AUTHOR (S)
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LESSON TITLE
Tracking the Evidence from Fossil Dinosaur Footprints

GRADE LEVEL
Elementary School
3rd Grade

TIME FRAME
This lesson can be split into two, one-hour long sessions

DRIVING QUESTION
What can dinosaur tracks tell us about how big they were and where were they headed?

LEARNING GOALS
I will be able to use fossil footprints to learn about motion and size in an extinct animal.

COLLABORATIONS
As a whole, the creation of this lesson was built on the collaboration between Luck Stone Quarry in Culpeper, Virginia, the University of Florida, the Virginia Museum of Natural History and the Science Museum of Minnesota. Similarly, students will collaborate to record and
interpret information they gather from mysterious dinosaur trackways discovered in Culpeper, Virginia!

Students will work in small groups of 4 to 5 to facilitate collaboration. Each student will be assigned or chose a role:

- **3D measurer** - responsible for making sure the measurements of the virtual 3D trackways are as accurate as possible
- **Scribe** responsible for recording the measurements
- **Artist** responsible for bringing the trackways to life by leading their reconstruction i.e. accurate paper cutouts of dinosaur footprints
- **Investigator** responsible for leading the group investigation and proposing what kind of dinosaur made which tracks and how they moved based on evidence gathered in the powerpoint presentation, lesson plan, and any other appropriate research source

As a whole class wrap up, each group will share and compare results highlighting discrepancies in data. The class can discuss inevitable biases and errors that occur in every aspect of scientific research.

**STEM INTEGRATION**
Science: Physical Science, Arguing from Evidence, and Patterns
Mathematics: Measuring and making quantitative data
Technology: Using 3D models and learning about photogrammetry
ELA – Gathering evidence from text and video for scientific argument

**ASSESSMENT**
Students will write scientific arguments stating a claim with evidence about the motion of an extinct animal.

**ANCHORING EVENT & PROCEDURE**

**Warm Up: Take a Stand!**
State each statement aloud: students who agree will stand up, those who disagree remain seating.

1. All dinosaurs are too big to fit in this classroom.
2. Scientists learn about dinosaurs by studying their bones.
3. Scientists learn about dinosaurs by studying their footprints.
4. Dinosaurs with 2 legs run faster than ones with 4 legs.
5. When you run your footprints are farther apart than when you walk.
Discovering Dinosaur Footprints

Footprints of extinct animals can be used to learn important features like how they moved, how fast they could go, how big they were, and what their environment was like. You have access to 3D digital models of 3 trackways from dinosaurs that lived about 211 million years ago during the Triassic Period. In fact, the K15A and K15B models are two parts of the same trackway, but a section is missing between them. These are currently still in the rock quarry in Virginia. The third one is a set of 2 footprints from The Museum of Culpeper History.

Challenge:

Your class is going to recreate the full K15 trackway in your classroom, including the missing section. You’re also going to make wall art of the dinosaur that made the tracks, at the actual size.

Part A – Making Tracks

Step 1: In order to recreate the fossil tracks from Virginia, you’ll need to take accurate measurements. This can be done directly from the digital models. Use the digital tools to fill in the table below. You’ll need these measurements to make the footprints. Since this is a scientific exercise, we will measure in centimeters. The Fossil Track ID Guide shows you how to measure the tracks. The guide also has a figure to help you determine if the footprints are from the left or the right. Your class can divide into two teams (A & B) to work on these.

Tracks are labeled here as A1 for the first track of K15A, and B1 for the first track of K15B.

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</table>
A **pattern** is something that happens in a repeated or regular way. What patterns do you see in this data table?

_________________________________________________________________________________
_________________________________________________________________________________

**Step 2:** Using sheets of paper, draw dinosaur footprints that are the actual size of each track. Go ahead and write A1–5 and B1–6 on them so you can remember where they go. These do not have to be perfect, just do your best to make the length correct.

**Step 3:** Now you’ll need to know how far apart to put your dinosaur footprints. For this, you are going to measure Step (distance from the tip of one toe to the next). The Fossil Track ID Guide shows how to measure this too.

