CENTRAL QUESTION: What dinosaur did these bones come from?

TIME: 90-120 minutes

OVERVIEW:

- **SECTION 1** (20 minutes)
  What types of bones are these?
- **SECTION 2** (25 minutes)
  What species of dinosaur do these bones come from?
- **SECTION 3** (30 minutes)
  What evidence have we found?
- **SECTION 4** (15-45 minutes)
  What can we learn from communicating our arguments?

MATERIALS:

- One computer per two students
- One computer with the ability to broadcast material onto a screen visible by the entire class
- Printed ***Research Assistant Notebooks*** for students to record notes
- Whiteboard or other surface for teacher to use while facilitating class discussions
- Additional resources:
  - ***Student Learning Assessment Tool***
  - ***Student Rubric for Presenting Arguments***
  - ***Student Rubric for Assessing Learning Outcomes***

GETTING STARTED

Before class...

- Review this lesson plan, making notes on standards and/or skills you would like to focus on with your students. (**Hint:** Review the documents entitled *Curriculum Alignment* and the *Student Learning Assessment Tool* for ideas about skills and alignments best supported by this investigation.)
- Review the following recommended strategies for optimizing student learning outcomes.
    - Working in pairs ensures that every student has the opportunity to share their ideas. As students progress though the investigation, you may want to combine pairs of students into small groups to provide more practice sharing and responding to the ideas of their peers.
    - Build a shared vocabulary for the learning tasks by identifying target vocabulary beforehand and encouraging students to use these words often. Model correct usage if needed.
    - Think about places you can activate prior knowledge by prompting students to relate new concepts to a familiar context.
    - Think about how to integrate the *Research Quest* investigations with other curriculum-aligned activities.
    - Create and engage student interest in the program by expressing your enthusiasm and/or describing your personal interest in this investigation. You may also want to emphasize that students will be working with authentic materials on research questions that scientists actually address in their work.
    - Introduce students to sentence stems that reinforce flexible thinking and help students verbalize their thought processes:
        - "I see..."
        - "I think..."
        - "I wonder..."

In class...

- Provide a brief overview of the lesson to the class.
- Introduce the objectives the class will be focusing on today.
- Provide each student with a copy of the *Research Assistant Notebook* (RAN).
- Navigate to www.researchquest.org and login using the email address and password you used to create your *Research Quest* account. Then, navigate to the investigations tab.
- Locate this investigation on that page - far right - and click on the orange button with the text that reads, "Student Login Information," located below the name and thumbnail for this investigation. The student URL and your unique student access code will appear on the screen.
- Arrange students into pairs, one pair per computer. Instruct them to navigate to the following URL shown on the "Student Login Information" page, and enter the student access code found on this same page: www.researchquest.org/student/. It is important you have students use this particular URL and access code to get into the investigations. This allows you to keep your administrative account free of student activity.
- Once logged in, students will be on the landing page for this investigation. They should watch the two videos on this page before they start the investigation. This will give them necessary background information.

SECTION 1: WHAT TYPES OF BONES ARE THESE? *(20 minutes)*

OVERVIEW

Students will gather empirical data by making quantitative and qualitative observations of 3D models of three mystery fossils from Cleveland-Lloyd Dinosaur Quarry, analyze and interpret the data based on provided guidelines, and communicate their arguments, which should include an explanation with supporting evidence.

ASSESSMENT

In this section, the instructor may find it useful to focus on the following critical thinking skills, defined in more detail in the *Student Learning Assessment Tool* located under the "Teacher Support" tab of the website:

- **Observation:** Make detailed, sense-based observations that discriminate between objects.
- **Interpretations:** Make inferences and interpretations that clearly articulate a link between the evidence and the interpretation.

