station 4 *Homo erectus*
- Station 5 *Homo neanderthalensis*
- Station 6 *Homo sapiens*

Students rotate through the stations.

🎨 **Step 4 — Finishing the Prints**

- Skulls can remain the natural filament color.
- For a more realistic fossil appearance, models can be printed in:
  - Ivory
  - Beige
  - Tan
  - Light brown
- Alternatively, lightly paint the models with acrylic paint.

Important

- Do **not** paint anatomical features different colors if students are supposed to discover those features independently.
- The objective is observation, not simply matching colors.

Step 5 — Label the Specimens

Initially label skulls:

- **Specimen A**
- **Specimen B**
- **Specimen C**

etc.

- Do NOT initially give students the species names or chronological order.
- This transforms the lesson into an investigation.

Step 6 — Prepare the Stations

At each station place:

- One skull
- Metric ruler
- Calipers if available
- Specimen letter
- No species identification
- Students should investigate the evidence **before learning the identity of the specimen**.

⏱️ **Lesson Timeline**

Time	Activity
5 min	Engage — Mystery Skulls
10 min	Mini-Lesson — Reading a Skull
25–30 min	Skull Investigation Stations
10 min	Sequence the Mystery Skulls

10–15 min	Reveal & Analyze Evolutionary Trends
10 min	Graph/Data Analysis
5 min	Exit Ticket
75–85 min	**Approximate Total**

For a traditional 50-minute period, divide the investigation over **two class periods**.

🔎 PART 1 — ENGAGE

Mystery Skulls

5 Minutes

- Display two dramatically different hominid skulls without identifying them.

For example:

- **Australopithecus**
- **Homo sapiens**

Ask:

- **What differences can you identify without knowing anything about these specimens?**

Record observations.

Students might notice:

- Different skull sizes
- Different jaw sizes
- Different forehead shapes
- Different brow ridges
- Different facial projection

Then ask:

- **Could these differences tell scientists something about human evolution?**

Introduce today's challenge:

- **You are part of a research team studying 3D replicas of fossil hominid skulls. Your job is to collect anatomical evidence and determine what trends these specimens reveal about human evolution.**

🧠 **PART 2 — MINI-LESSON**

How to Read a Skull

- 10 Minutes
- Using one demonstration skull, introduce the structures students will investigate.

Braincase

- Examine the size and shape of the cranium.

Ask:

- What might a larger braincase suggest?

Jaw

- Compare the size and projection of the jaw.

Ask:

- Does the jaw project far forward or remain relatively flat beneath the face?

Teeth

- When preserved on the model, examine:
    - Tooth size
    - Canine size
    - Molars

Brow Ridge

- Examine the area immediately above the eye sockets.

Ask:

- Is the brow ridge pronounced or relatively small?

Forehead

- Compare:
    - **Sloping** vs **More vertical** foreheads.

Foramen Magnum

- If visible, examine the opening where the spinal cord enters the skull.

- Explain that its position can provide information about how the head was positioned over the vertebral column and therefore can contribute evidence related to locomotion.

Observation vs. Inference

- This distinction is critical.

Observation

- "Specimen A has a larger jaw than Specimen B."

Inference

- "Based on several anatomical features, Specimen A may represent an earlier hominin."

Students should not confuse the two.

🔬 **PART 3 — HOMINID SKULL INVESTIGATION**

25–30 Minutes

Students rotate through each specimen.

At every station they:

OBSERVE

- Examine the skull.

MEASURE

- Collect quantitative data.

RECORD

- Record anatomical characteristics.

INFER

- Make a tentative interpretation.

📋 STUDENT GUIDE SHEET

Name: _____ Group: _____ Date: _____

Hominid Skull Detectives

Part A — Comparative Skull Data

- Complete the table. Record size and other information:
- **Small / Medium / Large** or **Slight / Moderate / Pronounced**
- For each skull, record **two observations** and **one inference**.
- For example: Specimen A would have: **Observation 1, Observation 2, Inference:**
- Repeat for each specimen.

Feature	Specimen A	Specimen B	Specimen C	Specimen D	Specimen E	Specimen F
Skull length (mm)						
Skull width (mm)						
Jaw size						
Facial projection						
Brow ridge						
Forehead						

Braincase relative size						
Tooth size						
Foramen magnum position						

🧩 PART 4 — MYSTERY SKULL CHALLENGE

Put the Skulls in Order

- 10 Minutes

Students now use their observations to arrange the skulls from:

- Earlier anatomical characteristics to More recent anatomical characteristics

Tell students:

- **You are not trying to guess species names. Use anatomical evidence.**

Each group physically arranges its skulls or specimen cards.

