Using pictures, online articles, and databases to make an argument about the evolutionary relationships of three animals

MIGUEL HERNANDO AND JAEKEUN JUNG

Science is full of amazing facts, but at times it may be difficult to fully appreciate their significance without an understanding of the scientific practices that gave them meaning. The teaching of evolution may be an example of this situation; there are many interesting facts to consider, but it is equally important for students to learn where those facts come from and to have opportunities to weigh the evidence themselves. We designed an activity that allows students to take on the role of researchers and scientists themselves.
In this task students collect and use evidence to determine the evolutionary relationship between three (carefully chosen) animals. This task is aligned to HS-LS4-1; There are multiple lines of evidence supporting evolution, which is our main content objective. The idea of asking students to use evidence to determine evolutionary relationships has been implemented before (e.g., BSCS 2016), but we introduce some novel elements.

The first is a strong focus on SEP 7, Engaging in Argument from Evidence. Choosing evidence-based argumentation as a primary skill is very important, especially in our context. We want students to gain an appreciation of where the facts come from and how the scientific process advances through collecting and evaluating evidence. Our lessons include significant time for students to conduct research and work with their data. We strengthen the connection to SEP 7 by requiring students to write a formal, evidence-based argument at the end. This ensures that students have a first-hand experience of the process of evaluating and weighing evidence.

Our second novel element is an emphasis on teaching the language of science. All our students are English language learners (ELLs) at WIDA levels 1-3. At these proficiency levels students typically lack a large part of the vocabulary, grammar, and discourse structures needed to engage in scientific argumentation in English. We thought that this high-interest activity could be used to stimulate language learning, and designed it to support students learning the language of argumentation and comparison in the context of evolution. These three strategies from ELL instruction are very important throughout the unit:

- Having robust language objectives with specific vocabulary, sentence, and discourse forms for students to learn.
- Modeling processes and structures for students. (Fairbairns and Jones Vo 2010)
- Recognizing that students’ native language is a strength that can be leveraged to learn content and English faster (Ballenger 2008, Beeman and Urow 2013, Fairbairns and Jones Vo 2010)

To reach these goals, our unit uses daily formative assessments to check on student progress with both content and language. Figure 1 summarizes those assessments and can be consulted for a quick overview of the activity.

Ours is a public high school located in Chelsea, Massachusetts. Our classes tend to have around 20-25 students mostly in grades 9 and 10, and consist entirely of ELL students at WIDA levels 1-3. This task took 5 consecutive periods that were 77 minutes long. This task has minimal costs—a few photocopies for each student, and printouts that are freely available online; and either paper or online spreadsheets.

## Planning

Our planning started by writing an exemplar argument (see Figure 2). Arguments can have many forms, but having a specific exemplar at hand helped us to tie down the daily content and language objectives that we needed to support students. To develop the exemplar, we chose a trio of animals and went through the activity ourselves, collecting and recording data and writing the argument.

Our district requires us to use a common, proprietary rubric to evaluate argument writing. This rubric is adjusted and revised periodically, and it provides vertical alignment in science classes. During our planning we took care that our exemplar reflected most of the domains in the district’s rubric (see Figure 6, Online Connections).

We wanted our exemplar to be an authentic piece of grade-level scientific writing (since students were likely to encounter similar language in the state assessment), but at the same time we wanted to minimize the linguistic difficulty (Fairbairns and Jones Vo 2010). We focused on identifying a few vocabulary forms and sentence structures that were grade-level appropriate and could be repeated in several places.

The length and complexity of the exemplar can obviously be adjusted and differentiated to reflect the levels of support needed by the students in front of you, especially if they require accommodations. Depending on your student population, you

---

**FIGURE 1**

### Activity Assessments.

**Day 1**

Formative Assessment. According to you, which two animals are more closely related? Why?

**Day 2**

Formative Assessment 1. Complete the anatomical evidence section of the spreadsheet.

Formative Assessment 2. Using the sentence forms you learned, describe the anatomical evidence you collected.

**Day 3.**

Formative Assessment 1. Complete the reproductive biology evidence section of the spreadsheet.

Formative Assessment 2. Using the sentence forms you learned, describe the reproductive biology evidence you collected.

**Day 4.**

Formative Assessment 1. Complete the protein evidence section of the spreadsheet.

Formative Assessment 2. Using the sentence forms you learned, describe the protein sequence evidence you collected.

