High School Students' Learning and Perceptions of Phylogenetics of Flowering Plants

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Basic phylogenetics and associated "tree thinking" are often minimized or excluded in formal school curricula. Informal settings provide an opportunity to extend the K-12 school curriculum, introducing learners to new ideas, piquing interest in science, and fostering scientific literacy. Similarly, university researchers participating in science, technology, engineering, and mathematics (STEM) outreach activities, increase awareness of college and career options as well as highlight interdisciplinary fields of science research and augment the science curriculum. To aid in this effort, we designed a six-hour module in which students utilized 12 flowering plant species to generate morphological and molecular phylogenies using biological techniques and bioinformatics tools. The phylogenetics module was implemented with high school students during week-long University STEM immersion programs and aimed to increase student understanding of phylogenetics and co-evolution of plants and pollinators. Student response reflected positive engagement and learning gains as evidenced through content assessments, program evaluation surveys, and program artifacts. We present the results of the first year of implementation and discuss modifications for future use in our immersion programs as well as use in multiple course settings at the high school and undergraduate levels.

Background/Students

A plant phylogenetic and plant/pollinator interactions module was conducted with high school students over two consecutive summers. The goal was to increase interest in botany which is often only covered at a cursory level in Florida high schools, as well as to give students practice in actual laboratory techniques used in the research lab. Over the two summers this module was conducted, 247 high school students and 10 teachers participated, as well as 10 high school teachers. The breakdown of participation is below.

Overall number of program participants

	Years		Total
Year	2013	2014*	
Male	62	74	136
Female	50	71	121
Total	112	145	257

* 10 high school teachers (3M/7F) also participated in the module; 48 students (24M/24F) participated in the forensic module.

2013 Program participants demographics

	Participants		Total
Grade	11th	12th	
Male	21	24	45
Female	21	17	38
Total	42	41	83