Group Claim

We predict the sequence is:

_____ → _____ → _____ → _____ → _____ → _____

Evidence

Identify **three pieces of anatomical evidence** supporting your sequence.

1. Evidence #1 — Braincase
2. Evidence #2 — Jaw/Face
3. Evidence #3 — Another Anatomical Feature

🧠 PART 5 — REVEAL THE SPECIMENS

10–15 Minutes

- Reveal the species names and approximate ages.
- Students compare their sequence with the scientific information.

Ask:

- **Did your anatomical evidence lead you toward the general evolutionary trend?**

Students should NOT be graded simply on whether every species is in the exact chronological order.

The important question is whether they recognized the **overall trends**.

Major Trends Students Should Identify

- Across hominid evolution, students should recognize general trends including:

  🧠 Braincase

  Generally: **Smaller → Larger**

🦷 Jaw

- Generally: **Larger/projecting → Smaller/less projecting**

😬 Teeth

- Generally: **Larger → Smaller**

🧑‍🦲 Face

- Generally: **More projecting → Flatter**

🦴 Brow Ridge

- Not a perfectly linear trend, but modern humans generally have reduced brow ridges compared with several earlier members of *Homo*.

🧍 Skull Position

- Changes associated with habitual bipedalism are reflected in skull anatomy, including the position of the foramen magnum.

Important Scientific Caution

- Tell students:
  - **Evolution does not mean every anatomical characteristic changes continuously in one direction.**
  - Different hominin species had different combinations of traits.
  - That is why scientists examine **multiple characteristics and multiple lines of evidence**.

📊 **PART 6 — MATHEMATICS & DATA ANALYSIS**

Can We See Evolutionary Trends in the Numbers?

10 Minutes

- Students choose one quantitative measurement.
- For example:

Jaw Length or **Cranial Width**

Create a graph.

- X-Axis
- Approximate age of specimen
- Y-Axis

Measurement

Students then answer:

1. Is there an obvious trend?
2. Is the trend perfectly linear?
3. Are there specimens that don't fit the general pattern?
4. Why is it dangerous to make an evolutionary conclusion from only ONE measurement?

🔬 PART 7 — THINK LIKE A SCIENTIST

Answer using evidence from the models.

1. What general trend did you observe in braincase size?
2. What general trend did you observe in jaw size and facial projection?
3. Which two specimens appeared most anatomically different? What evidence supports your answer?
4. Why is comparing several anatomical characteristics better than comparing only one?
5. A student says: **"Humans evolved from chimpanzees."** Explain why this statement is scientifically inaccurate.
6. Another student says: **"Evolution means one hominid species turned into the next one in a straight line."** Explain the problem with this statement.
7. Evidence-Based Claim: What evidence from the skulls supports the idea that hominids changed over evolutionary time? Use **at least three observations**.

💭 CLASS DISCUSSION QUESTIONS

- Which skull characteristic changed most noticeably?
- What happened generally to braincase size?
- What happened generally to jaw size?
- What happened to facial projection?
- Were all trends perfectly linear?
- Why might different hominin species have existed at the same time?
- What can a skull tell scientists?
- What **can't** a skull tell scientists?
- How do fossils provide evidence for evolution?
- Why is comparative anatomy useful?
- Why should scientists examine multiple specimens?
- What is the difference between an observation and an inference?
- Why might a 3D print be useful to a scientist?
- What information could be lost when an original fossil becomes a 3D model?
- How could future technology improve the way scientists study fossils?

🎟️ EXIT TICKET

What Can a Skull Tell Us?

1. Which trend generally occurred during hominid evolution?

A. Brain size decreased dramatically.
B. Braincase size generally increased.
C. Jaws became increasingly larger.
D. Facial projection continually increased.

Answer: B

2. Which is an OBSERVATION?

A. This species lived before the others.
B. This hominid probably made tools.
C. Specimen B has a larger jaw than Specimen D.
D. This skull belonged to an intelligent individual.

Answer: C

3. Fossil skull comparisons provide evidence primarily through:

A. Comparative anatomy
B. Photosynthesis
C. Ecology
D. Cellular respiration

Answer: A

4. Identify ONE general anatomical trend observed during the investigation.

5. Explain how the 3D skull models provide evidence for hominid evolution.

Assessment

Formative Assessment

- During the lab, assess students' ability to:
- Handle scientific models appropriately.
- Make detailed anatomical observations.
- Measure consistently.
- Distinguish observation from inference.
- Compare multiple specimens.
- Identify anatomical trends.
- Support conclusions with evidence.