**Day 5.**

Final Assessment. Using your writings from each day and an argument exemplar, write an argument to answer your research question.
can focus on having more or fewer types of evidence, more or less linguistic complexity, and more or less emphasis on a written, spoken, or presentation product. Generating exemplars at different difficulty levels will help you think about how to adjust the steps of the activity to the students in front of you.

Day 1: Introduction to the task
On day 1 we give each student pictures of a trio of animals and ask them to predict their evolutionary relationships (see Figure 3). The trios are chosen strategically so that superficially similar animals are not, in fact, the ones most closely related.

Our content objective for this day is to write an initial claim and produce a short paragraph defending the claim with evidence from the pictures and the students’ own background. Our language objective is to state evolutionary relationships using “…is more closely related to… than…” We translate this sentence frame to the students’ languages (translator programs can be very helpful, if the teacher does not know the language of the students) and point out correlations between the words in their language and the words in the English structure (Beeman and Urow 2013). We also show students how to recycle parts of the research question to make their claim.

We then set up a time for students to share their questions and answers and to offer suggestions to each other. Students with low English proficiency levels do this mostly in their own native languages. We then direct students to revise their answers based on their discussion.

Even if students’ initial answers are incorrect, discussion is a very important part of the argumentation process. First, by discussing their own ideas, students start building a scientific story about the task. This scientific story is the one that will make the task meaningful to them (Mortimer and Scott 2003). Second, students start to recognize that they can use evidence (in this case, facts that they know) to predict evolutionary relationships. When students discover more evidence later in the unit they can reassess where the balance of the evidence lies. Third, this step provides students with materials that they can use for writing their argument on the last day of the unit.

FIGURE 2

Evolutionary relationships exemplar.

Are salamanders more closely related to reptiles or to fish?

My research question is, are salamanders more closely related by evolution to crocodiles or to fish?

According to my research, salamanders and crocodiles have a more recent common ancestor than salamanders and fish. Or, in other words, salamanders are more closely related to crocodiles than to fish. Three evidences that support this claim are comparative anatomy, reproductive biology, and DNA sequences.

Comparative anatomy is my first evidence. I compared the skeletons of salamanders, fish and crocodiles, and I found the following. First, both salamanders and reptiles have femur, but fish do not have femur. Second, both salamanders and reptiles have a pelvis, but fish do not have a pelvis. Third, both salamanders and reptiles have arms and legs, but fish do not have any arms and legs. Fourth, only fish have fins, but salamanders and reptiles do not have fins. As you can see, there are more similarities between the skeletons of salamanders and crocodiles, than between salamanders and fish. These shared characteristics by salamanders and reptiles show their evolutionary relationship, because it is plausible that the most recent common ancestor also had these traits.

My second evidence comes from studying how these animals reproduce. For this purpose, I studied the information in animaldiversity.org. According to this website, both salamanders and reptiles are oviparous. Both salamanders and reptiles are oviparous possibly because the common ancestor of salamanders and reptiles also laid eggs.

My third evidence comes from comparing the DNA sequences of specific proteins using BLAST. First, I looked up the DNA sequences for NADH dehydrogenase, which is a protein that is found in mitochondria and catalyzes a reaction involving NAD+. According to the BLAST website, the genes for NADH dehydrogenase in salamanders and reptiles are 76% similar, while the genes for NADH in salamanders and fish are 71% similar. Second, I looked up the DNA sequence for the myosin, which is a protein that makes up muscle tissue. According to the BLAST website, the genes for myosin in salamanders and crocodiles are 82% identical, while the genes for myosin in salamanders and fish are only 75% identical. This result shows that salamanders and crocodiles diverged more recently from a common ancestor that had similar DNA sequences.

Some people could argue that salamanders and fish are more related, because both lay eggs in water, while reptiles lay eggs on land. However, this is false, because there is more evidence from DNA sequences and comparative anatomy that shows that salamanders share more similarities with reptiles.

In conclusion, all this evidence clearly shows that salamanders are more closely related to crocodiles than to fish. An implication of this argument is that perhaps, it is not only salamanders and reptiles, but also all the other animals that are related through the evolutionary process.
According to the Common Core definition, an argument must include a fair discussion and rejection of a counterclaim, a view opposite to the one they are defending (see Common Core Standards, WHST 9-10.1.B). By letting students spell out their evidence in favor of the wrong answer, students are generating material that they can later re-use.