Flowering Species Used

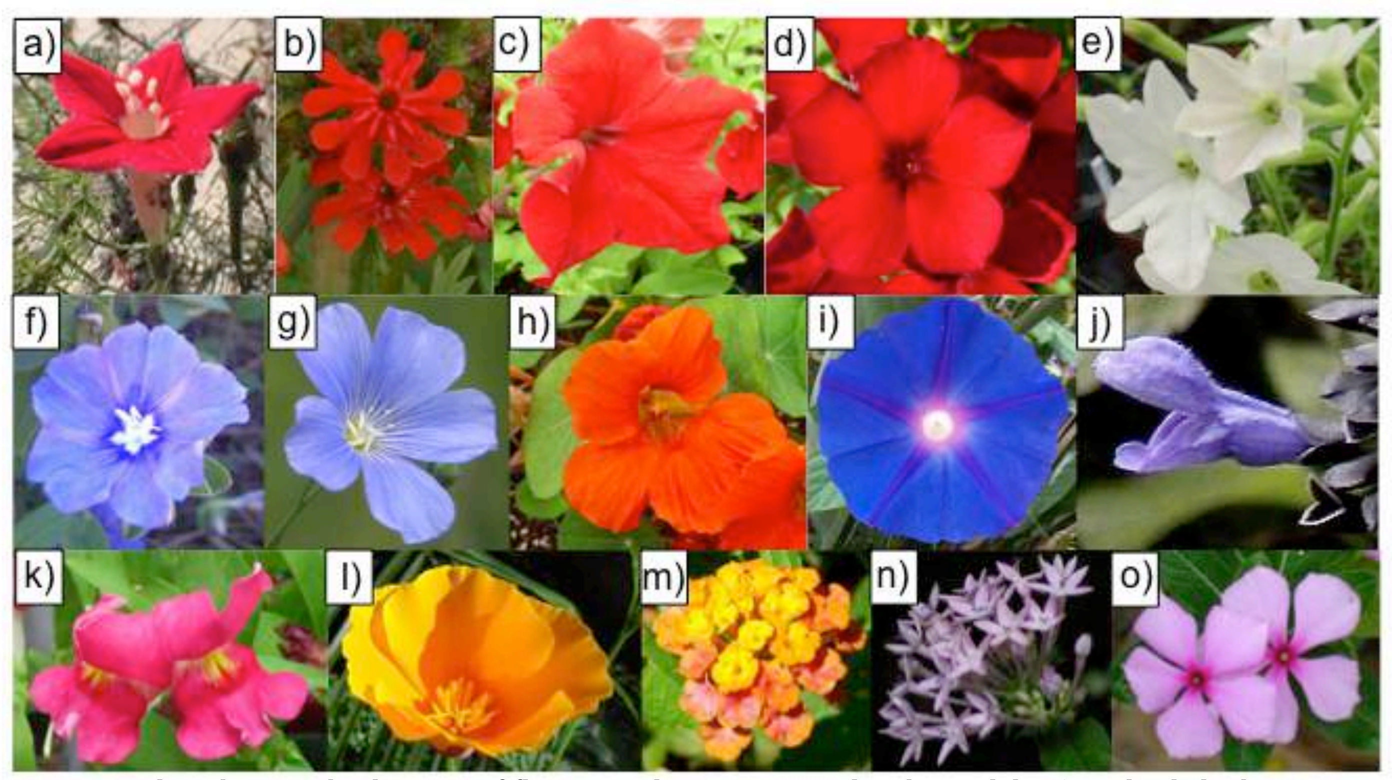
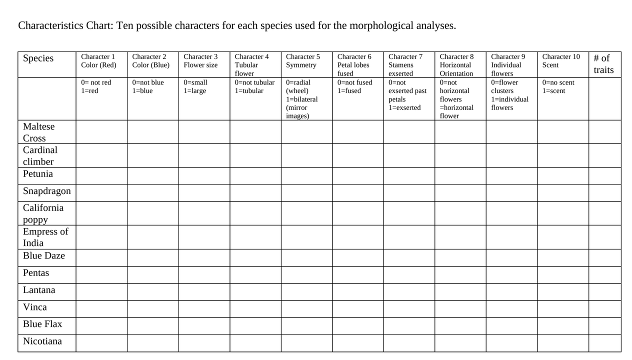


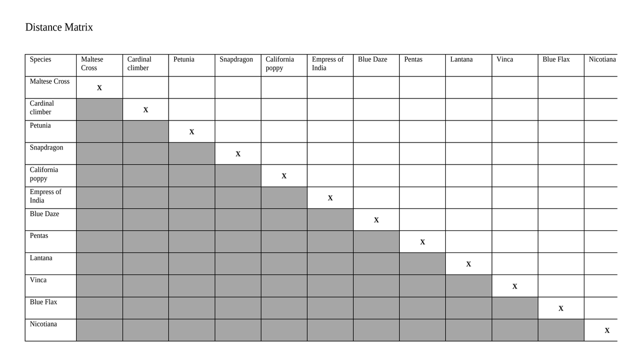
Figure 1. Plate showing the diversity of flowering plant species used in the module, a) cardinal climber (*Ipomea quamoclit*), b) maltese cross (*Lychnis chalcedonia*), c) supercascade red *Petunia* (*Petunia hybrida*), d) red *Phlox* (*Phlox drummondii*), e) heavenly scent *Nicotiana* (*Nicotiana alata*), f) blue daze (*Evolvulus glomeratus*), g) blue flax (*Linum usitatissimum*), h) empress of India (*Tropaeolum majus*), i) morning glory (*Ipomoea violacea*), j) *Salvia* (*Salvia farinacea*), k) snapdragon (*Antirrhinum majus*), l) California poppy (*Eschscholzia californica*), m) *Lantana* (*Lantana camara*), n) *Pentas* (*Pentas hybrida*), o) vinca (*Catharanthus roseus*).

