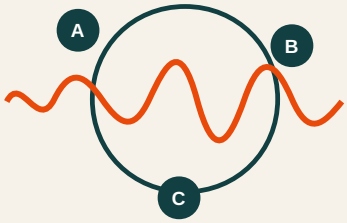
TEACHER GUIDE

EARTHQUAKE DETECTIVE

Quick start for using the Earthquake Detective Activity Pack



Earthquake Detective is a simplified interactive seismology investigation. Students read seismograms, pick P- and S-wave arrivals, estimate source distance, test earthquake depth, locate an epicenter and compare how distance and local ground conditions affect recorded motion.

RECOMMENDED USE

Best for: secondary / middle-school Earth science, geology, geography or STEM.

Devices: one internet-connected device per student or pair works well.

Timing: selected activities fit a 45-60 minute lesson; the full pack is best spread across two lessons (about 90-120 minutes total).

Materials: Student Activity Pack, Earthquake Detective interactive, Answer Key and this Teacher Guide.

BEFORE STUDENTS START

- Open **digearthstudio.com/earthquake-detective/** and check that the interactive loads.
- Demonstrate one clean P-wave pick and one clean S-wave pick before students work independently.
- Emphasize that students pick the **onset of a phase**, not the largest wiggle.
- Keep station ground conditions on **Firm ground** unless an activity specifically asks students to change them.
- Do not reveal earthquake location, depth or magnitude until the worksheet tells students to do so.

OPEN EARTHQUAKE DETECTIVE
digearthstudio.com/earthquake-detective/

Dig Earth Studio

CORE SCIENCE

WHAT STUDENTS WILL LEARN

By the end of the activities, students should be able to distinguish P and S waves, make reasonable arrival picks, calculate a P-S time gap, use that gap to estimate source distance, distinguish epicenter from hypocenter, explain why depth changes map geometry, and separate earthquake magnitude from recorded amplitude and site response.

OBSERVE -> MEASURE -> LOCATE -> EXPLAIN

P waves

Fastest body waves, so they arrive first. They are compressional waves: particle motion is approximately parallel to the direction of travel. P waves can travel through solids, liquids and gases.

$$v_P \approx 6 \text{ km/s}$$

S waves

Slower than P waves, so they arrive later. They are shear waves: particle motion is perpendicular to the direction of travel. S waves travel through solids, but not liquids.

$$v_S \approx 3.4 \text{ km/s}$$

WHY THE P-S GAP MATTERS

P and S waves begin at the source at about the same time, but P waves travel faster. The farther both waves travel, the more arrival-time separation develops at the station.

KEY RELATIONSHIP

$$\text{source distance} \approx \Delta t \times 8 \text{ km/s}$$

where $\Delta t = t_S - t_P$. The result is an approximate **station-to-hypocenter distance**.

WHERE DOES 8 KM/S COME FROM?

Travel time is t = D / v. For the same source distance D:

$$\Delta t = D(1/v_S - 1/v_P)$$

Rearranging gives:

$$D = \Delta t / (1/v_S - 1/v_P)$$

Using the simplified velocities in the interactive gives a convenient conversion close to 8 km of source distance for every second of P-S separation.

MODEL SIMPLIFICATION

8 km/s is a conversion factor, not a seismic-wave velocity. Earthquake Detective uses approximate, constant velocities so students can focus on timing, distance and geometry. In the real Earth, seismic velocities vary with material, pressure, temperature and depth.

PRACTICAL SKILL

HOW TO PICK ARRIVAL TIMES

Arrival picking is the most important practical skill to demonstrate. Students should read each seismogram from left to right and identify the **beginning of a new seismic phase**.

Picking P

1. Follow the quiet background trace.
2. Find the first clear departure from that background.
3. Place the P marker at the **start** of the change.

Picking S

1. Continue to the right after P.
2. Look for a second clear change in motion, often with stronger amplitude.
3. Place the S marker at the **onset** of that phase.

DO NOT TEACH PEAK PICKING

Arrival time is not the largest peak. A large peak may occur several seconds after a phase first reaches the station. Ask: “Where does this new motion begin?”

OVERLAPPING ARRIVALS

P-wave motion does not have to stop before the S wave arrives. In a nearby case the P-S gap can be small, so the S phase begins while P-wave oscillations are still visible.

LOCKED CLASSROOM CASE

Scenario C - Station C - Firm ground is the deliberate overlap example used in Student Page 8.

Expected true arrivals are approximately **P = 20.9 s** and **S = 30.6 s**, giving a gap of about **9.7 s** and a source distance of about **78 km**.

Students should look for the change into the stronger S-wave phase around 30-31 s even though P-wave motion is still visible.

MEASUREMENT UNCERTAINTY

Two students can make slightly different reasonable picks. Because the simplified conversion is 8 km per second of P-S separation:

1 s difference ≈ 8 km difference in estimated source distance

Mark for reasonable interpretation, not identical clicks. Large errors should be corrected when a student has clearly selected a peak or the wrong phase.

RECOMMENDED FIRST DEMONSTRATION

Use **Scenario A**. It has clean, widely separated arrivals and an idealized depth of 0 km, so students can learn the workflow before encountering depth or overlap complexity.