### Day 2: Anatomical evidence

The objective for day 2 is to analyze, record, and describe anatomical evidence regarding skeleton structure. We use pictures of labeled skeletons, printing one skeleton per page and giving each student one for each animal in their trio.

We support students by modeling how to look at the diagrams. We project skeletons of 3 animals that no student has (a salamander, a fish, and a crocodile) and physically point out similarities and differences in specific bones. Next we model how to record the findings in a spreadsheet; in a column marked “femur” the salamander and the crocodile would get a “Yes” while the fish gets a “No” (see Figure 4).

We then release students to study their own animals. Students take around 15 minutes to record 5 characteristics. The biggest problem has been the uneven quality of the skeleton printouts. Some printouts leave out important bones (our mouse skeleton did not label the pelvis, and students took this to mean that mice had no pelvis). Also, students realize that owls, bats, and mice all have phalanges, but many students do not think to count them.

Day 2 also has two language objectives. The first is to learn the vocabulary of bones. The use of labeled printouts paired with a meaningful context of application helps students understand and apply this difficult and very new vocabulary (Marzano, Pickering, and Pollock 2001).

Our second language objective is for students to write three-term comparisons regarding anatomical structure. To this end, we have developed the technique of double-modeling: We show students a model of the language they need to use and then we model the process of constructing that language from the resources they have. In our planning we had come up with a few sentence models to make anatomical comparisons between three animals:

- Both the crocodile and the salamander have a femur, but the fish does not have a femur.
- The fish has fins, but neither the crocodile nor the salamander have fins.
- The crocodile, the fish and the salamander all have skull.

We project these sentence models on the board and provide translations. When we are sure students understand, we model the process of writing the sentences. We project our model spreadsheet and, for each word in the sentence, make a show of physically pointing at the relevant parts of the spreadsheet connected to it. We then ask students to write a sentence for each structure recorded in the spreadsheet. These sentences represent the formative assessment for the day.

![Figure 3](image-url)  
**Figure 3**  
**Trios of animals for investigation.**

<table>
<thead>
<tr>
<th>Trios</th>
<th>Question</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dolphin, cow, and shark</td>
<td>Which animal is more closely related by evolution to the dolphin: The cow or the shark?</td>
</tr>
<tr>
<td>Manatee, elephant, and shark</td>
<td>Which animal is more closely related by evolution to the manatee: The elephant or the shark?</td>
</tr>
<tr>
<td>Bats, owls, and mice</td>
<td>Which animal is more closely related by evolution to the bat: The owl or the mouse?</td>
</tr>
<tr>
<td>Platypus, ducks, and dogs</td>
<td>Which animal is more closely related by evolution to the platypus: The duck or the dog?</td>
</tr>
<tr>
<td>Crab, barnacle, limpet</td>
<td>Which animal is more closely related by evolution to the barnacle: The limpet or the crab?</td>
</tr>
<tr>
<td>Panda, red panda, polar bear</td>
<td>Which animal is more closely related by evolution to the panda: The red panda or the polar bear?</td>
</tr>
<tr>
<td>Elephant, shrew, elephant shrew (sengis)</td>
<td>Which animal is more closely related by evolution to the sengis: The shrew or the elephant?</td>
</tr>
</tbody>
</table>
Day 3: Reproductive evidence
On day 3 we research, record, and describe evidence regarding reproductive strategies, starting with a mini-lecture on the differences between oviparous, viviparous, and ovoviviparous strategies. The lecture includes definitions, pictures, and short videos, of animals both well-known and unfamiliar to the students. We also show students how to access library resources; any good encyclopedia will suffice for the purpose of research. (We used animaldiversity.org). Students then research and record their findings in their growing spreadsheets (see Figure 4).

Our language objective for this day includes learning the vocabulary of reproduction (oviparous, viviparous and ovoviviparous) and producing 3-term comparison sentences regarding the reproductive strategies of their three animals. For the writing portion, we ask students to use the same sentence models as for the previous day, which are easily adapted for this purpose.

It is possible the content of this day will not fill a full class period. A good use of the extra time is to give students time to take stock of their investigation and compare what they thought on day 1 with what they are thinking now. It is also a good opportunity for students to catch up with their writing if they are falling behind.