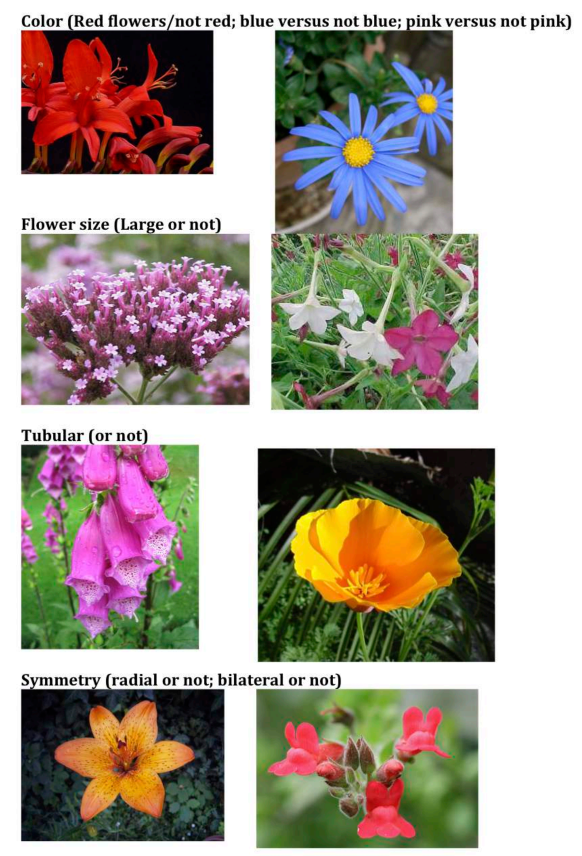
List of plants used during the module including common name, scientific name, known pollinator, Genbank accession numbers for both nuclear and chloroplast genes, as well as source of plant material.

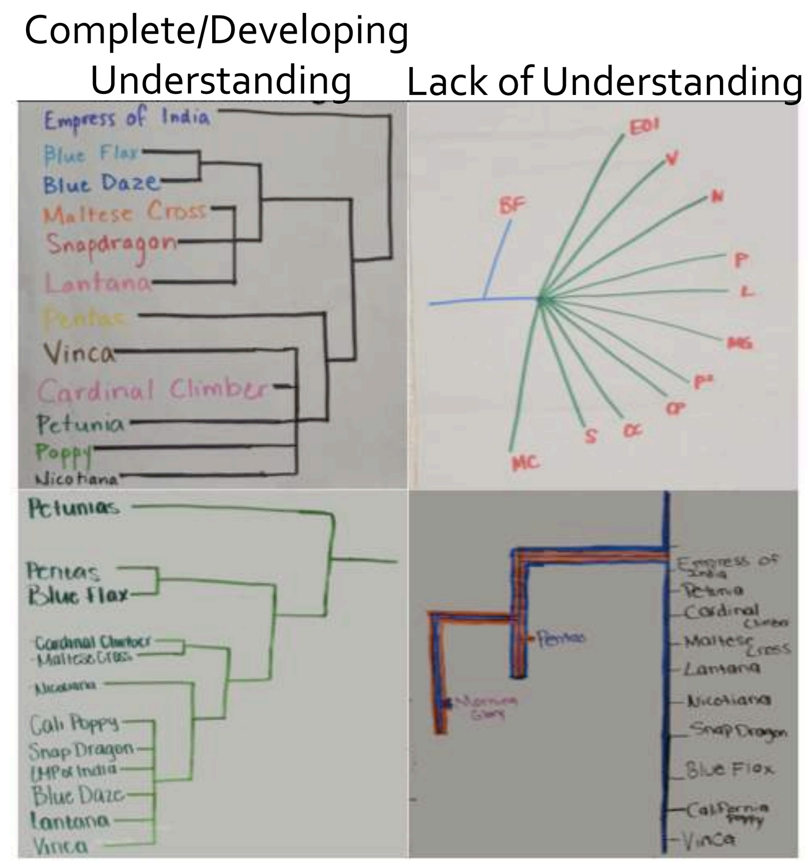
Common name	Scientific name	Pollinator	Nuclear	Chloroplast	Material
Cardinal climber	*Ipomea quamoclit*	Hummingbird	AY538323	AY101065	Eden Brothers
Maltese cross	*Lychnis chalcedonia*	Hummingbird	EF602379	FJ404990	Eden Brothers
Petunia	*Petunia hybrida*	Hummingbird	DQ208093	AY098702	Burpee
Red *Phlox*	*Phlox drummondii*	Hummingbird	JN115041	EF433261	Eden Brothers
Heavenly scent	*Nicotiana alata*	Hummingbird	AJ492424	AY098701	Burpee
Blue daze	*Evolvulus glomeratus*	Bee	EF567109	AY101121	Lowe's
Blue flax	*Linum usitatissimum*	Bee	JN115032	FJ160887	Eden Brothers
Empress of India	*Tropaeolum majus*	Bee	AF254020	AB043665	Eden Brothers
Morning glory	*Ipomoea violacea*	Bee	AY538329	AY101071	Burpee
Salvia	*Salvia farinacea*	Bee	EU169483	AY570479	Burpee
Snapdragon	*Antirrhinum majus*	Bee	FJ648325	AY591322	Burpee
California poppy	*Eschscholzia californica*	Bee	DQ912883	JN051803	Burpee
Lantana	*Lantana camara*	Butterfly	AF437858	HM216633	Lowe's
Pentas	*Pentas hybrida*	Butterfly	AM267047	AM266961	Lowe's
Vinca	*Catharanthus roseus*	Butterfly	AF136743	JN574648	Lowe's