	STUDENT ACTION	TIPS FOR SUPPORTING CRITICAL THINKING
STEP 1	Students watch the video on Step 1 of the investigation (1:20 minutes).	• Direct students' attention to the following before beginning the video: *In this video, Carrie Levitt, a paleontologist from the Natural History Museum of Utah, is going to talk about the purpose of this investigation and explain the first task. Listen for Carrie's explanation of what we can learn from this investigation and how to get started on the first task.*
STEP 2	Students make observations of Mystery Fossil #1, writing down detailed descriptions and comparisons to more familiar objects. *RESEARCH ASSISTANT NOTEBOOK (RAN):* Page 1	• Have a brief class discussion about the limitations of the model. For instance, you might discuss what types of data you can and cannot get from the 3D models. • Get a baseline reading of students' observation skills using the *Student Learning Assessment Tool*. • Discuss how students can improve their observation skills.
STEP 3	Students watch the video on Step 3 of the investigation (2:56 minutes).	• Direct students' attention to the following before beginning the video: *Carrie is going to model how she gathered, analyzed, and interpreted evidence by making detailed observations of Mystery Fossil #1. Pay especially close attention to how Carrie's detailed notes helped her identify evidence, and how she evaluated that evidence as she developed her claim.*

SECTION 1: WHAT TYPE OF BONE IS THIS? *(Continued)*

	STUDENT ACTION	TIPS FOR SUPPORTING CRITICAL THINKING
STEPS 4 & 5	Students continue on to Steps 4 & 5 of the website, gathering evidence through detailed observations, making inferences that are supported by evidence, and recording and evaluating the strength of that evidence in the RAN. *RAN: pages 1 & 2*	▪ Initiate a brief discussion and ask students to provide examples and non-examples of advanced-level observations using objects around the room. ▪ Get a baseline reading of students' interpretation skills using the *Student Learning Assessment Tool.* ▪ Discuss how students can improve their interpretations.
REFLECT	In pairs, students answer four reflection questions presented on the *Research Quest* website.	▪ You can view your students' responses under the "My Account" tab when logged into the *Research Quest* website. ▪ Note: If students' reflections are consistent with Carrie's they will be prompted to move on to the next step. If their reflections are mostly different, they will be prompted to go back and make more detailed observations of the Mystery Fossils.
STEP 6	In pairs, students discuss their evidence and construct an argument that addresses the following question: *What part of the dinosaur do you think these bones come from and why?* Next, students share their arguments in small groups, offering respectful feedback to each other as they discuss their explanation and evidence.	▪ Note: This step is an important warm-up to get students talking, sharing, and exchanging ideas. They will build on these skills as they continue through the rest of the investigation. ▪ Encourage students to use the conversation hints posted in this step of the investigation. It may be helpful to review students' responses to the reflection questions that followed Step 5 to see what concepts students might need clarified and/or modeled. ▪ As students construct and share their arguments, facilitate small group conversations that draw out inferences with open-ended questions like: – "What makes you think...?" – "What else could this mean?"
STEP 7	Students watch the video on Step 7 of the investigation (2:50 minutes).	▪ Direct students' attention to the following before beginning the video: *Carrie is going to model how she came to her conclusions about what part of the dinosaur the Mystery Fossils come from. Listen for anything Carrie noticed about the Mystery Fossils that you missed and write these observations down. These detailed observations will be helpful in the next part of the investigation.*

SECTION 2: WHAT SPECIES OF DINOSAUR IS THIS? *(25 minutes)*

OVERVIEW
Students will compare the Mystery Fossils to 3D models of fossils already classified by type and species from Cleveland-Lloyd Dinosaur Quarry. The data they collect will serve as the basis for their answer to the central question of this investigation, "What dinosaur did these bones come from?"

ASSESSMENT
In this section, the instructor may find it useful to focus on the following critical thinking skills, defined in more detail in the *Student Learning Assessment Tool* located under the "Teacher Support" tab of the website:

- **Comparisons:** Note similarities and differences across objects and articulate consistent and inconsistent data.
- **Flexible Thinking:** Keep mind open to multiple ideas.
- **Evaluation:** Consider the strength of each piece of evidence.
- **Connections:** Use multiple materials and objects; use evidence from one source to examine related data in another source.

