Table S1. Percentage of student responses that contained specific forms of reasoning to evaluate taxa relatedness for each instrument and style of phylogenetic tree.

| Taxa Relatedness Reasoning         | Pre-HW [n=74] | Post-HW [n=75] | Unit Exam [n=81] | Final Review [n=72] |
|-----------------------------------|---------------|----------------|------------------|---------------------|
| **Diagonal Phylogenetic Trees**   |               |                |                  |                     |
| Most Recent Common Ancestry       | 14%           | 41%            | 51%              | 47%                 |
| Monophyletic Grouping             | 1%            | 0%             | 0%               | 0%                  |
| Counting Nodes                    | 23%           | 28%            | 31%              | 32%                 |
| Counting Synapomorphies           | 35%           | 16%            | 10%              | 19%                 |
| Branch Tip Proximity              | 36%           | 13%            | 4%               | 1%                  |
| External Insights                 | 5%            | 5%             | 2%               | 1%                  |
| Other Responses                   | 8%            | 11%            | 14%              | 11%                 |
| **Bracket Phylogenetic Trees**    |               |                |                  |                     |
| Most Recent Common Ancestry       | 11%           | 53%            | 64%              | 57%                 |
| Monophyletic Grouping             | 4%            | 4%             | 1%               | 3%                  |
| Counting Nodes                    | 28%           | 23%            | 23%              | 24%                 |
| Counting Synapomorphies           | 41%           | 13%            | 7%               | 19%                 |
| Branch Tip Proximity              | 22%           | 9%             | 5%               | 1%                  |
| External Insights                 | 7%            | 3%             | 2%               | 1%                  |
| Other Responses                   | 12%           | 5%             | 6%               | 7%                  |

*Italics* indicate correct forms of reasoning for taxa relatedness. Student responses could include multiple forms of reasoning (percentages sum to greater than 100%). See Dees et al. (2014) for complete descriptions and student-generated examples of reasoning categories.
**Table S2.** Percentage of phylogenetic trees constructed by students that contained specific errors for each instrument and style of phylogenetic tree.

| Major Errors | Pre-HW [n=74] | Post-HW [n=75] | Unit Exam [n=64]# | Final Review [n=56]# |
|--------------|---------------|----------------|------------------|---------------------|
| Incorrect Relatedness | 22% | 13% | 11% | 11% |
| Incorrect Traits | 27% | 16% | 19% | 18% |
| Contemporary Descent | 3% | 4% | 2% | 0% |

| Minor Errors | Pre-HW [n=74] | Post-HW [n=75] | Unit Exam [n=64]# | Final Review [n=56]# |
|--------------|---------------|----------------|------------------|---------------------|
| Empty Branches | 42% | 40% | 39% | 39% |
| Extra Nodes | 61% | 52% | 52% | 52% |

| Major Errors | Pre-HW [n=74] | Post-HW [n=75] | Unit Exam [n=17]* | Final Review [n=16]* |
|--------------|---------------|----------------|-------------------|--------------------|
| Incorrect Relatedness | 22% | 13% | 0% | 6% |
| Incorrect Traits | 24% | 15% | 12% | 13% |
| Contemporary Descent | 3% | 3% | 6% | 6% |

| Minor Errors | Pre-HW [n=74] | Post-HW [n=75] | Unit Exam [n=17]* | Final Review [n=16]* |
|--------------|---------------|----------------|-------------------|--------------------|
| Empty Branches | 9% | 4% | 12% | 13% |
| Extra Nodes | 19% | 8% | 12% | 6% |
| Side Branches* | 16% | 11% | 18% | 13% |

#Students constructed one phylogenetic tree in the style of their choice during the unit exam and review activity for the final exam. *Error is unique to the bracket style. Student responses could include any combination of errors or no errors (percentages do not sum to 100%). See Dees and Momsen (2016) for complete descriptions and student-generated examples of errors.