Morphological Phylogeny







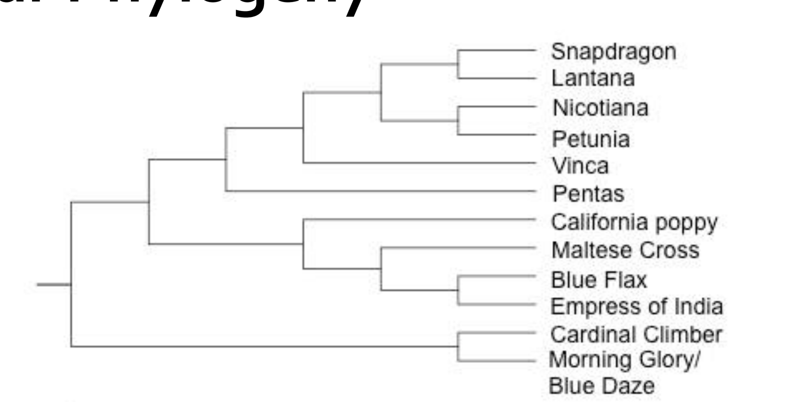


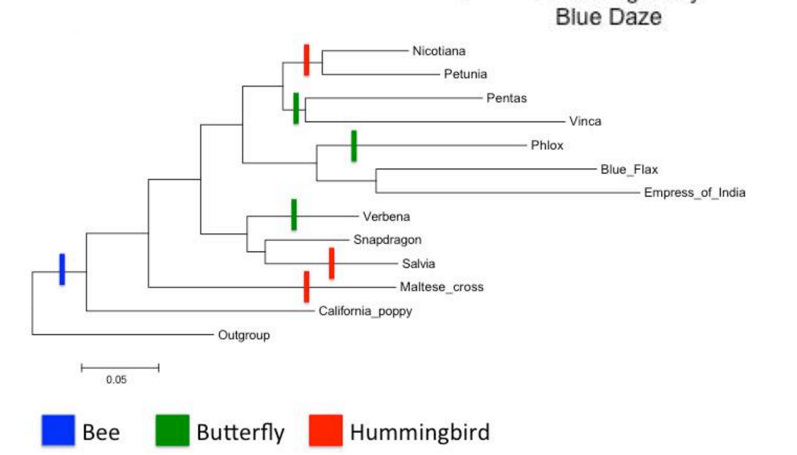
Left: Plants were arranged around the room for student inspection. For the morphological analyses, students were to pick three flower characters useful in distinguishing plants. Examples of possible characters were given, as well as suggestions for scoring. Students scored all 12 species for their selected three characters and completed a differences matrix to use for phylogenetic construction.