	STUDENT ACTION	TIPS FOR SUPPORTING CRITICAL THINKING
STEP 8	Students watch the video on Step 8 of the website (2:10 minutes).	• Direct students' attention to the following before beginning the video: *Carrie is going to provide instructions for the next task, which is making comparisons between the Mystery Fossils and other fossils from Cleveland-Lloyd Dinosaur Quarry. Listen for how she makes comparisons.*
STEPS 9 & 10	Following the instructions on Steps 9 & 10 of the website, students look for anatomical similarities and differences between Mystery Fossils 1 & 2 and models of other fossils found at Cleveland-Lloyd Dinosaur Quarry in order to identify what type of dinosaur the Mystery Fossils come from. *RAN: pages 3 & 4*	• Note: You may find it helpful to model and/or walk through the process of filling out this chart together as a class. • Combine student pairs into small groups to complete the investigation. • Ask students to model how to make strong comparisons. Using the *Student Learning Assessment Tool* as a guide, provide feedback that will help students make "advanced-level" comparisons. • Encourage students to keep their minds open to multiple ideas.
DISCUSS	Students discuss and make a claim for what type of dinosaur (Ornithischian, Sauropod, or Theropod) they think the Mystery Fossils come from.	• Prompt students to use the terms "strong," "weak," and "disconfirming" while discussing their reasoning and evidence. Note: In the charts on pages 3 & 4 of the RAN, rows with one check mark provide strong evidence, rows with two or more check marks provide weak evidence, and "x"s indicate disconfirming evidence.

SECTION 2: WHAT SPECIES OF DINOSAUR IS THIS? *(Continued)*

	STUDENT ACTION	TIPS FOR SUPPORTING CRITICAL THINKING

STEP 11	On Step 11, students select the button that corresponds with the type of dinosaur to which the evidence from Mystery Fossils 1 & 2 led them. This will pull up the jaw library for that type of dinosaur, now annotated with species names, so that students can narrow down their claim to a specific species from that type.
	
	RAN: page 5
		▪ Note: At this point students can benefit from additional class discussion. Building off their comparisons of the claw and femur for the type of dinosaur- inevitably the theropod- you may want to look at page 5 in the RAN together. Most students can use additional support orienting themselves to this next step in the investigation. If you have the investigation projected in the room you can point out where the species names are for each of the theropod jaws to which they will compare the Mystery Fossil jaw. These are the names they will write in the column headers. This and more is explained in the RAN.
		▪ Note: Some evidence may be strong as an answer for a particular question but weak for another question. Check for understanding of this key concept with a quick class discussion. Possible questions for discussion:
		  ▪ What evidence was strong for identifying the type of dinosaur?
		  ▪ Is that evidence strong or weak for identifying the species of dinosaur?
		  ▪ What can we learn from this?

REFLECT	In pairs, students answer three reflection questions presented on the *Research Quest* website.	▪ You can view your students' responses under the "My Account" tab when logged into the *Research Quest* website. ▪ Note: If students' reflections are consistent with Carrie's they will be prompted to move on to the next step. If they are mostly different, they will be prompted to go back and make more detailed observations of the Mystery Fossils.

SECTION 3: WHAT EVIDENCE HAVE WE FOUND? *(25 minutes)*

OVERVIEW
Students will analyze the comparisons they have made. They will determine which species their observations/evidence is pointing them to by evaluating that evidence as strong, weak, or disconfirming for that explanation.

ASSESSMENT
In this section, the instructor may find it useful to focus on the following critical thinking skills, defined in more detail in the *Student Learning Assessment Tool* located under the "Teacher Support" tab of the website:

- **Flexible Thinking:** Keep mind open to multiple ideas.
- **Evaluation:** Consider the strength of each piece of evidence.
- **Interpretations:** Make inferences and interpretations that clearly articulate a link between the evidence and the interpretation.

	STUDENT ACTION	TIPS FOR SUPPORTING CRITICAL THINKING
STEP 12	Students watch the video on Step 12 of th investigation (2:08 minutes).	• Direct students' attention to the following before beginning the video: *Carrie is going to discuss how to evaluate the evidence you find. Pay close attention to what she says about how to discuss evidence with your peers.*
STEP 13	In small groups, students discuss their inferences about what species of dinosaur the Mystery Fossils come from and go back to look at and analyze the evidence they have gathered and recorded in the RAN. They can begin filling out page six of the RAN, listing their disconfirming, strong, and weak evidence for what species of dinosaur the Mystery Fossils come from. *RAN: page 6*	• Remind students about your previous discussion of evidence strength and how the strength of a piece of evidence is dependent upon the question you are asking. At this moment, students are asking (and answering) the question, "what species of dinosaur did these bones come from?" • Model and clarify how to analyze and evaluate evidence, as needed. • Note: Step 13 of the website includes brief reminders of the definitions Carrie presented for strong, weak, and disconfirming evidence.
STEP 14	Students complete page six of the RAN, explaining how each piece of evidence supports their explanation for the type and species of dinosaur the Mystery Fossils come from. *RAN: page 6*	• After students have evaluated their evidence, prompt them to move on to Step 14 of the investigation. This page provides tips for constructing an evidence-based explanation. • Evaluate students on the critical thinking skills you are targeting using the *Student Learning Assessment Tool* as a guide. • To emphasize strong argument construction at this point, distribute the *Student Rubric for Presentation of Arguments*, located under the "Teacher Support" tab of the website. Students can use this as a guide when constructing their argument.

