Effects of phylogenetic tree style on student construction and comprehension

Danielle Freiermuth[1], Jon Dees[2], Jenni Momsen[2]

[1]Department of Education, Bethel University, [2]Department of Biological Sciences, North Dakota State University

Evolution is a core concept of biology[1]

- Phylogenetic trees are visual representations of evolution and are used to model and communicate evolutionary hypotheses.[1]
- Multiple styles of phylogenetic trees exist and current research suggests that bracket trees result in greater student comprehension.[2, 3]
- Conclusions regarding the influence of construction tasks on student understanding of phylogenetic trees are unclear due to multiple confounding variables.[4, 5]

## Prior to instruction, do introductory biology students

1. Demonstrate differential **understanding** of bracket and diagonal phylogenetic trees?
2. Demonstrate differential **construction abilities** for bracket and diagonal phylogenetic trees?
3. Demonstrate differential understanding of **self-constructed** and **instructor-provided** phylogenetic trees?

Following instruction, do introductory biology students

4. Demonstrate differential phylogenetic tree **style preference** for interpretation and construction?

In an introductory biology class (n=107)

- Undergraduates were asked to do the following on a *pre-instruction* homework:
  - Determine traits of a taxon
  - Identify the most recent common ancestor (MRCA) of taxa
  - Identify a monophyletic group
  - Determine the relatedness of taxa
  - Construct a tree of their own.
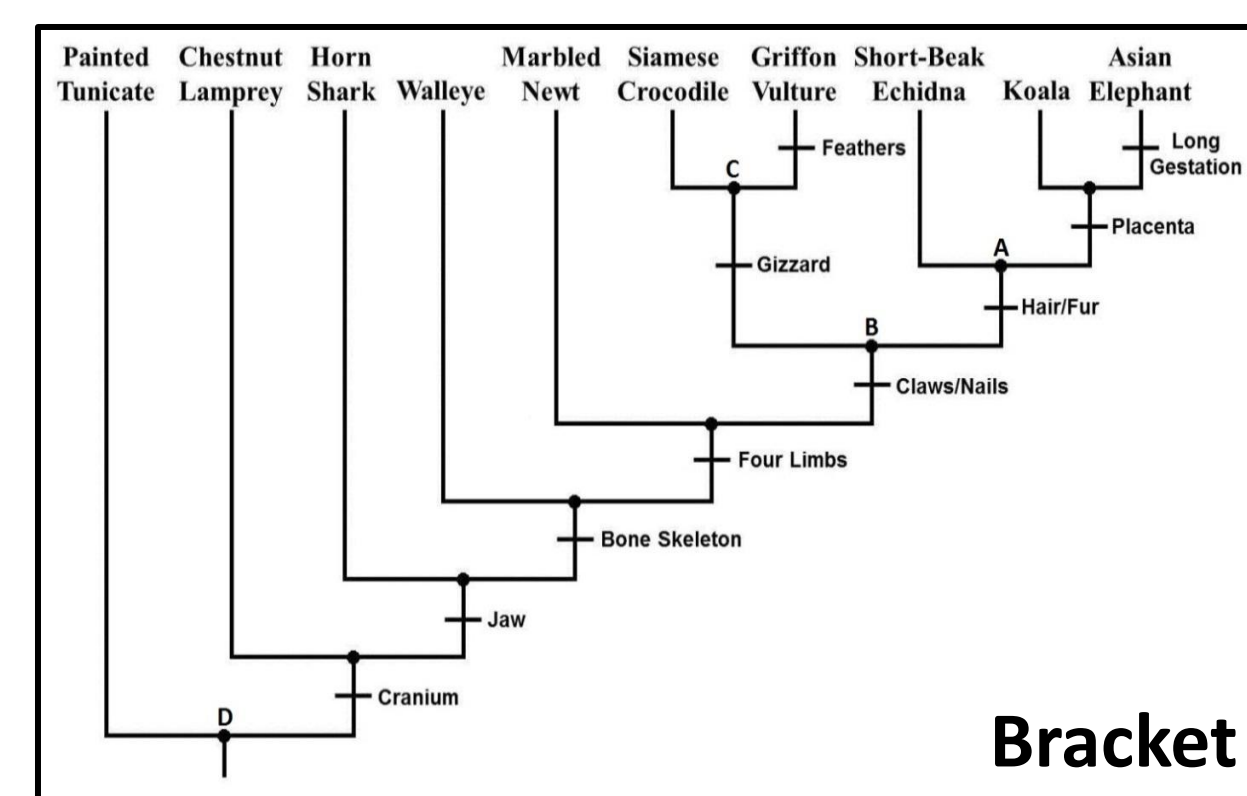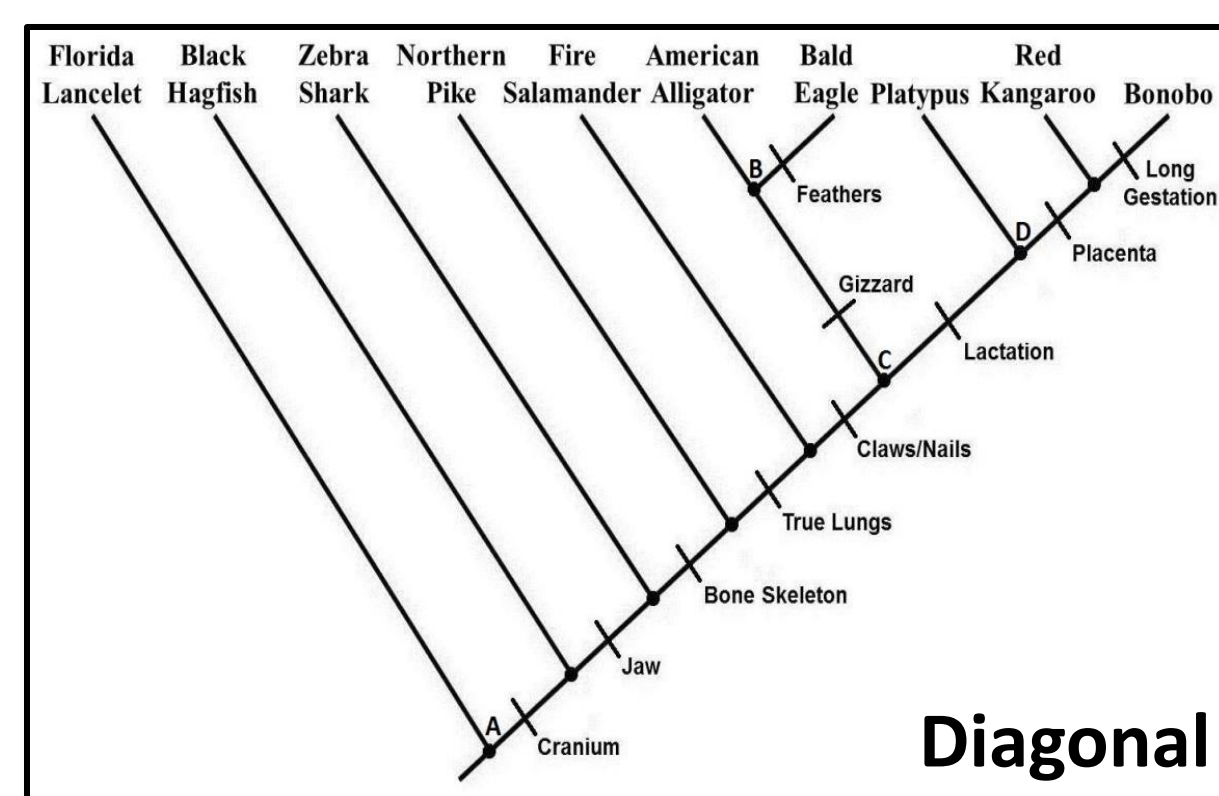
- In class, undergraduates constructed and interpreted phylogenetic trees individually and in groups.
- Undergraduates generated and interpreted phylogenetic trees using these data *post instruction*.

PLANTS

TRAITS	Lady fern	Durum wheat	White spruce	Scented liverwort	Ginkgo biloba	Saguaro cactus
Seeds		X	X		X	X
Needles			X			
Spines						X
Flowers		X				X
Stomata	X	X	X	X	X	X
Cones			X		X	

RQ#1: Students differentially interpret bracket and diagonal trees

	Trait Possession		MRCA Identification		MG Identification	
	Diagonal	Bracket	Diagonal	Bracket	Diagonal	Bracket
Correct	83 (90%)	81 (88%)	75 (82%)	91 (99%)	63 (68%)	78 (85%)
Incorrect	9 (10%)	11 (12%)	17 (18%)	1 (1%)	29 (32%)	14 (15%)
	p= 0.813		p< 0.001		p=0.014	

Identification of MRCA of taxa and identification of a monophyletic group were dependent upon style of tree. Students had more success when analyzing bracket trees.