**References**

Dees J, Momsen JL (2016). Student construction of phylogenetic trees in an introductory biology course. Evol Educ Outreach 9, ar3.

Dees J, Momsen JL, Niemi J, Montplaisir L (2014). Student interpretations of phylogenetic trees in an introductory biology course. CBE Life Sci Educ 13, 666–676.
The following interpretation and construction tasks referred to diagonal phylogenetic trees.

**Figure 1: phylogenetic tree of vertebrates (diagonal style)**

**Most Recent Common Ancestor**

Which node on the phylogenetic tree of vertebrates in Figure 1 represents the most recent common ancestor of griffon vultures and short-beak echidnas? Select one option.

- ___ node A
- ___ node B
- ___ node C
- ___ node D

**Monophyletic Group**

On the phylogenetic tree of vertebrates in Figure 1, draw a circle around one monophyletic group that includes at least two species.

**Contemporary Descent**

According to the phylogenetic tree of vertebrates in Figure 1, did griffon vultures evolve from saltwater crocodiles? Select one option.

- ___ Yes
- ___ No

Explain the reasoning for your choice.
**Taxa Relatedness**

According to the phylogenetic tree of vertebrates in Figure 1, how would you describe the relatedness of saltwater crocodiles to tiger salamanders and koalas? Select one option.

- ___ Saltwater crocodiles are more closely related to tiger salamanders than koalas.
- ___ Saltwater crocodiles are equally related to tiger salamanders and koalas.
- ___ Saltwater crocodiles are more closely related to koalas than tiger salamanders.

Explain the reasoning for your choice.

**Construction Task**

Directions: Use the morphological traits in Table 1 to construct a phylogenetic tree of land plants in the diagonal style (see Figure 1 on the first page for an example of diagonal style). Be sure to label all synapomorphies on the phylogenetic tree.

Table 1: morphological traits of land plants (X = trait possessed)

| TRAITS | Alligator | Juniper | Alpine Clubmoss | Scarlet Banana | Bearded Pawwort | Queen Sago | Saguaro Cactus |
|--------|-----------|---------|----------------|---------------|----------------|-----------|---------------|
| Stomata| X         | X       | X              | X             | X              | X         | X             |
| Fruit  |           | X       |                |               | X              |           |               |
| Scale Leaves | X       |         |                |               |                |           |               |
| Leaves |           |         |                |               |                |           |               |
| Seeds  | X         |         | X              | X             | X              |           |               |
| Spines |           |         |                |               |                |           | X             |
| Cones  | X         |         |                |               |                |           |               |

Remember to construct a phylogenetic tree in the diagonal style (see Figure 1 for an example).
Instrument #1: Pre-Instructional Homework (Continued)

The following interpretation and construction tasks referred to bracket phylogenetic trees.

**Most Recent Common Ancestor**

Which node on the phylogenetic tree of vertebrates in Figure 1 represents the most recent common ancestor of great cormorants and platypuses? Select one option.

- _____ node A  
- _____ node B  
- _____ node C  
- _____ node D  

**Monophyletic Group**

On the phylogenetic tree of vertebrates in Figure 1, draw a circle around one monophyletic group that includes at least two species.

**Contemporary Descent**

According to the phylogenetic tree of vertebrates in Figure 1, did great cormorants evolve from black caimans? Select one option.

- _____ Yes  
- _____ No  

Explain the reasoning for your choice.
Instrument #1: Pre-Instructional Homework (Continued)

Taxa Relatedness

According to the phylogenetic tree of vertebrates in Figure 1, how would you describe the relatedness of black caimans to marbled newts and agile wallabies? Select one option.

- ___ Black caimans are more closely related to agile wallabies than marbled newts.
- ___ Black caimans are equally related to marbled newts and agile wallabies.
- ___ Black caimans are more closely related to marbled newts than agile wallabies.

Explain the reasoning for your choice.