Day 4: Protein evidence
On day 4 students research and compare DNA sequences for specific proteins in their three animals using the BLAST and GENE databases. We start with a review and mini-lecture about DNA, mutations, and the Genome Project. We then share a written protocol (see Figure 5, Online Connections). We demonstrate how to use the protocol with a specific protein (NADH dehydrogenase) in our three animals. This is a challenging activity, because it involves navigating websites with a lot of information. We model one step, then wait for all students to catch up and circle near struggling students.

When students are ready to start, we provide them with a very short list of proteins to research using the protocol. The biggest challenge is selecting the appropriate protein and animal from the various menus in the GENE and BLAST websites. For example, a search for “elephant” triggers a drop-down menu where the first choice is the elephant shrew, which is not at all an elephant. (Next time we will use the scientific names, like a reviewer suggested.) Like always, we circulate and addressed trends as needed. After each BLAST, students record their percentage of similarity in their spreadsheets.

Our first language objective consists of understanding the names of the proteins the students are researching. We ask students to take notes from online sources, and also to relate the protein to processes they have already studied. Then they report on the function of the protein following this sentence model:

I looked up the DNA sequences for NADH dehydrogenase, which is a protein that is found in mitochondria and helps with cellular respiration.

Describing the DNA evidence from day 4 was not possible with the sentence structures from previous days, so our second language objective is to use this type of sentence:

According to the BLAST website, the genes that code for NADH dehydrogenase in salamanders and reptiles are 76% similar, while the same genes in salamanders and fish are 71% similar.

Once again we translate these models to make them comprehensible, and we model the process of writing them using the information recorded in the spreadsheet. While students work on their own sentences, we circulate and ask students to compare their writing with the model.

Day 5: Writing the argument
Students’ objective for day 5 is to write a claim about the relationship between their three animals, and to support the claim by writing an argument. Writing an argument requires critical thinking skills as well as sophisticated linguistic skills, and
for this reason it is very important to continue to support the
students during this part of the process. We budgeted at least a
whole class period so that students could complete the writing
in class, rather than at home.

We again use double modeling to teach argument structure.
We start by sharing the exemplar argument we developed dur-
ding our planning (see figure 2). We ask students to read the ex-
emplar (L1 translations are also made available so that students
can read them side by side) and annotate the topic of each para-
graph (for example: anatomical evidence paragraph). We then
model the process of writing by showing students correspond-
ating parts of the evidence spreadsheet, the sentences they had
written on previous days, and parts of the essay.

During writing, we observe students simultaneously using
the evidence spreadsheet, the sentences they had written previ-
ously, the exemplar argument, the translation of the exemplar,
and their own growing essay. One student struggle regarding
the use of the exemplar argument concerned distinguishing
generic vocabulary and grammar that could be recycled from
details that could not. In our coaching we encourage students to
compare their writing with their evidence spreadsheet to make
sure the evidence they reference in their own essay is relevant.

The writing assignment from day 1 made figuring out and
attacking a counterclaim easy for students. For example, students
who initially thought the dolphin was more closely related to the
shark had some evidence both in favor and against this claim.

To evaluate the student work we used our district’s propri-
etary rubric on Scientific Argumentation (see Online Connec-
tions). As students go on to take other science class-

es like Chemistry and Physics, they will continue to be evalu-
ated with the same rubric, which will help them build on their
skill of scientific argumentation.

ONLINE CONNECTIONS

Animal online encyclopedia: https://animaldiversity.org/
Common Core Standards for Writing in History, Science and Technical
Subjects: http://www.corestandards.org/ELA-Literacy/WHST/9-10/
English language development standards: https://wida.wisc.edu/teach/
standards/eld
Student instructions and grading rubric: https://www.nsta.org/online-
connections-science-teacher

REFERENCES

Teaching Science to English Language Learners: Building on Students’ Strengths,
between Languages. Philadelphia: Caslon Publishing.
Publishing Company.
Fairbairn, S. and S. Janes Vo. 2010. Differentiating Instruction and Assessment for
English Language Learners. Philadelphia: Caslon Publishing.
Research-based strategies for increasing student achievement. Alexandria, VA:
ASCD.
Philadelphia: Open University Press.
National Governors Association Center for Best Practices, Council of Chief State

Jaekeun Jung (jaekeun93@hotmail.com) is a medical assistant at Pleasant Hill Family Medicine in Duluth, Georgia. Miguel Hernando
(mhernando94@msn.com) is a science and ESL teacher at the Bridge Academy in Chelsea High, Chelsea, Massachusetts.