	Contemporary Descent	
	Diagonal	Bracket
Correct	53 (58%)	73 (79%)
Partial	12 (13%)	9 (10%)
Incorrect	27 (29%)	10 (11%)
	p=0.003	

Students' ability to determine that one taxon did not evolve from another taxon was dependent upon style of tree. They had more success when analyzing bracket trees.

Students' ability to determine taxa relatedness was not dependent upon style of tree. In addition, the specific reasoning that students used was not dependent on tree style .

|	Taxa Relatedness	
	Diagonal	Bracket
Correct/Correct	5 (5%)	9 (10%)
Correct/Mixed	1 (1%)	1 (1%)
Correct/Incorrect	6 (7%)	6 (7%)
Incorrect/Correct	1 (1%)	1 (1%)
Incorrect/Mixed	3 (3%)	2 (2%)
Incorrect/Incorrect	76 (83%)	73 (79%)
	p=0.94	

RQ#4: Students exhibit differential style preference

The number of students who preferred to interpret bracket trees but drew diagonal trees is significantly different from the number of students who preferred to interpret diagonal trees but drew bracket trees. An alarming 34 (32%) of students preferred to interpret a bracket tree, but drew a diagonal tree.

	Preference versus Exam	
	Diagonal	Bracket
Diagonal	44	2
Bracket	34	17
McNemar	X^2= 26.69, df= 1, p<0.001	