SECTION 3: WHAT EVIDENCE HAVE WE FOUND? *(Continued)*

	STUDENT ACTION	TIPS FOR SUPPORTING CRITICAL THINKING
STEP 15	On Step 15 of the website, students select the button with the name of the species of dinosaur the Mystery Fossils come from.	▪ You can view your students' responses under the "My Account" tab when logged in to the *Research Quest* website.
REFLECT	In pairs, students answer three reflection questions presented on the *Research Quest* website.	▪ You can view your students' responses under the "My Account" tab when logged in to the *Research Quest* website.

SECTION 4: WHAT CAN WE LEARN FROM COMMUNICATING OUR ARGUMENTS? *(15-45 minutes)*

OVERVIEW
Students will engage in argument from evidence as they communicate their explanation and the reasoning behind it, responding respectfully to criticism and questions from peers. Students will also listen and respectfully communicate questions and critiques of peers' arguments.

ASSESSMENT
In this section, the instructor may find it useful to focus on the following critical thinking skills, defined in more detail in the *Student Learning Assessment Tool* located under the "Teacher Support" tab of the website:

- **Problem Finding:** Propose relevant ideas and articulate the need for further information to evaluate the idea.
- **Flexible Thinking:** Keep mind open to multiple ideas.
- **Evaluation:** Consider the strength of each piece of evidence.

In addition, students may evaluate themselves and their peers using the *Student Rubric for Presentation of Arguments* and the *Student Rubric for Assessing Learning Outcomes*.

	STUDENT ACTION	TIPS FOR SUPPORTING CRITICAL THINKING
STEP 16	Students review the tips for communicating their arguments with their peers on Step 16 of the website, and prepare to present with their small groups. Students may use the *Student Rubric for the Presentation of Arguments* to evaluate the strength of their argument and improve it prior to presenting.	▪ Facilitate a group conversation about communicating arguments, or let students discuss these tips in their small groups. ▪ This is also a good time to distribute the *Student Rubric for Presenting Arguments* if you have not already done so. Students can assess the strength of their group's argument and make changes to strengthen it as needed. Note that they can also use this rubric to evaluate the strength of their peers' arguments in the next step.

SECTION 4: WHAT CAN WE LEARN FROM COMMUNICATING OUR ARGUMENTS? *(Continued)*

	STUDENT ACTION	TIPS FOR SUPPORTING CRITICAL THINKING
PRESENT	Students present their argument to their peers. This includes generating, receiving, and responding to respectful critiques and clarifying questions. This can be formatted several ways from informal presentations, class discussion, debate, etc. Students may use the *Student Rubric for the Presentation of Arguments* to evaluate the strength of their peers' arguments. Students should also be asking clarifying questions and/or offering respectful critiques.	• Ask open-ended questions to draw out inferences. • Some students may benefit from using sentence stems to help facilitate discussion about their ideas. • Evaluate students on the critical thinking skills you are targeting in this section using the *Student Learning Assessment Tool* as a guide.
STEP 17	Students watch the video on Step 17 of the website.	• It may be useful to direct students' attention to the following before beginning the video: *Carrie is going to share her argument for what dinosaur the Mystery Fossils come from and explain her reasoning. Listen carefully for ways her argument was similar or different from yours.*
STEP 18	Students may complete additional extension activities.	• Optional extension activities are provided on the website to take student learning a step further. • The *Student Rubric for Assessing Learning Outcomes* is located in the support materials for each investigation. Using this rubric, students can reflect on the critical thinking skills they developed and practiced during this investigation and think about ways they can continue to use these skills in the future. • Reinforce critical thinking skills, vocabulary, and other target behavior during curriculum-aligned activities.