Construction Task

Directions: Use the morphological traits in Table 1 to construct a phylogenetic tree of land plants in the bracket style (see Figure 1 on the first page for an example of bracket style). Be sure to label all synapomorphies on the phylogenetic tree.

Table 1: morphological traits of land plants (X = trait possessed)

| LAND PLANTS          | Swamp Rose | Bamboo | Bristly | Dragon | Durum | Sensitive | Fern |
|----------------------|------------|--------|---------|--------|-------|-----------|------|
| Prickles             | X          |        |         |        |       |           |      |
| Pollen               | X          | X      |         | X      | X     |           |      |
| Tracheids            | X          | X      | X       | X      | X     | X         |      |
| Naked Seeds          | X          |        | X       |        |       |           |      |
| Needles              |            |        |         |        |       |           | X    |
| Flowers              | X          |        |         |        |       |           | X    |

Remember to construct a phylogenetic tree in the bracket style (see Figure 1 for an example).
**Instrument #2: Post-Instructional Homework**

*The following interpretation and construction tasks referred to diagonal phylogenetic trees.*

![Figure 1: phylogenetic tree of reptiles and birds (diagonal style)](image)

**Most Recent Common Ancestor**

Which node on the phylogenetic tree of reptiles and birds in Figure 1 represents the most recent common ancestor of pancake tortoises and gharials? Select one option.

- node A  
- node B  
- node C  
- node D

**Monophyletic Group**

On the phylogenetic tree of reptiles and birds in Figure 1, draw a circle around one monophyletic group that includes at least two species.

**Contemporary Descent**

According to the phylogenetic tree of reptiles and birds in Figure 1, did pancake tortoises evolve from painted turtles? Select one option.

- Yes  
- No

Explain the reasoning for your choice.
Instrument #2: Post-Instructional Homework (Continued)

**Taxa Relatedness**

According to the phylogenetic tree of reptiles and birds in Figure 1, how would you describe the relatedness of painted turtles to green anacondas and merlins? Select one option.

- ____ Painted turtles are more closely related to merlins than green anacondas.
- ____ Painted turtles are equally related to green anacondas and merlins.
- ____ Painted turtles are more closely related to green anacondas than merlins.

Explain the reasoning for your choice.

**Construction Task**

Directions: Use the morphological traits in Table 1 to construct a phylogenetic tree of green plants in the diagonal style (see Figure 1 on the first page for an example of diagonal style). Be sure to label all synapomorphies on the phylogenetic tree.

Table 1: morphological traits of green plants (X = trait possessed)

| TRAITS             | Venus Flytrap | Fragile Stonewort | Giant Sequoia | Golden Eardrops | Sugar Pine | Bridal Rainbow |
|--------------------|---------------|-------------------|--------------|-----------------|------------|----------------|
| Flowers            | X             |                   |              |                 |            |                |
| Cones              |               |                   | X            |                 |            |                |
| Alternating Generations | X       |                   | X            |                 | X          |                |
| Snap Traps         | X             |                   |              |                 |            |                |
| Awl Leaves         |               |                   |              |                 |            | X              |
| Carnivory          | X             |                   |              |                 |            |                |

Remember to construct a phylogenetic tree in the diagonal style (see Figure 1 for an example).
The following interpretation and construction tasks referred to bracket phylogenetic trees.

**Most Recent Common Ancestor**

Which node on the phylogenetic tree of reptiles and birds in Figure 1 represents the most recent common ancestor of pond sliders and American alligators? Select one option.

- _____ node A
- _____ node B
- _____ node C
- _____ node D

**Monophyletic Group**

On the phylogenetic tree of reptiles and birds in Figure 1, draw a circle around one monophyletic group that includes at least two species.

**Contemporary Descent**

According to the phylogenetic tree of reptiles and birds in Figure 1, did pond sliders evolve from smiling terrapins? Select one option.

- _____ Yes
- _____ No

Explain the reasoning for your choice.
**Instrument #2: Post-Instructional Homework (Continued)**

**Taxa Relatedness**

According to the phylogenetic tree of reptiles and birds in Figure 1, how would you describe the relatedness of smiling terrapins to copperheads and kakapos? Select one option.