<table>
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<tr>
<td>A3 to A4</td>
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<td>A4 to A5</td>
<td></td>
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<tr>
<td>A5 to A6</td>
<td></td>
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<td>B1 to B2</td>
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<td></td>
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<tr>
<td>B4 to B5</td>
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<tr>
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<td></td>
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Now tape down the footprints to the floor using a tape measure to make sure they are the correct distance apart. You will need to **leave 460 cm** between the tip of the longest toe of A5 and the heel of the foot of B1 to represent the missing section.
For the missing section, the dinosaur would have continued in the same direction and about the same speed. Based on the spacing you determined, and whether the last footprint of K15A and first of K15B are left or right, how many tracks do you think are missing?

Number of missing footprints: ___________________

Now make this number of extra footprints out of paper, making sure that they are not any larger than the measurements you made from the actual footprints.

Place these down on the floor in the missing section, keeping your spacing similar to those from K15A & B. Now you should have a full trackway! Test it out by trying to match your steps with the dinosaur.

**Part B - Making a Dinosaur**

**Step 1:** In order to make the wall art, you'll first need to know what kind of dinosaur made the tracks. Luckily, paleontologists have discovered quite a lot of different fossil tracks and have some very good ideas about the kind of animals that made them. Because fossil bones are not found in the same place as tracks though, we cannot be certain what exactly made them, but we can definitely make an educated guess (estimate).

Based on the Fossil Track ID Guide, what kind of animal track is this and what was the likely track-maker?

Type of Track: ____________________

Likely Track-Maker: ____________________

**Step 2:** Next, you'll need to know how big it was. For this we'll need a footprint length measurement from a really well-preserved track. Take a look at the digital models and use the measurement you took in Part A and fill this in again here.

Footprint Length: ___________ cm

Paleontologists have worked out a way to estimate the height at the hip (h) for two-legged dinosaurs based on the size of their feet.

\[ h = 5.235 \times \text{Footprint Length} \]

That means all you need to do is multiply your measurement by 5.235 and you will know about how tall this dinosaur was at the hips!

Dinosaur Height (at the hips): ____________________ cm
Step 3: Your class can make your dinosaur either on a white board or paper taped to the wall. It’s okay, if you don’t see the dinosaur’s feet or tail. Measure up from the floor to the dinosaur’s hip height and make a mark. Then draw the rest of the dinosaur to get a sense of what it was like to stand next to it! If you need help with what it looked like, go back to your Fossil Track ID Guide.

Extension: Part C - Learning more about Paleontology: the study of dinosaurs

Step 1: Students watch the video: Paleontology: Paleontologists Study Tracks and Traces to learn more about Paleontology, how scientists learn from tracks.

Step 2: Students read articles to learn more about Paleontology and the motion of dinosaurs https://newsela.com/read/prehistoric-fossil-robot/id/48863/?search_id=3523f928-61cf-46a3-8d88-c1d852844607

STANDARDS
NEXT GENERATION SCIENCE STANDARDS (NGSS)

Forces and Interactions

Performance expectation:
3-PS2-2: Make observations and/or measurements of an object’s motion to provide evidence that a pattern can be used to predict future motion.

Science Practices | Connection to the Lesson
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Planning and Carrying Out Investigations Make observations and/or measurements to produce data to serve as the basis for evidence for an explanation of a phenomenon or test a design solution. | Students predict the pattern of dinosaur footprints based on their observations and measurements.
Connections to Nature of Science Science findings are based on recognizing patterns. |  

Disciplinary Core Ideas | Connection to the Lesson
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The patterns of an object’s motion in various situations can be observed and measured; when that past motion exhibits a regular pattern, future motion can be predicted from it. (Boundary: Technical terms, such as magnitude, velocity, momentum, and vector | Students measure and predict the motion of a dinosaur based on the pattern on its footprints.
quantity, are not introduced at this level, but the concept that some quantities need both size and direction to be described is developed.)

### Crosscutting Concepts

**Patterns of change can be used to make predictions**

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### Connection to the Lesson

Dinosaur tracks model the pattern of a dinosaur’s motion.

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### CCSS STANDARDS

**ENGLISH AND LANGUAGE ARTS**

W.3.8 - Recall information from experiences or gather information from print and digital sources; take brief notes on sources and sort evidence into provided categories. (3-PS2-1), (3-PS2-2)

**MATHEMATICS**

- **MP.5** - Use appropriate tools strategically. (3-PS2-1)

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### Connection to the Lesson

- Students make calculations about the motion of a dinosaur to determine its identity.
- Students learn about paleontology from digital and print sources.
- MP.5 Use rulers in the metric system.