Above: Example student phylogenies representing groups that understood the task, and those that lack an element of understanding based on the four criteria rubric modified from Young et al. (2013). Understanding did not represent an accurate topology, since only a small subset of the characters scored were used to create phylogenies.

Molecular Phylogeny

Students extracted DNA from four plant species using the Extract and Amp Kit (Sigma). They then amplified ITS for each plant species and visualized their PCR products using E-gels (Life Technologies).

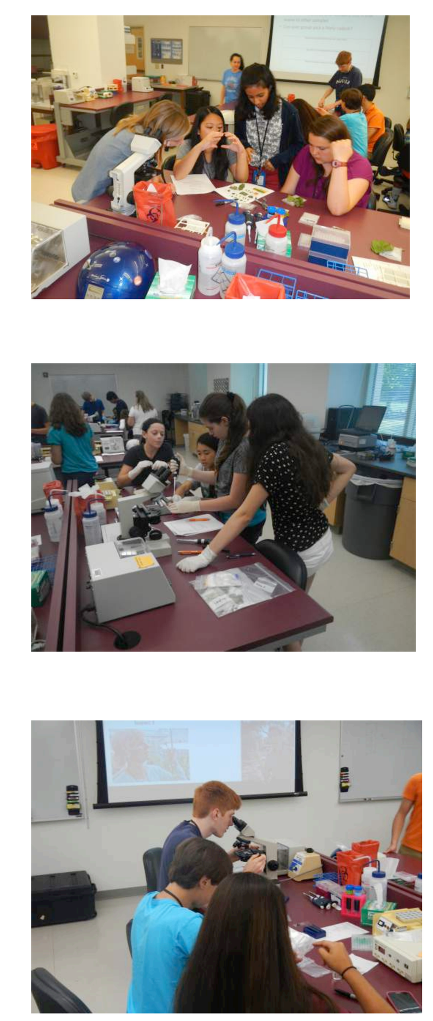




Sequences of ITS downloaded from Genbank for all 12 species were aligned in Mega5 using the default parameters for Muscle. A parsimony tree was reconstructed to compare to morphology trees students generated. A maximum-likelihood tree was then generated for students to trace on their three chosen flower characters illustrating how they were evolving in relation to pollinators as shown here.

Additional Activity – Forensic Case

High school students were presented with a story of a murder involving four suspects. They were given evidence to process and determine the culprit. Evidence consisted of leaf samples from suspects and crime scene. With this material, they compared leaf morphology, as well as extracting DNA from all samples. Four combinations of microsatellite markers from *Vitis rotundifolia* were used for PCR and results visualized using gel electrophoresis. Each group of four students had to determine who they thought committed the crime based on the evidence. Overall there were 48 participants over two weeks, all rising sophomores from Florida high schools.



Crime Scene

Based solely on leaf morphology, who is the likely criminal?
Based solely on DNA, who is the likely criminal?
Based solely on the fiber analysis, who is the likely criminal?
Do all three pieces of evidence tell the same story? If not, how do they differ?
Based on all of the data combined, which suspect (if any) would your group charge with the crime?

Recent Iterations Summer 2014

- More reliable assessment instrument. Students completed pre/post assessments to measure conceptual understanding of the plant phylogenetics module. Assessment items were validated prior to module.
- Incorporation of The Great Clade Race from Goldsmith (2003). This exercise was done prior to completing the large morphological phylogeny to give students a deeper understanding of the procedure.
- Increased effort of drawing the big picture and why studying both plants and phylogenetics is important. An example is showing pictures of cats and then asking where did house cats come from?
- Module available online: http://www.cpet.ufl.edu/resources/plant-phylogenetics/

Acknowledgments and References

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