- ____ Smiling terrapins are more closely related to copperheads than kakapos.
- ____ Smiling terrapins are equally related to copperheads and kakapos.
- ____ Smiling terrapins are more closely related to kakapos than copperheads.

Explain the reasoning for your choice.

**Construction Task**

Directions: Use the morphological traits in Table 1 to construct a phylogenetic tree of green plants in the bracket style (see Figure 1 on the first page for an example of bracket style). Be sure to label all synapomorphies on the phylogenetic tree.

Table 1: morphological traits of green plants (X = trait possessed)

| TRAITS         | Cobra Lily | Old Man Orchid | Sikkim Larch | Felty Fingers | Sticky Starwort | Chestnut Dioon |
|----------------|------------|----------------|--------------|---------------|-----------------|---------------|
| Fronds         |            |                |              |               |                 | X             |
| Pitfall Traps  | X          |                |              |               |                 |               |
| Naked Seeds    | X          | X              | X            | X             |                 |               |
| Cuticle        | X          | X              | X            | X             | X               |               |
| Fruit          | X          | X              | X            |               |                 | X             |
| Tricolpate Pollen | X      |                |              |               |                 |               |

Remember to construct a phylogenetic tree in the **bracket style** (see Figure 1 for an example).
The following interpretation tasks referred to a diagonal phylogenetic tree.

**Most Recent Common Ancestor**

Which node on the phylogenetic tree of tetrapods in Figure 1 represents the most recent common ancestor of spectacled caimans and polar bears? Select one option.

- ___ node A
- ___ node B
- ___ node C
- ___ node D

**Monophyletic Group**

On the phylogenetic tree of tetrapods in Figure 1, draw a circle around one monophyletic group that includes at least two species.

**Contemporary Descent**

According to the phylogenetic tree of tetrapods in Figure 1, did olive ridleys evolve from ostriches? Select one option.

- ___ Yes
- ___ No

Explain the reasoning for your choice.
Taxa Relatedness

According to the phylogenetic tree of tetrapods in Figure 1, how would you describe the relatedness of polar bears to ostriches and olive ridleys? Select one option.

____ Polar bears are more closely related to ostriches than olive ridleys.
____ Polar bears are equally related to ostriches and olive ridleys.
____ Polar bears are more closely related to olive ridleys than ostriches.

Explain the reasoning for your choice.

The following interpretation tasks referred to a bracket phylogenetic tree.

![Phylogenetic tree of tetrapods](image)

Figure 2: phylogenetic tree of tetrapods (bracket style)

Most Recent Common Ancestor

Which node on the phylogenetic tree of tetrapods in Figure 2 represents the most recent common ancestor of muggers and giraffes? Select one option.

_____ node A  _____ node B  _____ node C  _____ node D
**Monophyletic Group**

On the phylogenetic tree of tetrapods in Figure 2, draw a circle around one monophyletic group that includes at least two species.

**Contemporary Descent**

According to the phylogenetic tree of tetrapods in Figure 2, did black mambas evolve from whooper swans? Select one option.

___ Yes  ___ No

Explain the reasoning for your choice.

**Taxa Relatedness**

According to the phylogenetic tree of tetrapods in Figure 2, how would you describe the relatedness of giraffes to whooper swans and black mambas? Select one option.

___ Giraffes are more closely related to black mambas than whooper swans.

___ Giraffes are equally related to whooper swans and black mambas.

___ Giraffes are more closely related to whooper swans than black mambas.

Explain the reasoning for your choice.

*The following single construction task allowed students to use the style of their choice.*

Use the morphological traits in Table 1 to build a phylogenetic tree of vascular plants in the style of your choice (see Figures 1–2 for examples). Be sure to label all synapomorphies.