RQ#2: Students exhibit differential construction ability

	Accuracy versus Style	
	Diagonal	Bracket
Correct	10	13
Adequate	28	4
Incorrect	21	9
Total	59	26
	p=0.002	
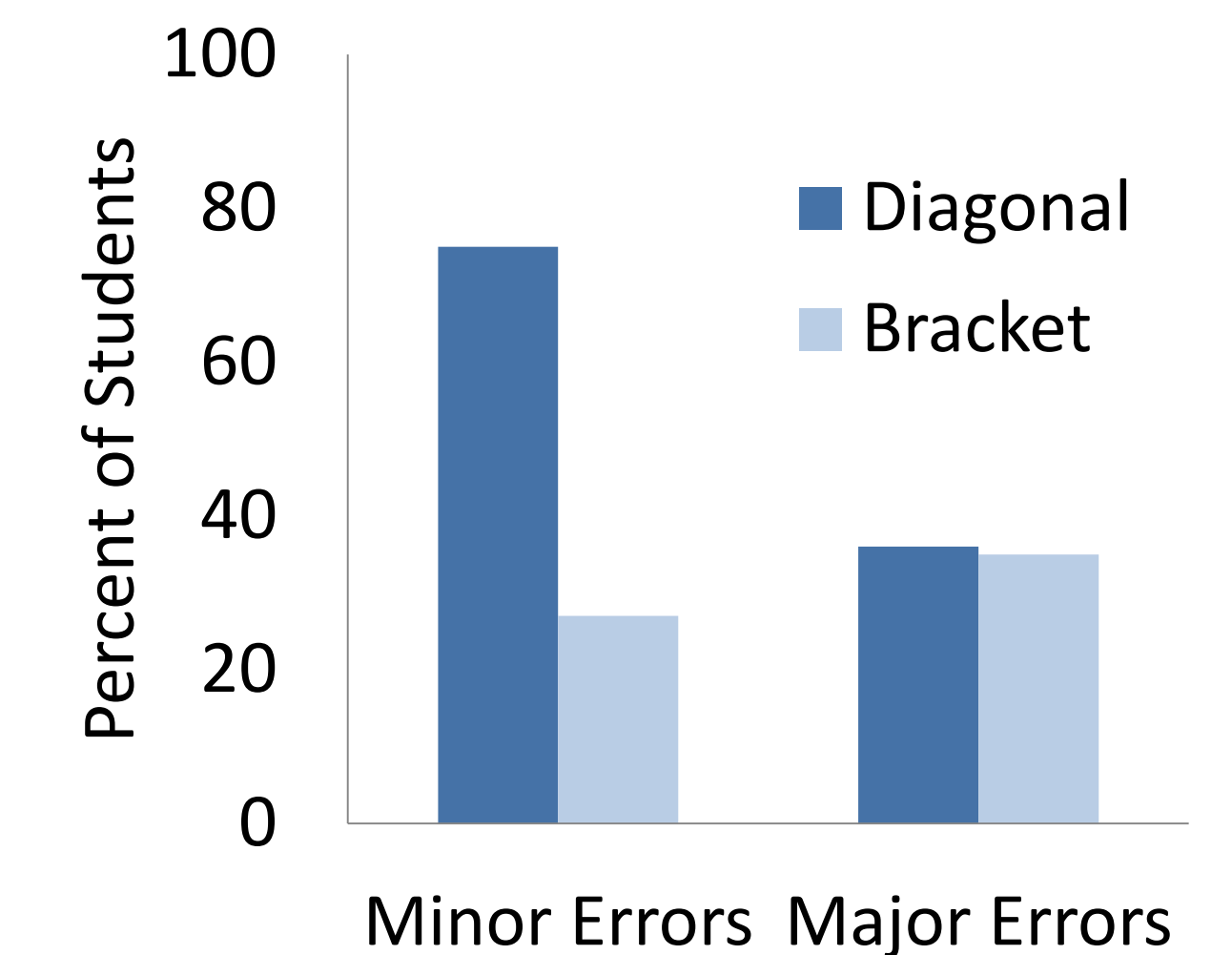
The number and type of errors that students made was dependent on the style of tree that they drew. Specifically, students