3-D GEOMETRY

FROM SOURCE DISTANCE TO LOCATION

EPICENTER AND HYPOCENTER

The **hypocenter** is the point inside the Earth where the earthquake begins. The **epicenter** is the point on the surface directly above it. The P-S measurement estimates the station-to-hypocenter distance, which is a three-dimensional source distance.

WHY SCENARIO A WORKS DIRECTLY

Scenario A is an idealized 0 km-depth teaching case. In that special geometry, the hypocentral distance and horizontal epicentral distance are the same:

$$D_h = D_e$$

The measured distance can therefore be drawn directly as a circle around each station. Three circles should converge near the source.

WHY DEEPER CASES DO NOT

For a subsurface source, the measured hypocentral distance includes both horizontal distance and vertical depth:

$$D_h^2 = D_e^2 + z^2$$

Rearranging gives the horizontal map radius:

$$D_e = \sqrt{(D_h^2 - z^2)}$$

WORKED EXAMPLE

If D_h = 100 km and z = 60 km:

$$D_e = \sqrt{(100^2 - 60^2)} = 80 \text{ km}$$

The surface circle should have an 80 km radius, not 100 km.

WHAT STUDENTS SHOULD DISCOVER

In a deeper scenario, the raw source-distance circles are too large when drawn on the surface map. Students test assumed depth values until the corrected horizontal circles converge most closely around a common epicenter.

SCIENTIFIC FRAMING

The interactive uses straight-line geometry and constant velocities. Real earthquake-location systems solve source position, depth and origin time using many observations and seismic velocity models; seismic rays can bend through the layered Earth.

TEACHING NOTES

COMMON MISCONCEPTIONS

“The biggest wiggle is the arrival.”

No. The pick is the **onset** of the phase.

“The P-S gap gives distance to the epicenter.”

Not directly in a deep case. It estimates station-to-**hypocenter** distance.

“8 km/s is the speed of a seismic wave.”

No. It is the simplified P-S distance conversion factor derived from the assumed P- and S-wave speeds.

“Three circles should always meet perfectly.”

Student picks and rounding introduce measurement uncertainty. In deep cases, uncorrected circles also fail because depth has not yet been accounted for.

“A bigger trace means a bigger earthquake.”

Not necessarily. Recorded amplitude depends on magnitude, source distance, wave path and local site response.

“Soft sediment makes the earthquake stronger.”

The earthquake source and magnitude do not change. Soft sediment produces greater amplification and longer-lasting motion in this simplified site-response model.

“Bedrock means no shaking.”

Bedrock still shakes. It is represented here as a lower-amplification, shorter response than soft sediment.

“Epicenter and hypocenter are the same point.”

The hypocenter is underground; the epicenter is directly above it at the surface.

“Triangulation” versus “trilateration.”

The classroom method is often called triangulation, but the technique used here is technically **trilateration** because it uses distances, not angles.

MAGNITUDE VS AMPLITUDE - LOCKED COMPARISON

Student Page 10 compares **Scenario C - Station C** with **Scenario G - Station B**, both on Firm ground.

Case	Magnitude	Source distance	Relative recorded motion
C - Station C	M6.2	≈ 78 km	≈ 2.33×
G - Station B	M6.7	≈ 345 km	≈ 0.90×

The smaller M6.2 earthquake produces the larger trace at the chosen station because it is much closer.

LESSON PLANNING

SEQUENCE, ASSESSMENT & EXTENSIONS

RECOMMENDED FULL-PACK SEQUENCE

Lesson 1 (about 45-60 min): Pages 2-4 P/S waves, arrival picking and Scenario A; Pages 5-6 introduce depth with Scenario D.

Lesson 2 (about 45-60 min): Page 7 deeper independent case; Page 8 overlap challenge; Pages 9-10 site response and magnitude; Page 11 final case; Page 12 quiz.

CORE SCENARIOS

Student page	Case	Purpose
4	Scenario A	Clean first success; idealized 0 km depth and classic distance circles.
5-6	Scenario D	Discover that depth matters; expected true depth 80 km.
7	Scenario E	Independent application; expected true depth 120 km.
8	Scenario C - Station C	Overlapping P/S arrivals; apply onset picking to a less tidy trace.
10	Part A: assigned Part B: C-C vs G-B	Part A: compare distance on Firm ground (Scenario D recommended). Part B: magnitude vs amplitude.
11	Scenario G	Final integrated case; expected true depth 220 km and magnitude M6.7.

ASSESSMENT

A strong student should be able to:

- make reasonable P- and S-wave onset picks;
- calculate Δt and source distance with correct units;
- explain why the result is a hypocentral distance;
- use depth to convert source distance into horizontal epicentral distance;
- distinguish magnitude from recorded amplitude;
- describe site response without saying the earthquake itself changes;
- identify at least one simplification in the interactive.

EXTENSIONS

- **Uncertainty:** move an S pick by 1-2 s and calculate the resulting distance change.
- **Geometry:** calculate De for several assumed depths using the right-triangle equation.
- **Model critique:** list assumptions that would not hold everywhere in the real Earth.
- **Open exploration:** use Random case after students understand the complete method.

FINAL TEACHING MESSAGE

Earthquake Detective moves students from a simple observation - **P arrives before S** - to a chain of evidence: **arrival times -> P-S gap -> source distance -> depth -> epicenter and hypocenter**. The goal is not only to find an earthquake, but to understand how measurements become evidence.