Student Products

Collect:

- Hominid Skull Investigation Guide
- Comparative data table
- Skull sequence
- Evidence supporting sequence
- Graph/data analysis
- Evidence-based conclusion
- Exit ticket

Evidence of Mastery

Students demonstrate mastery when they can:

- **Use comparative anatomical evidence from hominid skulls to identify basic trends in human evolution, including changes in braincase and jaw size, and support their conclusions using observations and measurements.**

Differentiation

Students Needing Additional Support

Provide:

- Labeled skull anatomy diagram
- Vocabulary cards with pictures
- Fewer specimens initially
- Partially completed data table
- Measurement demonstration
- Sentence starters

Sentence Starters

- **I observed that _____.**
- **Compared with Specimen A, Specimen B _____.**
- **The evidence suggests _____ because _____.**
- **One trend I observed was _____.**

Advanced / Honors Extension

Students can investigate additional characteristics:

- Cranial capacity
- Dental arcade shape
- Sagittal crest
- Zygomatic arch
- Foramen magnum position

- Prognathism
- Supraorbital torus
- Occipital region

Students can then create a **multivariable comparison** rather than relying on one characteristic.

🧮 OPTIONAL MATHEMATICS EXTENSION

Estimate Cranial Capacity

- If your models permit reliable internal measurements—or if you provide published cranial-capacity data—students can compare estimated cranial capacities among hominins.

Students create a scatterplot:

- X-axis: Time before present
- Y-axis: Cranial capacity (cm^3)

Students analyze:

- Overall trend
- Variation
- Outliers
- Overlapping values

Then ask:

- **Does increasing cranial capacity occur as a perfectly straight progression through time?**

  Students should discover that evolutionary data are more complex than a simple "bigger brain = later species" rule.

🔎 Optional Extension — Mystery Hominin

1. After students complete the investigation, give each group one additional skull labeled: UNKNOWN SPECIMEN X
2. Students must determine where it belongs within the collection.
3. They cannot simply identify the species.
    a. Instead they submit:
    b. CLAIM Where does the unknown belong?
    c. EVIDENCE What anatomical observations support the placement?
    d. REASONING Why do those characteristics support the conclusion?

This makes an excellent assessment because students must apply what they learned to a **new specimen**.

Teacher Preparation at a Glance

When	Preparation
1–2 weeks before	Locate scientifically accurate digital hominid models and verify scale
Several days before	Slice and print skull models
2–3 days before	Remove supports, inspect and finish models
Day before	Label models A–F and prepare investigation stations
Day before	Print student guides, specimen cards and exit tickets
Lesson day	Place mystery skulls and measuring tools at stations

Teacher Hands-On Preparation

Approximately **45–90 minutes**, excluding printing time.

3D Printing Time

Potentially substantial. Skull models can require many hours each depending on:

- Scale
- Layer height
- Infill
- Supports
- Printer speed

For classroom sets, **half-scale models** can significantly reduce printing time and filament use while retaining useful anatomical characteristics.

Teacher Answer Guide — General Trends

Feature	Earlier Hominins — General Tendency	Modern Humans — General Tendency
Braincase	Smaller	Larger
Jaw	Larger/more robust	Smaller
Face	More projecting	Flatter
Teeth	Generally larger	Generally smaller
Forehead	More sloping	More vertical
Brow Ridge	Often more pronounced	Reduced
Cranium	Generally lower/elongated	Higher/rounded

Important Teacher Note

- These are **general trends**, not rules that apply uniformly to every hominin species.
- Avoid presenting human evolution as:

ape → primitive human → modern human

Instead emphasize:

- Human evolution is a branching evolutionary history. Fossil hominins show different combinations of ancestral and derived characteristics.

Final Student Takeaway

Fossils are evidence. By measuring and comparing anatomical structures in fossil skulls, scientists can identify patterns of change over evolutionary time. Hominid evolution generally included an increase in braincase size and reduction in jaw size and facial projection, but human evolution was a branching process rather than a simple straight line.

Student Design Prototypes -Student Project Ideas:

Elementary (Grades K-5)

1. Ramp Racer — Speed — Physical Science

Standard: SC.4.P.12.1 (an object in motion always changes position, and may change direction) and SC.4.P.12.2 (the speed of an object is determined by the distance it travels in a unit of time).