who drew a bracket tree made fewer minor (non meaning-changing) mistakes. Tree style made no difference on presence of major errors.
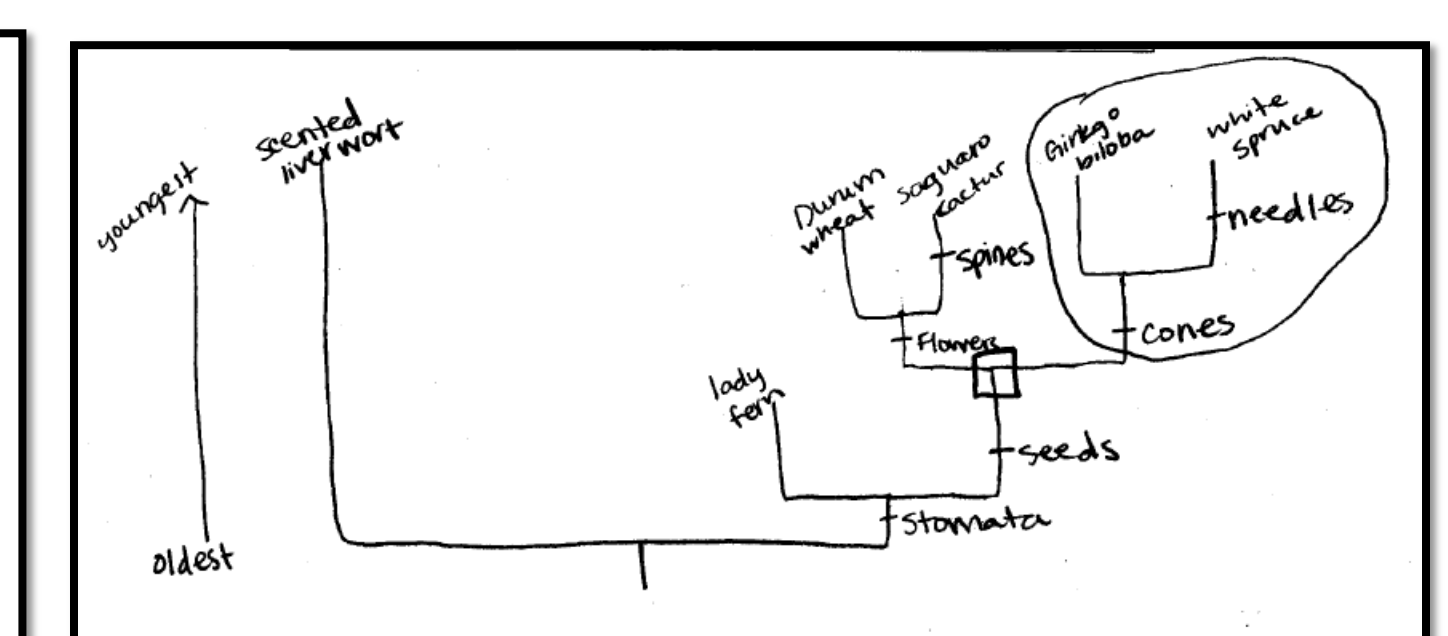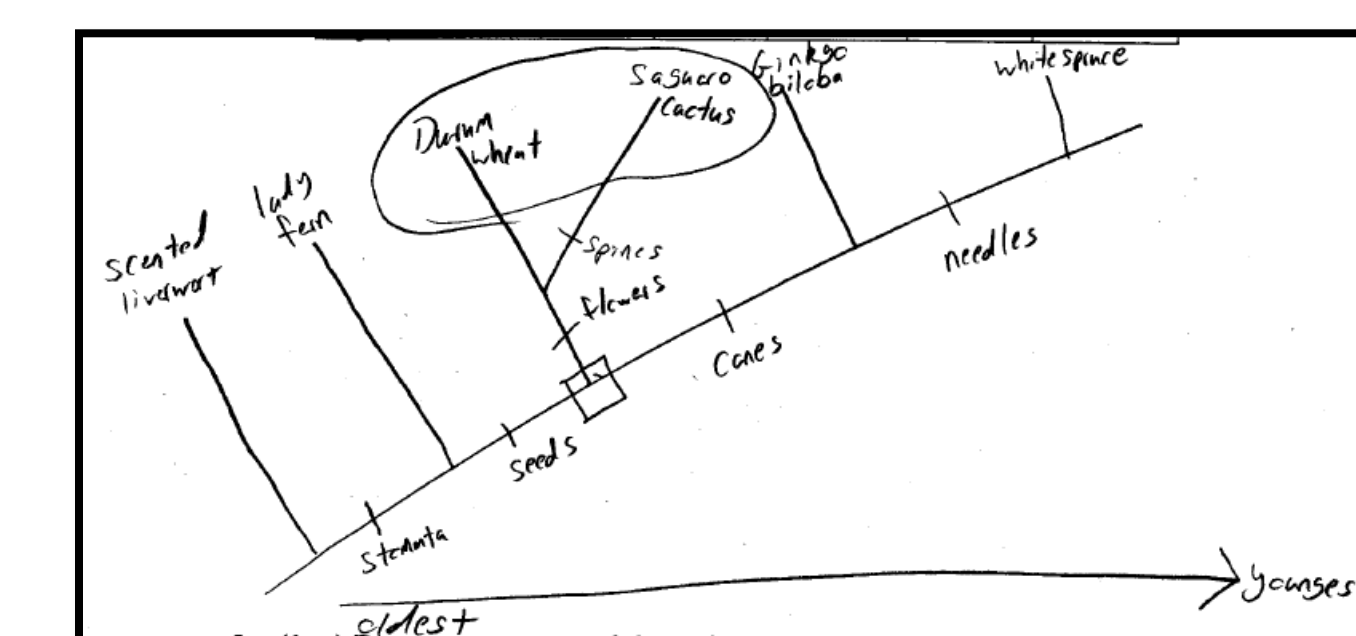
RQ#3: Students do not exhibit differential understanding of instructor-provided and self-constructed trees