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### RESOURCES & MATERIALS

#### 3D MODELS

1. Create a free account in MorhoSource: https://www.morphosource.org/
2. Request permission to download: https://www.morphosource.org/Detail/ProjectDetail/Show/project_id/1075
3. To view and measure the tracks, install the free 3D View app for Google Chrome: https://chrome.google.com/webstore/detail/3dview/hhngcikngebkeffhafnaodkfidcdlca0
4. Launch the 3DView app. Tutorial: https://youtu.be/vD9tJrj6D1Y (3:55 min)
5. Upload the file into 3DView

#### VIDEOS

**Paleontology: Paleontologists Study Tracks and Traces**

**James Hagadorn, Paleontologist: Traces of Early Animal Life**

**Ichnology: Dinosaur Footprints and Other Animal Traces from the Past**
https://www.youtube.com/watch?v=WXO9ub054QM
ARTICLES
For Students:

- Teeny skull trapped in amber belongs to smallest dinosaur ever found
- This feathery dinosaur probably flew, but not like any bird you know
- A student obsessed with dinosaurs since childhood discovers a triceratops skull
- The Permian extinction: When life nearly came to an end
- Robot recreates the walk of a 290-million-year-old creature
- Project Earth Archive seeks to create a record of the Earth’s landscapes

For Teachers:

OTHER
Paleontology glossaries:
http://palaeos.com/paleontology/glossary.html
Geologic Time Scale (free download)

KEY ACADEMIC AND/OR SCIENTIFIC LANGUAGE
- Fossils
- Patterns
- Paleontologist
- Trackway
Discovering Dinosaur Footprints
Paleontology: study of ALL ancient life
What is a fossil?

- Evidence of past life
- 2 types

**Body Fossil**: Actual mineralized remains from a living thing

**Trace Fossil**: Evidence of ancient life that does not include any actual part of it (ex: footprint)
How do body fossils form?

• Sediment replaces original biological material
How dinosaur tracks fossilize

1. Dinosaur steps in mud
2. Dinosaur leaves behind a footprint
3. Over millions of years, soft mud gently fills the track and both layers get pressed into rock
4. The top layer weathers away, or a person breaks the rock, separating the layers
5. Footprint is exposed & someone can discover it!
Dinosaurs in Virginia

• Digital tracks from Culpeper, Virginia
• Created using Photogrammetry!
Photogrammetry

• Take lots of photos & use computer program to turn them into a digital 3D model!
Who made the tracks?

- Different animals make different kinds of footprints.
Styles of Motion

- Bipedal = 2-legged
- Quadrapedal = 4-legged
Activity
Time!
Fossil Track ID Guide
Culpeper, Virginia
Measuring Tracks

- Footprint Length
- Step Length
- Hip Height

Art CC license: https://en.m.wikipedia.org/wiki/File:Neovenator.png
Left versus Right

- 2-legged dinosaurs have weight shifted to outside of foot
- Meaning: track should be deeper on right side of a right foot

Tracks modified from Weems 1992
Track: *Kayentapus minor*

Likely Track-Maker: *Dilophosaurus*

Track from Weems 1992

Art by Heather Kyoht Luterman, 2009
Track: *Anomoepus curvatus*

Likely Track-Maker: *Scutellosaurus*

Tracks from Olsen & Rainforth 2003

Art by PaleoGuy @ DeviantArt
Track: *Brachychoirotherium parvum*

Likely Track-Maker: Aetosaur

Art CC license: [https://commons.wikimedia.org/wiki/File:Typothorax_coccinarum.jpg](https://commons.wikimedia.org/wiki/File:Typothorax_coccinarum.jpg)

Tracks from Lucas & Heckert 2011
Track: *Apatopus lineatus*

Likely Track-Maker: Phytosaur

Tracks from Klein & Lucas 2013

Art CC license: [https://commons.wikimedia.org/wiki/File:Protome_batalaria.jpg](https://commons.wikimedia.org/wiki/File:Protome_batalaria.jpg)
References


Teacher Guide

Downloading Instructions

Before the exercise, you will want to download all three dinosaur track files from MorphoSource. In order to do this:

- Request permission to download: https://www.morphosource.org/Detail/ProjectDetail/Show/project_id/1075

- Object will be downloaded as .zip file with the fossil trackway saved as a .ply 3D file.