The build: Students design and print a simple wheeled vehicle — a block-shaped body on a printed axle with printed or added wheels — using only basic Tinkercad shapes. They race it down a ramp, timing it with a stopwatch and measuring distance to calculate speed. Then they make one deliberate design change (wheel size, body shape, added weight) and re-test to see if speed improved. Easy to build, prints fast, and the test is literally "does it go faster."

2. Bridge Load Test — Strength — Physical Science

Standard: SC.5.P.13.1 (familiar forces that cause objects to move, including gravity acting on falling objects), SC.5.P.13.2 (the greater the force applied, the greater the change in motion), and SC.5.P.13.3 (the more mass an object has, the less effect a given force will have on its motion).

The build: Students design and print a small beam bridge or tower using a fixed, small footprint and a limited amount of material (e.g., must fit in a 4"x2" base and use less than a set amount of filament/print time). They test it by stacking pennies, washers, or small weights on top until it fails, recording how much mass it held. Then they try one change — thicker beams, a triangle brace, a different shape — and re-test. Simple geometric shapes only, and the "test" is immediate and visual: it holds, or it doesn't.

Middle School (Grades 6–8)

3. Florida Landform & Erosion Relief Model — Earth & Space Science

Standard: SC.6.E.6.2 — Recognize that there are a variety of different landforms on Earth's surface (coastlines, dunes, rivers, mountains, glaciers, deltas, lakes) and relate these landforms as they apply to Florida.

The build: Students model a topographic relief map of a Florida region (coastline, dune system, or river delta) as a 3D-printed terrain block, then add a second, "before/after" version showing the effects of erosion or sea-level change on that same landform. The challenge is translating elevation data or a contour sketch into a printable 3D surface, and justifying the erosion changes with real processes (wave action, wind, water flow).

4. Atomic Structure & Bonding Model Set — Physical Science

Standard: SC.8.P.8.7 (explore the scientific theory of atoms/atomic theory) and SC.8.P.8.6 (elements are grouped in the periodic table by similar properties).

The build: Students design a set of interlocking 3D-printed atom models (nucleus + electron shells) for two or three elements from different periodic table groups, then combine pieces to model a simple

molecule (e.g., H_2O or CO_2) showing how bonding works. The challenge is representing electron shell capacity and valence accurately enough that the pieces physically "make sense" when connected.

High School (Grades 9–12)

5. Functional Plant/Animal Cell Model — Biology

Standard: SC.912.L.14.2 — Relate structure to function for the components of plant and animal cells, including the role of the cell membrane as a selective barrier.

The build: Students design a cutaway or cross-sectional 3D-printed cell model (plant or animal) where each organelle is a separate, correctly shaped, removable piece that fits into a labeled housing — essentially a 3D "puzzle" version of a cell diagram. The challenge is beyond "what does it look like": students must justify each organelle's size, position, and shape relative to its function, and the model needs to physically hold together as an assembly.

6. Newton's Laws Motion Machine — Physics

Standard: SC.912.P.12.2 — Analyze the motion of an object in terms of position, velocity, and acceleration as functions of time (paired with SC.912.P.10.4 on energy transfer via heat/work as an extension).

The build: Students design and print a small mechanical device — a catapult, a ramp-and-cart system, or a chain-reaction (Rube Goldberg–style) mechanism with at least two linked stages — that they can measure and graph (position/velocity/acceleration over time) using video or motion-tracking tools. The challenge is that it has to actually work: gears, levers, or ramps must be dimensioned correctly for the mechanism to function, not just look right.

Website Resources and 3D Printer Brands

Websites for Downloads and Design	Link	Notes
	Thingiverse	You can find almost anything here. A great place to start Sometimes blocked by school server!
	Printables	A good educational source Sometimes blocked by school server
	Tinkercad	A place for students to learn and to make their own designs
	NASA 3D Resources	Great quality 3D prints available from NASA!
	NIH Laboratory 3D Print Exchange	Quality advanced resources for biological sciences
	Fusion 360	This is perfect for advanced students and programs. Get the Educator version!

Vendors for 3D printing

Printer and Link		Approximate Cost
	Flash Forge	Currently $249 on Amazon
	ELEGOO Neptune 3 Pro 3D Printer	Currently $199 on Amazon
	ELEGOO Neptune 4 Pro 3D Printer	Currently $210 on Amazon

Where to get filament:

- Amazon
- Hobby Lobby
- Michaels (Use your teacher discount!)
- Vendor sites

What kind of filament:

- PLA for starters – it is the cheapest and most readily available