	Taxa Relatedness	
	Provided	Created
Correct/Correct	6	3
Correct/Mixed	1	1
Correct/Incorrect	4	5
Incorrect/Correct	1	1
Incorrect/Mixed	0	1
Incorrect/Incorrect	73	74
	p=0.936	

Students' understanding of taxa relatedness was not dependent on whether the tree was instructor-provided or self-constructed. Students had difficulties determining taxa relatedness with provided and created trees.

Bracket trees result in greater student comprehension and constructions abilities

- Tree style made a difference for certain tasks, but made no difference for other tasks.
- Students are inconsistent in their tree style preference; they prefer to interpret bracket trees, but construct diagonal trees.
- Overall, students need frequent exposures to bracket and diagonal trees so they can fluently construct and comprehend either style.

Literature Cited
1. AAAS. Vision and Change: A Call to Action. Washington, DC: AAAS; 2010.
2. Novick, R. L., & Catley, K. M. (2007). Understanding phylogenies in biology: The influence of a gestalt perceptual principle. JEP 13:4, 197-223
3. Novick, R. L., & Catley, K. M. (2013). Reasoning about evolution's grand patterns: College students' understanding of the tree of life. AERJ 50:1, 138-177
4. Eddy, S. L., et al (2013). How should we teach tree thinking? An experimental test of two hypotheses. Evo Educ Outreach 6:13
5. Halverson, K. L. (2011) Improving tree-thinking one learnable skill at a time. Evo Educ Outreach 4: 95-106