**Table 1: morphological traits of vascular plants (X = trait possessed)**

| TRAITS              | Bobtail Barley | Maidenhair Spleenwort | Virginia Creeper | Bishop Pine | Skeleton Fork Fern | Western Redcedar |
|---------------------|----------------|-----------------------|------------------|-------------|--------------------|------------------|
| Cones               | X              |                       |                  |             |                    | X                |
| Flowers             | X              |                       |                  | X           |                    |                  |
| Tricolpate Pollen   |                |                       |                  | X           | X                  |                  |
| Seeds               | X              | X                     |                  | X           |                    | X                |
| Fronds              |                |                       |                  |             |                    |                  |
| Scale Leaves        |                |                       |                  |             |                    | X                |
The following interpretation tasks referred to a diagonal phylogenetic tree.

**Most Recent Common Ancestor**

Which node on the phylogenetic tree of tetrapods in Figure 1 represents the most recent common ancestor of red pandas and marine iguanas? Select one option.

_____ node A  _____ node B  _____ node C  _____ node D

**Monophyletic Group**

On the phylogenetic tree of tetrapods in Figure 1, draw a circle around one monophyletic group that includes at least two species.

**Contemporary Descent**

According to the phylogenetic tree of tetrapods in Figure 1, did platypuses evolve from naked mole rats? Select one option.

_____ Yes  _____ No

Explain the reasoning for your choice.
Instrument #4: Review Activity for the Final Exam (Continued)

**Taxa Relatedness**

According to the phylogenetic tree of tetrapods in Figure 1, how would you describe the relatedness of marine iguanas to naked mole rats and platypuses? Select one option.

___ Marine iguanas are more closely related to naked mole rats than platypuses.
___ Marine iguanas are equally related to naked mole rats and platypuses.
___ Marine iguanas are more closely related to platypuses than naked mole rats.

Explain the reasoning for your choice.

*The following interpretation tasks referred to a bracket phylogenetic tree.*

![Phylogenetic Tree](image)

Figure 2: phylogenetic tree of tetrapods (bracket style)

**Most Recent Common Ancestor**

Which node on the phylogenetic tree of tetrapods in Figure 2 represents the most recent common ancestor of maned sloths and ospreys? Select one option.

___ node A       ___ node B       ___ node C       ___ node D
Instrument #4: Review Activity for the Final Exam (Continued)

Monophyletic Group

On the phylogenetic tree of tetrapods in Figure 2, draw a circle around one monophyletic group that includes at least two species.

Contemporary Descent

According to the phylogenetic tree of tetrapods in Figure 2, did short-beak echidnas evolve from quokkas? Select one option.

_____ Yes  _____ No

Explain the reasoning for your choice.

Taxa Relatedness

According to the phylogenetic tree of tetrapods in Figure 2, how would you describe the relatedness of ospreys to quokkas and short-beak echidnas? Select one option.

_____ Ospreys are more closely related to short-beak echidnas than quokkas.

_____ Ospreys are equally related to quokkas and short-beak echidnas.

_____ Ospreys are more closely related to quokkas than short-beak echidnas.

Explain the reasoning for your choice.

The following single construction task allowed students to use the style of their choice.

Use the morphological traits in Table 1 to build a phylogenetic tree of vascular plants in the style of your choice (see Figures 1–2 for examples). Be sure to label all synapomorphies.

Table 1: morphological traits of vascular plants (X = trait possessed)

| TRAITS           | Giant Dioon | Swollen Bladderwort | Meadow Horsetail | Sweet Potato | Limber Pine | Hairy Lip Fern |
|------------------|-------------|---------------------|------------------|--------------|-------------|----------------|
| Needles          |             |                     |                  | X            |             |                |
| Pollen           | X           | X                   |                  | X            | X           |                |
| Suction Traps    |             |                     |                  |              |             |                |
| Sori             |             |                     |                  |              | X           |                |
| Fruit            |             |                     |                  | X            | X           |                |
| Naked Seeds      | X           |                     |                  |              |             |                |