Manipulating 3D Files

- To view and measure the tracks, install the free 3D View app for Google Chrome: https://chrome.google.com/webstore/detail/3dview/hhngciknjenkeffhafnaodkfiddlcao

- Launch the 3DView app. Tutorial: https://youtu.be/vD9tJrj6D1Y (3:55 min)
- Upload the file into 3DView

- Measure using measure tab by clicking on the two points you want to record
An alternative software to 3D View app for Google Chrome would be Meshlab:  
https://www.meshlab.net/#download
- Launch the Meshlab app and upload the file.

- Measure using measure tab by clicking on the two points you want to record
Material List
• Computer or tablet capable of running Google 3D View (at least one per group)
• Fossil Track ID Guide (either print-outs or pdf file loaded onto tablets)
• 17 sheets of paper
• Scissors
• Markers
• Tape
• Ruler (metric)
• Measuring tape (metric)
• Large sheet of paper (and bare wall to hang it on) or white/blackboard
  For whole dinosaur (not necessary, can cut off feet and/or tail):
    140 cm [~4.5 ft] x 280 cm [~9.2 ft]
• Calculator (at least one per group)
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<td>20.0</td>
<td>Left</td>
</tr>
<tr>
<td>A2</td>
<td>24.9</td>
<td>Right</td>
</tr>
<tr>
<td>A3</td>
<td>20.1</td>
<td>Left</td>
</tr>
<tr>
<td>A4</td>
<td>21.1</td>
<td>Right</td>
</tr>
<tr>
<td>A5</td>
<td>16.0</td>
<td>Left</td>
</tr>
<tr>
<td>B1</td>
<td>23.4</td>
<td>Right</td>
</tr>
<tr>
<td>B2</td>
<td>27.0</td>
<td>Left</td>
</tr>
<tr>
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<td>22.3</td>
<td>Right</td>
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<td>90.3</td>
</tr>
<tr>
<td>A3 to A4</td>
<td>86.0</td>
</tr>
<tr>
<td>A4 to A5</td>
<td>85.3</td>
</tr>
<tr>
<td>B1 to B2</td>
<td>107.2</td>
</tr>
<tr>
<td>B2 to B3</td>
<td>98.1</td>
</tr>
<tr>
<td>B3 to B4</td>
<td>103.1</td>
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Now tape down the footprints to the floor using a tape measure to make sure they are the correct distance apart. You will need to leave 460 cm between the tip of the longest toe of A5 and the heel of the foot of B1 to represent the missing section.
For the missing section, the dinosaur would have continued in the same direction and about the same speed. Based on the spacing you determined, and whether the last footprint of K15A and first of K15B are left or right, how many tracks do you think are missing?

Number of missing footprints: __6________________

Now make this number of extra footprints out of paper, making sure that they are not any larger than the measurements you made from the actual footprints.

Place these down on the floor in the missing section, keeping your spacing similar to those from K15A & B. Now you should have a full trackway! Test it out by trying to match your steps with the dinosaur.

**Part B - Making a Dinosaur**

**Step 1:** In order to make the wall art, you’ll first need to know what kind of dinosaur made the tracks. Luckily, paleontologists have discovered quite a lot of different fossil tracks and the kind of animals that made them. Because fossil bones are not found in the same place as tracks though, we cannot be certain what exactly made them, but we can definitely make an educated guess (estimate).

Based on the Fossil Track ID Guide, what kind of animal track is this and what was the likely track-maker?

Type of Track: _Kayentapus minor_ _____________
Likely Track-Maker: _Dilophosaurus_ _____________

**Step 2:** Next, you’ll need to know how big it was. For this we’ll need a footprint length measurement from a really well-preserved track. Take a look at the digital models and use the measurement you took in Part A and fill this in again here.

Footprint Length: ___24.9_____ cm Note: Any answer from the first table is fine

Paleontologists have worked out a way to estimate the height at the hip (h) for two-legged dinosaurs based on the size of their feet.

\[
h = 5.235 \times \text{Footprint Length}
\]
That means all you need to do is multiply your measurement by 5.235 and you will know about how tall this dinosaur was at the hips!

Dinosaur Height (at the hips): 130.35 cm

**Step 3:** Your class can make your dinosaur either on a white board or paper taped to the wall. It’s okay, if you don’t see the dinosaur's feet. Measure up from the floor to the dinosaur's hip height and make a mark. Then draw the rest of the dinosaur to get a sense of what it was like to stand next to it! If you need help with what it looked like, go back to your Fossil Track ID Guide.